Santos Ltd
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60 Flinders Street
Adelaide, South Australia 5000
Telephone: 61 8 8116 5000
Facsimile: 61 8 8116 5050
www.santos.com

2 February 2026

Santos Reference: EQ22-13

Camilla Scott
Principal Environmental Officer
Energy and Extractive Resources | Environmental Services and Regulation
Department of Environment, Tourism, Science and Innovation
Level 7, 400 George Street
BRISBANE QLD 4001

Dear Camilla,

Application for a new site-specific Environmental Authority – PL 1123

Santos Ventures Pty Ltd (Santos), on behalf of its joint venture partners, has prepared the attached application for a new site-specific Environmental Authority (EA) to authorise petroleum production operations on proposed Petroleum Lease (PL) 1123.

Santos is the principal applicant, and we have undertaken formal pre-lodgement with respect to this application with DETSI 16th May 2025.

PL 1123 will wholly replace all existing blocks of Authority to Prospect (ATP) 2053, which is an existing exploration tenure operated by Santos. Santos proposes to develop PL 1123 as part of the Santos Roma Phase 7-7B-SD20 Development (Project). The Project will involve the progressive construction, operation, decommissioning and rehabilitation of up to 24 Coal Seam Gas (CSG) wells and associated infrastructure located in PL 1123.

Due to varying joint venture and commercial arrangements, PL 1123 cannot be added to any of the existing adjacent Santos EAs as an authorised tenure. The holders of Santos operated petroleum tenures surrounding PL 1123 are different to those of PL 1123, and therefore PL 1123 cannot be added as an authorised tenure to their respective EAs. Santos is therefore seeking a new site-specific EA to authorise petroleum production on proposed PL 1123.

Given the proximity of PL 1123 to existing Santos petroleum operations in the Roma region, the Project is proposed to be carried out as a single integrated operation with existing authorised petroleum tenures and activities authorised under the existing Santos Roma Shallow Gas Project Area (RSGPA) EA (EPPG00898213). Santos is therefore seeking EA conditions consistent with those of the RSGPA EA to ensure operational and compliance consistency across adjacent tenure boundaries RSGPA EA conditions are predominately based on the DETSI *streamlined model conditions for petroleum activities* (ESR/2016/1989).

Santos is also requesting the following Environmentally Relevant Activity (ERA) is authorised on the new EA:

- Schedule 3 – 3 – A petroleum activity that is likely to have a significant impact on a category A or B Environmentally Sensitive Area.

Further, the Project was referred to the Commonwealth Department of Climate Change, Energy, the Environment and Water (DCCEEW) for assessment under the requirements of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The Project was determined not to be a Controlled Action (NCA) by DCCEEW on 22nd December 2025 (EPBC 2025/10227).

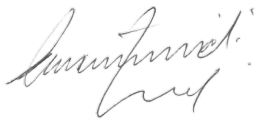
The following information is attached in support of the application:

- Appendix 1 – EPBC Act referral – decision notice;
- Appendix 2 – Application form for a site specific application for a new EA for a resource activity; and
- Appendix 3 – Supporting information report.

The prescribed fee for this application is $754.00, plus 30% of the annual fee for the relevant activity ($118,314.00), which totals $36,248.20.

Please contact Alex Clarke, Senior Environmental Advisor, at alex.clarke@santos.com, should you have any questions in relation to the application.

Yours sincerely,



William Inonda

Team Leader Environment – Eastern Queensland and NSW
Santos Ltd

Santos

Appendix 1

EPBC Act Referral – Decision Notice

Australian Government
Department of Climate Change, Energy, the Environment and Water

Notification of referral decision – not controlled action

Roma Phase 7-7B-SD20 Development, near Wallumbilla, Queensland (EPBC 2025/10227)

This decision is made under section 75 of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Proposed action

person proposing to take the action	SANTOS VENTURES PTY LTD ABN: 123 982 749
proposed action	Progressive construction, operation, decommissioning and rehabilitation of up to 24 CSG wells and associated infrastructure. The proposed site is located 5 kilometres east of Wallumbilla, central-eastern Queensland, within the Maranoa Regional Council area (See EPBC Act referral 2025/10227).

Referral decision: not a controlled action

status of proposed action	The proposed action is not a controlled action.

Person authorised to make decision

name and position	Mark Say Acting Branch Head Environment Assessments Queensland Branch
signature	
date of decision	22 December 2025

Santos

Appendix 2

Application form for a site specific application for a new EA for a resource activity

Application Form

Environmental Protection Act 1994

Site specific application for a new environmental authority for a resource activity

This is the approved form to make a site-specific application for an environmental authority under sections 124, 125, 126 and 126A of the Environmental Protection Act 1994 *(EP Act) for an environmentally relevant activity (ERA) which is a resource activity*

Note: You can apply to the Department of the Environment, Tourism, Science and Innovation (the Department) through Online Services at: https://www.business.qld.gov.au/running-business/environment/online-services.

It is recommended that you read the information on what to provide with an application, prior to making an application. This information is located on the Business Queensland website at www.business.qld.gov.au (use the search term "environmental licence"). This website also has a diagnostic tool called a "Forms and fees finder" which will take you through a series of questions and provide a customised result which will identify any forms, fees and supporting information you need to make an application.

Only use this application form if you are applying for a new environmental authority (EA) where:

- ☑ *All applicants are registered as suitable operators*[1]*. A suitable operator is a person or a corporation assessed under section 318I of the EP Act as being suitable to carry out an ERA and is listed on the suitable operator register*[2]*.*
- ☑ The ERA/s being applied for is/are a resource activity/activities, which involves: (a) a geothermal activity, (b) a greenhouse gas (GHG) storage activity, (c) a mining activity or (d) a petroleum activity. Note a resource activity is taken to include ancillary activities (prescribed ERAs) and other activities carried out under the authority as a resource activity.
- ☑ An application for a relevant resource tenure has been made or will be made at the same time as this application.
- ☑ The applicant/s for the resource tenure are exactly the same as the applicant/s for this EA application.
- ☑ The ERA/s being applied for will not form part of an ERA project under an existing EA.
- ☑ If more than one ERA is being applied for:
    - the ERAs being applied for will be carried out under the day to day management of a single responsible person (e.g. a site manager or operations manager); and
    - all of the ERAs are operationally interrelated, that is, the operation cannot function without all of the ERAs. Separate applications will need to be made for the ERAs that cannot be carried out as a single integrated operation; and
    - the ERA/s are, or will be, carried out at one or more places; and
    - the places where the ERAs will be carried out are close enough to make the integrated day to day management of the activities feasible.

---

[1] Your EA application must be refused if you are not a registered suitable operator when the application is decided. To become a registered suitable operator apply using the form Application to be a suitable registered operator (ESR/2015/1771).

[2] The Registered Suitable Operators register is available on the Queensland Government website.

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OR

☑ The administering authority has refused your amendment application and requires you to make a site-specific application for a new EA to replace your existing EA.

It is recommended that you have a pre-lodgement meeting about this application:

- Please fill out and lodge the form Application for pre-lodgement services (ESR/2015/1664), prior to lodging this application for an EA.

The fields marked with an asterisk * are mandatory, if they are not completed then your application may be considered not properly made under section 128 of the EP Act.

1 Applicant details

Is there more than one applicant?*	☐ No, please provide applicant's details here. ☒ Yes, please provide the principal applicant's details here and other applicants' details at attachment 1—Joint applicants and appointment of principal applicant
Name—individual or contact person if applicant is an organisation* Alex Clarke	
Organisation name, including any trading name (*if an organisation) Santos Ventures Pty Ltd	ABN/ACN (*if an organisation) 60123982749 / 123982749
Residential or registered business address (not a post office box)* Level 22, Santos Place, 32 Turbot Street, Brisbane, Queensland 4000 AUSTRALIA	ABN/ACN (*if an organisation) Insert.
Residential or registered business address (not a post office box)* Insert.	Phone* (07) 3838 3000
Postal address (if same as above, write "AS ABOVE")* GPO Box 1010 BRISBANE QLD 4001	Facsimile Insert.
Email* alex.clarke@santos.com	☒ *Indicate if you want to receive correspondence via email*

1.1 Nomination of an agent for this application

I/we nominate the below agent to act on my/our behalf and to receive correspondence relating to this application.

Do you want to nominate an agent for this application?* ☒ No → Go to *Question 2*. ☐ Yes → Complete the agent's details here.	
Name of agent—individual or contact person if the agent is an organisation Insert.	
Organisation name, including any trading name (if an organisation) Insert.	ABN/ACN (if an organisation) Insert.

Postal address Insert.	Phone Insert.
Email Insert.	☐ *Indicate if you want to receive correspondence via email*

2 Registered suitable operator status

A suitable operator is a person or a corporation assessed under Part 4, Chapter 5A of the EP Act as being suitable to carry out an ERA and is listed on the suitable operator register[3].

Are all applicants registered as a suitable operator?*	
☒ Yes	Suitable operator reference number* RSO000499 The suitable operator reference number provided must belong to the individual/organisation with the exact same name, DOB or ABN/ACN as the applicant. If there is more than one applicant, include all applicants' suitable operator reference numbers on Attachment 1.
☐ No	You must apply to be a registered suitable operator by completing the form Application to be a suitable registered operator (ESR/2015/1771) . Note: If there is more than one applicant, a separate form must be submitted for each applicant.

3 Details of the activity/activities being applied for

Complete the tables below by advising which activities you are applying for and the locations where they will be conducted.

Resource activity name as it appears in Schedule 3 of the Environmental Protection Regulation 2019 (EP Reg) * **For example, 1—Activities under a GHG injection and storage lease under the GHG storage Act, 3—A petroleum activity that is likely to have a significant impact on a category A or B environmentally sensitive area, 6—A petroleum activity carried out on a site containing a high hazard dam or a significant hazard dam,13—Mining black coal, 16—Mining gold ore**	**Tenure number(s)***
3 – A petroleum activity that is likely to have a significant impact on a category A or B Environmentally Sensitive Area.	PL 1123
Insert.	Insert.
Insert.	Insert.
Insert.	Insert.
Insert.	Insert.
Insert.	Insert.
Insert.	Insert.

[3] The register is available on the Queensland Government website at www.qld.gov.au, using the search term "suitable operator register".

Insert.	Insert.
Insert.	Insert.
Insert.	Insert.
Insert.	Insert.
Insert.	Insert.

What is a broad description of activity/activities?* **For example, gemstone mining, geothermal activities, exploration—minerals, data acquisition authority, petroleum exploration, petroleum production**	**Does the ERA have standard conditions that you can comply with?***	**Name of the ERA standard (*if applicable)**	**Tenure number(s)***
Petroleum exploration and production. Refer to Appendix 3 - supporting information.	☒ No ☐ Yes	Insert.	PL 1123
Insert.	☐ No ☐ Yes	Insert.	Insert.
Insert.	☐ No ☐ Yes	Insert.	Insert.
Insert.	☐ No ☐ Yes	Insert.	Insert.

Ancillary activity as it appears in Schedule 2 of the EP Reg*		
Threshold	**Name of ERA**	**Tenure number(s)**
Insert.	Insert.	Insert.
Insert.	Insert.	Insert.
Insert.	Insert.	Insert.
Insert.	Insert.	Insert.

4 Description of land where the activity/activities will be carried out

Tenure type/s* e.g. DAA, EPM, EPC	**Tenure number***	**Local government area (LGA) ***	**Date on application***
Petroleum Lease	1123	Maranoa Regional LGA	16/09/2022
Insert.	Insert.	Insert.	Insert date.
Insert.	Insert.	Insert.	Insert date.
Insert.	Insert.	Insert.	Insert date.
Insert.	Insert.	Insert.	Insert date.
Insert.	Insert.	Insert.	Insert date.
Insert.	Insert.	Insert.	Insert date.
Insert.	Insert.	Insert.	Insert date.
Insert.	Insert.	Insert.	Insert date.

GPS coordinates (*if known): Insert.
Provide a description of land below or on an attachment e.g. environmental values, bioregions and regional ecosystems, terrain, shallow ground water systems, floodplains, springs and soil descriptions* Refer to Appendix 3 – Supporting Information

☒ I have attached a description of land

5 Details of contaminated land

Is there a site management plan in effect for contaminated land that relates to the land that is the subject of this application?*		
☒ No	Go to *Question* ***Error! Reference source not found.***.	
☐ Yes	Description of land*	
	Lot and plan number(s)	LGA
	Lot Insert.	Plan Insert.
	Lot Insert.	Plan Insert.
	Lot Insert.	Plan Insert.
	Lot Insert.	Plan Insert.
	If you are not able to provide all relevant details above, please attach them to this application and indicate you have done so below: ☐ I have attached the description of the land for which a site management plan is in effect.	

6 Regional interests development approval

A regional interests development approval (RIDA) is required when a resource activity is proposed in an area of regional interest under the *Regional Planning Interests Act 2014*. Further information, including application forms, can be found on the Department of State Development, Infrastructure and Planning (DSDIP) website at https://www.planning.qld.gov.au/planning-issues-and-interests/areas-of-regional-interest.

Is the resource activity located anywhere within an area of regional interest? *	
☐ No	
☒ Yes	Which regional interest area, has or will require a RIDA? ☐ Priority Agricultural Areas (PAAs) ☐ Priority Living Areas (PLAs) ☐ Strategic Environmental Areas (SEAs) ☒ Strategic Cropping Area (SCA) ☐ No RIDA required, I am an exempt activity.
	If you have applied for a RIDA, provide the application reference below: Insert.

7 Environmental offsets

An environmental offset, under the *Environmental Offsets Act 2014*, may be required for an ERA where, despite all reasonable measures to avoid and minimise impacts on certain environmental matters, there is still likely to be significant residual impact on one or more of those matters.

You must verify the presence, whether temporary or permanent, of those environmental matters. For more information refer to the Queensland Environmental Offsets Policy and the Significant Residual Impact Guideline at the Queensland Government website at www.qld.gov.au, using the search term "environmental offsets".

Will the ERA/s being applied for result in a significant residual impact to a matter of State environmental significance (MSES)?*	
☒ No	Go to *Question 8*
☐ Yes	Please attach supporting information that: 1. Details the magnitude and duration of the likely significant residual impact on each prescribed environmental matter (other than matters of local environmental significance) for the entire activity; and 2. Demonstrates that all reasonable measures to avoid and minimise impacts on each of those matters will be undertaken.

7.1 Notice of election

Has a notice of election been submitted to the administering authority, or is being submitted as part of this application?	
☒ No	Go to *Question 7.2*
☐ Yes	You can attach the notice of election, if it has not already been submitted. Go to *Question 7.3*.

7.2 Staged environmental offsets

Offset delivery can be staged, however for this to occur, the condition of any approved EA needs to state that both the activity and the offset may be staged. As part of your notice of election for each stage under the *Environmental Offsets Act 2014*, you are required to provide a detailed assessment of the quantum of impact of that stage and the offset obligation requirement to be delivered for that stage.

Will the proposed activity/activities and delivery of an environmental offset be undertaken in stages?	
☒ No	
☐ Yes	You **must** attach supporting information that details of how the activity/activities are proposed to be staged.

7.3 Nature conservation environmental offset

Has another authority issued under the *Nature Conservation Act 1992* required an environmental offset for the same, or substantially the same, impact and the same, or substantially the same, MSES?	
☒ No	
☐ Yes	Provide permit number: Insert.

7.4 Marine parks environmental offset

Has marine park permit issued under the *Marine Parks Act 2004* required an environmental offset for the same, or substantially the same, impact and the same, or substantially the same, MSES?	
☒ No	
☐ Yes	☐ You **must** attach a copy of the marine park permit to this application.

8 Matters of national environmental significance

There are currently nine matters of national environmental significance (MNES) which have been defined in the *Environmental Protection and Biodiversity Conservation Act 1999 (Cth)* (EPBC Act). These are:

- world heritage properties
- national heritage places
- wetlands of international importance (listed under the Ramsar Convention)
- listed threatened species and ecological communities
- migratory species protected under international agreements
- Commonwealth marine areas
- the Great Barrier Reef Marine Park
- nuclear actions (including uranium mines)
- a water resource, in relation to coal seam gas development and large coal mining development

To determine whether the proposed activity/activities will have a significant impact on MNES and for referral requirements, please refer to the guidance provided by the Federal Government's Department of Agriculture, Water and the Environment on www.environment.gov.au.

Would the carrying out of the proposed activity/activities be likely to have a significant impact on a MNES? *	
☒ No	Go to *Question 9*.
☐ Yes	Has the proposal been referred to the Federal Department of Agriculture, Water and the Environment for formal assessment and approval? ☐ No → Go to *Question 9.* ☒ Yes → Go to *Question 8.1*.

8.1 EPBC Act approval for environmental offsets

Has an approval been issued under the EPBC Act required an environmental offset for the same, or substantially the same, impact and the same, or substantially the same, MSES?	
☒ No	Go to *Question 9*.
☐ Yes	☒ I have attached a copy of the approval under the EPBC Act.
	Are there any MNES which were assessed under the EPBC Act which are the same, or substantially the same as an MSES, but that were not conditioned in the approval? ☒ No → Go to *Question 10*. ☐ Yes → List these MNES: Insert.

9 ANZSIC Code for the activity

The Australian and New Zealand Industrial Classification (ANZSIC) is used by the Australian Bureau of Statistics.

What is the ANZSIC code for the activity?*	
☐ 1101 Black coal mining	☐ 1313 Copper ore mining
☐ 1102 Brown coal mining	☐ 1314 Gold ore mining
☐ 1311 Iron ore mining	☐ 1315 Mineral sand mining
☐ 1312 Bauxite mining	☐ 1316 Nickel ore mining
☐ 1317 Silver-lead-zinc ore mining	☒ 1200 Oil and gas extraction
☐ 1319 Metal ore mining (other metallic mineral ores)	☐ Other Insert.

10 Environmental Impact Statement and Impact Assessment Report under the *State Development and Public Works Organisation Act 1971*

Certain stages of the EA application process may not apply if the proposed activities were assessed as part of a coordinated project (an Environmental Impact Statement (EIS) or Impact Assessment Report (IAR) process) declared by the Coordinator-General under the *State Development and Public Works Organisation Act 1971* (SDPWO Act). You are only required to answer Questions 10.2 to 10.4 if your project is being, or was assessed, as part of a coordinated project under the SDPWO Act.

10.1 Coordinated project status

Has the Coordinator-General declared that the project the subject of this application is a coordinated project for which an EIS or IAR under that Act is required?	
☐ No	Go to *Question 11.*
☐ Yes	What is the name of the project? Insert. Go to *Question 10.2*

10.2 Has the EIS or IAR process been completed?

Has the EIS or IAR process under the SDPWO Act been completed? *		
☐ No	Go to *Question 13.*	
☐ Yes	Was the EIS or IAR completed for all activities that are the subject of this application?	
	☐ No	Please list the activities that were not included in the EIS or IAR or attach documentation with this information to this application: Insert. ☐ I have attached the required supporting information Go to *Question 10.3*
	☐ Yes	Go to *Question 10.3*

10.3 Environmental risks

Have the environmental risks or the way the activity/activities are proposed to be carried out changed since the EIS or IAR was completed?*	
☐ No	Go to *Question 10.4*
☐ Yes	I have attached supporting information. Go to *Question 10.4*

10.4 Coordinator-General's conditions

Are there conditions contained within an evaluation report that relate to the activities being applied for?*	
☐ No	Go to *Question 13.*
☐ Yes	Date Coordinator-General's evaluation report issued: Insert. Lapse date of report: Insert.

11 EIS under the EP Act

Certain stages of the EA application process may not apply if the proposed activities were assessed by EIS under the EP Act.

Note: You do not need to complete this section if you have indicated in Question 10 that the proposed activities are being, or have been assessed by the Coordinator-General as part of an EIS under SDPWO Act.

For this section, if the EIS assessment process for your project is complete please answer Questions 11.1-11.2. If the EIS assessment process has not been completed, please complete Questions 11.3 and 11.4.

Further information about the EIS process is available at www.qld.gov.au using the search term 'environmental impact statements'.

11.1 Completed EIS process

Has an EIS process under Chapter 3 of the EP Act been completed?*		
☐ No	Go to *Question 11.3.*	
☐ Yes	Was the EIS process completed for all activities that are the subject of this application?	
	☐ No	Please list the activities that were not included in the EIS or attach documentation with this information to this application: Insert. ☐ I have attached the required supporting information Go to *Question 11.2*
	☐ Yes	Go to *Question 11.2*

11.2 Environmental risks

Have the environmental risks or the way the activity/activities are proposed to be carried out changed since the EIS was completed?*	
☐ No	Go to *Question 13.*
☐ Yes	I have attached supporting information. Go to *Question 13.*

11.3 Current EIS process

11.3.1 Have you applied for a decision on whether an EIS would be required under the EP Act for an EA application under Part 3, Chapter 3?	
☐ No	*Go to question 11.3.2*
☐ Yes	What was the decision? ☐ EIS would be required. ☐ EIS would not be required Go to *Question 13*

11.3.2 Have you applied to voluntarily prepare an EIS under either Part 2 or Part 3 of Chapter 3 of the EP Act?		
☐ No	*Go to question 12*	
☐ Yes	What was the outcome of the application?	
	☐ Refused	Go to *question 13*
	☐ Approved	Have you submitted a draft TOR to the department? ☐ Yes Insert date of submission ☐ No Go to *Question 13*
		Do you intend to prepare an EIS under chapter 3, EP Act? ☐ Yes ☐ No Go to *Question 13*

12 EIS criteria

The information provided here will assist in determining whether an EIS (under the EP Act) is required. If your response to any question is yes, you must attach details of how the criterion is triggered including details of the impact. You do not need to fill this out if you have an approval to voluntarily prepare an EIS under Part 2 or Part 3 of Chapter 3 or received a decision that an EIS would not be required for an EA application for this application under Part 3, Chapter 3 **OR** if you have indicated in question 10 that the proposed activities are being or have been assessed by the Coordinator General as part of an EIS for a coordinated project. For further information refer to the guideline Criteria for environmental impact statements for resource projects under the *Environmental Protection Act 1994* (ESR/2016/2167).

#	**Criteria—EIS triggers (*if applicable)** **This question is not applicable if an EIS process under either the SDPOW Act or the EP Act has been completed for all the activities that are the subject of this application, and the environmental risks of the activities and the way they are proposed to be carried out has not changed since the EIS was completed.**	**Response**
	*Questions 12.1-12.3 are mandatory for **mining activities only**. If your proposed activity/activities is not a mining activity, tick N/A and proceed to *Question 12.4*.	☐ N/A
12.1*	Is the ERA project for a mining activity which involves the removal of two million tonnes/year or more of run-of-mine (ROM)[4] ore or coal?	☐ YES ☐ NO
12.2*	Is the ERA project for a mining activity that involves the removal of 1 million tonnes per year or more of run-of-mine (ROM) ore or coal on or under a floodplain or a coastal hazard area?	☐ YES ☐ NO
12.3*	Is the ERA project for a mining activity which involves the introduction of a novel or unproven resource extraction process, technology or activity[5]?	☐ YES ☐ NO
	*Questions 12.4-12.6 are mandatory for **petroleum and gas activities only**. If your proposed activity/activities is not a petroleum and gas activity, tick N/A and go to Question 0.	☐ N/A
12.4*	Is the ERA project for a petroleum and gas activity that is likely to have a total disturbance area of greater than 2000 hectares at any one time during the life of the proposed project? This includes areas occupied by well pads (single or multi-directional), access tracks and roads, water storages, and process plants?	☐ YES ☐ NO
12.5*	Is the ERA project for a petroleum and gas activity that is likely to involve the construction of a high pressure pipeline over a distance of 300 kilometres or greater?	☐ YES ☐ NO
12.6*	Is the ERA project for a petroleum and gas activity that is likely to involve the construction of a liquefied natural gas plant?	☐ YES ☐ NO
☐ I have attached details of how the criterion is triggered including details of the impact.		
There are numerous criteria used to make the EIS decision. Further information about the EIS process is available at www.qld.gov.au using the search term 'environmental impact statements'.		

[4] ROM ore or coal means the material excavated but prior to washing or chemical concentration. It does not include overburden.

[5] For example: underground coal gasification; in-seam coal slurrying; a new method of ore concentration. This will be decided on a case-by-case basis and this trigger is not intended to discourage innovation.

13 Progressive rehabilitation and closure plan (PRC plan) under the EP Act

Is this application for a new site-specific EA for a mining activity relating to a mining lease? *

☒ No

☐ Yes

If yes, this application **must** be accompanied by a PRC plan complying with 126C and submitted in the approved form unless:

- In relation to an EIS process under EP Act:
    - the administering authority has approved the voluntary preparation of an EIS under Part 2 or Part 3, Chapter 3 of the EP Act and the EIS has started (draft Terms of Reference submitted), or you stated in this application (question 11.3.2) that an EIS will be prepared; OR
    - The Department has made a decision that an EIS is required for this application under Part 3, Chapter 3 of the EP Act; OR
- In relation to an EIS process under SDPWO Act:
    - The Coordinator-General has declared that the project the subject of this application is a coordinated project for which an EIS is required.

In the above circumstances, the intention is for the PRC plan to be provided in the EIS. Following the EIS assessment process, the PRC plan should be formally lodged in the approved form.

The approved form for Submission of a progressive rehabilitation and closure plan (ESR/2019/4957) can be obtained here.

14 Assessment of the environmental impact

This question is **not applicable if any** of the following apply. If relevant, please tick which scenario is relevant to your project:

In relation to an EIS process under SDPWO Act:

☐ an EIS process has been completed for all the activities that are the subject of this application **and** the environmental risks of the activities and the way they are proposed to be carried out has not changed since the EIS was completed.

OR

☐ the Coordinator-General has declared that the project the subject of the application is a coordinated project for which an EIS under that Act is required.

OR

In relation to an EIS process under EP Act:

☐ an EIS process has been completed for all the activities that are the subject of this application **and** the environmental risks of the activities and the way they are proposed to be carried out has not changed since the EIS was completed.

OR

☐ an application to the chief executive to decide if an EIS was required for an EA application for the application was approved (Chapter 3, Part 3)

OR

☐ chief executive approved application to voluntarily prepare an EIS under either Part 2 or Part 3 of Chapter **and either**

- Proponent has submitted a draft TOR

  OR

  You stated in question 11.3.2 of this form that you (the applicant) intend to prepare an EIS under chapter 3, EP Act.

You must attach to this application an assessment of the likely impact of each ERA on environmental values (*if applicable), including:

- a description of the environmental values likely to be affected by each relevant activity
- details of any emissions or releases likely to be generated by each relevant activity
- a description of the risk and likely magnitude of impacts on the environmental values
- details of the management practices proposed to be implemented to prevent or minimise adverse impacts
- if you answered 'No' to Question 0, details of how the land the subject of the application will be rehabilitated after each relevant activity ceases

☒ I have attached an assessment of the environmental impact and specific supporting information.

15 Details of waste management

Describe the proposed measures for minimising and managing waste generated by the activity/activities below or on an attachment*
Refer to Appendix 3 – supporting information

☐ I have attached the proposed measures.

16 Coal seam gas activities

This question is **not applicable if** an EIS process under the SDPWO Act has been completed for all the activities that are the subject of this application **and** the environmental risks of the activities have not changed since the EIS was completed.

<table>
<tr><th colspan="3">Does the application relate to coal seam gas (CSG) activities? (*if applicable)</th></tr>
<tr><td>☐ No</td><td colspan="2">You will not be authorised to undertake CSG activities. Go to Question 17.</td></tr>
<tr><td rowspan="3">☒ Yes</td><td colspan="2">Will CSG water be generated by the proposed activities? (*if applicable)</td></tr>
<tr><td colspan="2">☐ No</td></tr>
<tr><td>☒ Yes</td><td>You must attach documentation detailing:
the quantity of CSG water the applicant reasonably expects will be generated in connection with carrying out each relevant CSG activity; and
the flow rate at which the applicant reasonably expects the water will be generated; and
the quality of the water, including changes in the water quality the applicant reasonably expects will happen while each relevant CSG activity is carried out; and
the proposed management of the water including, for example, the use, treatment, storage or disposal of the water; and
the measurable criteria (the management criteria) against which the applicant will monitor and assess the effectiveness of the management of the water, including, for example, criteria for each of the following:
(i) the quantity and quality of the water used, treated, stored or disposed of
(ii) protection of the environmental values affected by each relevant CSG activity
(iii) the disposal of waste, including, for example, salt, generated from the management of the water; and</td></tr>
</table>

		• the action proposed to be taken if any of the management criteria are not complied with. This will also need to include actions to make sure that the management criteria will be able to be complied with in the future; and • whether the proposed management of the CSG water is consistent with the Coal Seam Gas Water Management Policy 2012 (ESR/2016/2381), including the prioritisation hierarchy for managing and using CSG water; or • if the proposed management of the coal seam gas water is inconsistent with the prioritisation hierarchy for managing and using CSG water—the reason for managing the CSG water in the proposed way.
	Will brine or salt be generated by the proposed activities? (*if applicable)	
	☐ No	
	☒ Yes →	You **must** attach documentation detailing: • whether the proposed management of the salt or brine is consistent with the Coal Seam Gas Water Management Policy 2012 (ESR/2016/2381) including the prioritisation hierarchy for managing saline waste; or • if the proposed management of the salt or brine is inconsistent with the prioritisation hierarchy for managing saline waste—the reason for managing the salt or brine in the proposed way.
	Is a CSG evaporation dam proposed in connection with carrying out the CSG activity? (*if applicable)	
	☒ No	
	☐ Yes →	You **must** attach documentation detailing: (a) an evaluation of best practice environmental management for managing the CSG water; and (b) an evaluation of alternative ways for managing the water; and (c) how the evaluation demonstrates that there is no feasible alternative to a CSG evaporation dam for managing the water.
☐ I have attached the documentation to support all 'Yes' responses provided above.		

17 Exercising underground water rights

Underground water rights provide the tenure holder with a statutory right to take or interfere with underground water in the area of the tenure if the taking or interference with that water is necessarily and unavoidably obtained in the process of extracting the resource.

For more information about exercising underground water rights or the associated application requirements please refer to the guideline Requirements for site-specific and amendment applications-underground water rights (ESR/2016/3275).

If the activity/activities are proposed to be undertaken on a mineral development licence (MDL), mining lease (ML) or petroleum lease (PL), does the application propose to exercise underground water rights?*	
☐ N/A	The proposed activity/activities are not on a MDL, ML or PL. Go to *Question 18*.
☐ No	Go to *Question 18*.
☒ Yes	You **must** attach documentation detailing: • the areas in which underground water rights are proposed to be exercised; • for each aquifer affected, or likely to be affected, by the exercise of underground water rights: (i) a description of the aquifer; (ii) an analysis of the movement of underground water to and from the aquifer, including how the aquifer interacts with other aquifers and surface water; and (iii) a description of the area of the aquifer where the water level is predicted to decline because of the exercise of underground water rights; and (iv) the predicted quantities of water to be taken or interfered with because of the exercise of underground water rights during the period in which resource activities are carried out; • the environmental values that will, or may, be affected by the exercise of underground water rights and the nature and extent of the impacts on the environmental values; • any impacts on the quality of groundwater that will, or may, happen because of the exercise of underground water rights during or after the period in which resource activities are carried out; and • strategies for avoiding, mitigating or managing the predicted impacts on the environmental values or the impacts on the quality of groundwater.
☒ I have attached all relevant supporting documentation.	

18 Publication of application notice and documents

This question is only applicable if you are proposing to undertake a mining activity on a mining lease, or a geothermal, petroleum or greenhouse gas storage activity.

As the applicant, you may be required to make the application notice, application documents and the response to any information requests available on a website during the public notification period. By providing a website address below, you give permission for the administering authority to link to your website during the public access period.

What is the website address for the application notice and application documents (*if applicable)?		
https://www.santos.com/about-us/corporate-governance/public-notices/		
Details of contact person if technical assistance is required:		
Name: ALEX CLARKE	Phone: (07) 3838 3000	Email: ALEX.CLARKE@SANTOS.COM

19 Payment of fees

You are required to pay an application fee at the time of application. If your application is approved you will be required to pay a fee annually. Each ERA has a regulated fee and the annual fee will be the highest annual fee of any ERA associated with the project. The first annual fee will be invoiced when one or more of the tenures are granted. Information on fees is available on Forms and fees for environmental authorities | Business Queensland and in the information sheet Summary of fees for environmentally relevant activities (ESR/2015/1746).

The application fee is:	$36248.20

Preferred

☐ Apply using Online Services – submit the application online and pay by credit card.

Alternatively

☒ Email the completed application with a request to pay the application fee by Bpoint. Please do not email your credit card details – we will send you a link to pay securely by credit card via BPoint.

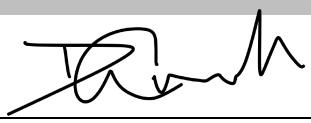
For more information on payment options go to the Business Queensland website at www.business.qld.gov.au and search 'Forms and fees for mining and resources'.

20 Applicant declaration

I declare that the information I have provided is true and correct. I understand that it is an offence under the EP Act to give information that I know is false, misleading or incomplete.

I will comply with all conditions on my EA as well as any relevant provision in the EP Act.

I understand that I am responsible for managing the environmental impacts of these activities, and that approval of this application is not an endorsement by the administering authority of the effectiveness of the management practices proposed or implemented.

Applicant's full name*	**Applicant's position (*if an organisation)**
DAVID GORNALL	Manager Environment EA PNG, Eastern AU & PNG EHSR
Applicant's signature*	**Date***
	30/01/26

21 Important note: Estimated rehabilitation cost (ERC)

It is a condition of all environmental authorities for resource activities, under section 297 of the EP Act, that the holder must not carry out, or allow the carrying out of, a resource activity under the authority unless an ERC decision is in effect, and the holder has paid scheme assurance and complied with the requirements under the *Mineral and Energy Resources (Financial Provisioning) Act 2018* for paying this assurance. If your application for an EA is approved, you must lodge a separate application for an ERC decision either using Online Services[6]or by submitting the approved form Application for a decision on the estimated rehabilitation cost (ESR/2018/4426). For further information regarding the estimated rehabilitation cost, refer to the guideline Estimated rehabilitation cost under the *Environmental Protection Act 1994* (ESR/2018/4425).

[6] Certain applications to the Department can be made using Online Services. For more information and to register to use Online Services go to https://business.qld.gov.au/running-business/environment/online-services.

Submitting your completed application

Submit your completed application (in word searchable electronic PDF format) via email to palm@detsi.qld.gov.au or:

Post:
Permit and Licence Management
Department of the Environment, Tourism, Science and Innovation
GPO Box 2454
BRISBANE QLD 4001

Further information:
www.business.qld.gov.au
Email: palm@detsi.qld.gov.au
Phone: 13 QGOV (13 74 68)

Privacy statement

The Department of the Environment, Tourism, Science and Innovation (the Department) and the Department of Natural Resources and Mines, Manufacturing, and Regional and Rural Development are collecting the information on this form in accordance with and as authorised by Chapter 5 of the EP Act.

Pursuant to section 540 of the EP Act, the Department is required to maintain a register of certain documents and information authorised under the EP Act. A copy of this document will be kept on the public register. The register is available for inspection by members of the public who are able to take extracts, or copies of the documents from the register. Documents that are required to be kept on the register are published in their entirety, unless alteration is required by the EP Act. There is no general discretion allowing the Department to withhold documents or information required to be kept on the public register. For more information on the Department's public register, search 'public register' at www.qld.gov.au. For queries about privacy matters please email privacy@detsi.qld.gov.au or telephone 13 74 68.

Docusign Envelope ID: AF36C1D0-D794-41DA-8EBE-7B2C028E39B5

Attachment 1—Joint applicants and appointment of principal applicant

We are joint applicants for this EA and hereby appoint: Santos Ventures Pty Ltd
as the principal applicant to receive statutory documents relating to this application.

Name—individual or contact person if applicant is an organisation	Suitable operator reference number 696651
Organisation name (include trading name if relevant) TOTAL ENERGIES EP AUSTRALIA	ABN/ACN (if an organisation) 112603880
Residential or registered business address (not a post office box) Level 26/360 Elizabeth St, Melbourne VIC 3000	Phone 61 455 444 779
Postal address (if different from above)	Facsimile
Email martin.tiffen@totalenergies.com	☐ *Indicate if you want to receive correspondence via email*
Signature DocuSigned by: Martin Tiffen 3DC308AA5B96470...	Date January 29, 2026 | 3:55 AM CET

Name—individual or contact person if applicant is an organisation	Suitable operator reference number 696652
Organisation name (include trading name if relevant) TOTAL ENERGIES EP AUSTRALIA II	ABN/ACN (if an organisation) 52149617167
Residential or registered business address (not a post office box) Level 26/360 Elizabeth St, Melbourne VIC 3000	Phone 61 455 444 779
Postal address (if different from above)	Facsimile
Email martin.tiffen@totalenergies.com	☐ *Indicate if you want to receive correspondence via email*
Signature DocuSigned by: Martin Tiffen 3DC308AA5B96470...	Date January 29, 2026 | 3:55 AM CET

Name—individual or contact person if applicant is an organisation	Suitable operator reference number 707082
Organisation name (include trading name if relevant) PAPL (UPSTREAM) PTY LIMITED	ABN/ACN (if an organisation) 131318888
Residential or registered business address (not a post office box) Level 36 Santos Place 32 Turbot Street BRISBANE QLD 4000	Phone
Postal address (if different from above)	Facsimile
Email	☐ *Indicate if you want to receive correspondence via email*
Signature	Date

Attachment 1—Joint applicants and appointment of principal applicant

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as the principal applicant to receive statutory documents relating to this application.

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Organisation name (include trading name if relevant) TOTAL ENERGIES EP AUSTRALIA	ABN/ACN (if an organisation) 112603880
Residential or registered business address (not a post office box) Level 26/360 Elizabeth St, Melbourne VIC 3000	Phone
Postal address (if different from above)	Facsimile
Email	☐ *Indicate if you want to receive correspondence via email*
Signature	Date

Name—individual or contact person if applicant is an organisation	Suitable operator reference number 696652
Organisation name (include trading name if relevant) TOTAL ENERGIES EP AUSTRALIA II	ABN/ACN (if an organisation) 52149617167
Residential or registered business address (not a post office box) Level 26/360 Elizabeth St, Melbourne VIC 3000	Phone
Postal address (if different from above)	Facsimile
Email	☐ *Indicate if you want to receive correspondence via email*
Signature	Date

Name—individual or contact person if applicant is an organisation AHMAD AZIZI BIN AHMAD KAMIL	Suitable operator reference number 707082
Organisation name (include trading name if relevant) PAPL (UPSTREAM) PTY LIMITED	ABN/ACN (if an organisation) 131318888
Residential or registered business address (not a post office box) Level 36 Santos Place 32 Turbot Street BRISBANE QLD 4000	Phone
Postal address (if different from above)	Facsimile
Email ahmadazizi@petronas.com	☐ *Indicate if you want to receive correspondence via email*
Signature 	Date 21 JAN 2026

Name—individual or contact person if applicant is an organisation	Suitable operator reference number 696655
Organisation name (include trading name if relevant) KGLNG E&P PTY LTD	ABN/ACN (if an organisation) 146143339
Residential or registered business address (not a post office box) Level 36, Santos Place 32 Turbot Street Brisbane QLD 4000	Phone
Postal address (if different from above)	Facsimile
Email	☐ *Indicate if you want to receive correspondence via email*
Signature	Date 14/01/2026

Santos

Appendix 3

Supporting Information

Santos

Supporting Information Report Site-Specific Environmental Authority Application Petroleum Lease 1123

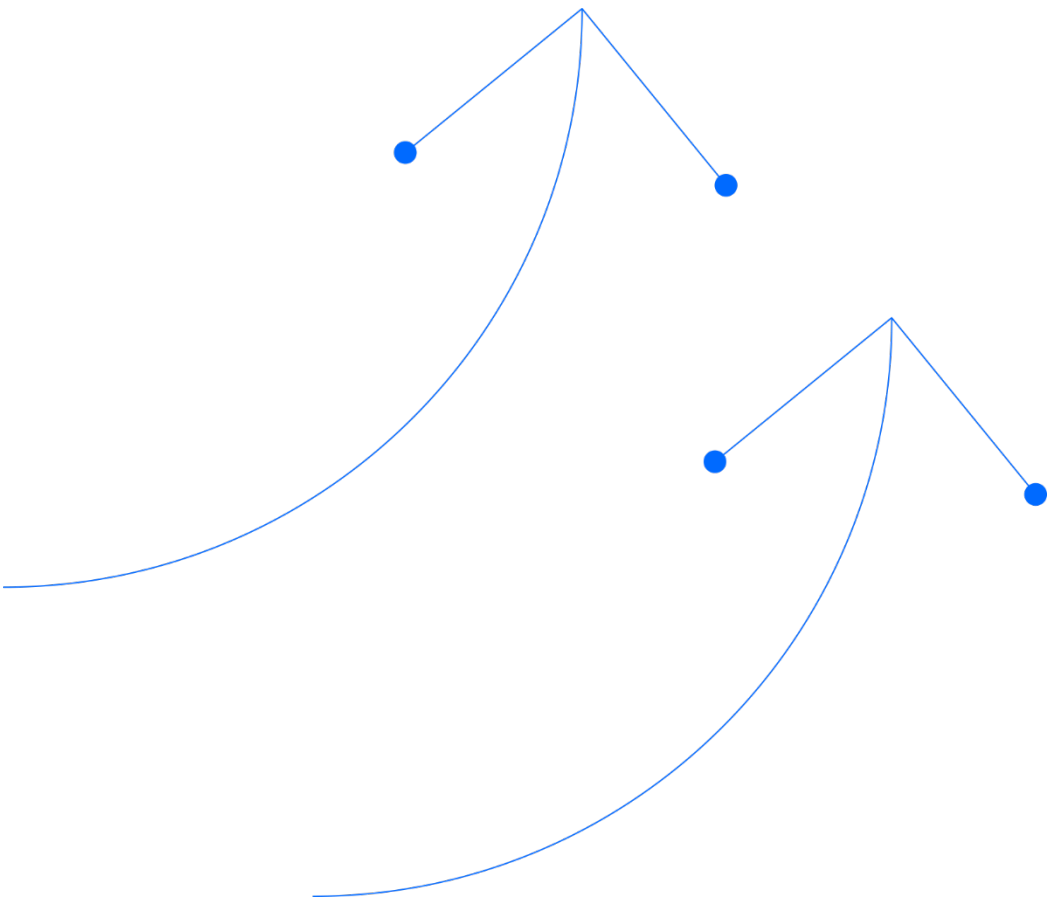


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Abbreviations and Units

Acronym	Description
ATP	Authority to Prospect
BoM	Bureau of Meteorology
BPEM	Best Practice Environmental Management
CSG	Coal Seam Gas
DEHP	Department of Environment and Heritage Protection, Queensland (now DETSI)
DETSI	Department of Environment, Tourism, Science and Innovation, Queensland
EA	Environmental Authority
EO Act	*Environmental Offsets Act 2014*
EP Act	*Environmental Protection Act 1994*
EP Reg	*Environmental Protection Regulation 2019*
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
EPP	*Environmental Protection Policy 2019*
ERA	Environmentally Relevant Activities
ESA	Environmentally Sensitive Area
EV	Environmental Value
GES	General Ecological Significance
GLNG	Gladstone Liquified Natural Gas
ha	Hectares
HES	High Ecological Significance
IEMS	Integrated Environmental Management System
km	Kilometre
LC	Least Concern
m	Metres
MSES	Matters of State Environmental Significance
MNES	Matters of National Environmental Significance
N/A	Not Applicable
NCA	*Nature Conservation Act 1992*
NCAP	No Concern at Present
PDF	Preliminary Disturbance Footprint
PL	Petroleum Lease
PEM	Prescribed Environmental Matter
PMST	Commonwealth Protected Matters Search Tool
RoW	Right of Way
SMS	Santos Management System
TEC	Threatened Ecological Communities

1.0 Introduction and Legislative Requirements

Santos Ventures Pty Ltd (Santos), on behalf of its joint venture (JV) partners TotalEnergies EP Australia II, KGLNG E&P Pty Ltd, TotalEnergies EP Australia and PAPL (Upstream) Pty Limited (the proponents) are applying for a new site-specific Environmental Authority (EA) to authorise petroleum production operations on proposed Petroleum Lease (PL) 1123. Santos is the principal applicant. PL 1123 will wholly replace all existing blocks of Authority to Prospect (ATP) 2053, which is an existing exploration tenure operated by Santos.

Santos proposes to develop PL 1123 as part of the Santos Roma Phase 7-7B-SD20 Development (Project). The Project will involve the progressive construction, operation, decommissioning and rehabilitation of up to 24 Coal Seam Gas (CSG) wells and associated infrastructure located in PL 1123 (the Project Area). Further detail on the proposed activities is provided in Section 2.2.

Further, the Project has been referred to the Commonwealth Department of Climate Change, Energy, the Environment and Water (DCCEEW) for assessment under the requirements of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The title holders of PL 1123 are:

- Santos Ventures Pty Ltd (ABN: 60 123 982 749)
- PAPL (Upstream) Pty Limited (ABN: 58 131 318 888)
- TotalEnergies E&P Australia (ABN: 96 832 035 151)
- TotalEnergies E&P Australia II (ABN: 52 149 617 167); and
- KGLNG E&P Pty Ltd (ABN: 31 146 143 339).

This document has been prepared in accordance with Sections 125, 126 and 126A of the *Environmental Protection Act 1994* (EP Act) and the Department of Environment, Tourism, Science and Innovation's (DETSI) *Guideline - Application requirements for petroleum activities* (ESR/2016/2357, Version 4.01). Refer to Section 1.2 for legislative requirements.

1.1 Background

The Project Area is located approximately 43 kilometres (km) east of the town of Roma and 5km east of the town of Wallumbilla in southern inland Queensland (refer to Figure 1).

PL 1123 (Project Area) is bounded on all sides by existing Santos operated tenues, including PLs 281, 282, 315, 318 and 1020 (as shown in Figure 1). Santos has undertaken extensive exploration, appraisal and production activities on adjacent tenures including PLs 281, 282, 315, 318 and 1020, which has supported proving the prospectivity of the Project Area.

Petroleum activities on the abovementioned adjacent tenures are authorised under existing EPBC Act approval decisions for the Gladstone Liquified Natural Gas Field Development Project (GLNG GFD) (EPBC approval numbers 2008/4059 and 2012/6615). Further, petroleum activities undertaken on PLs 281 and 282 are authorised under the *Environmental Protection Act 1994* (EP Act) via the Roma Shallow Gas Project Area East (RSGPAE) EA EPPG00662213, and petroleum activities undertaken on PLs 314, 315, 318 and 1020 are authorised under the Roma Shallow Gas Project Area (RSGPA) EA EPPG00898213.

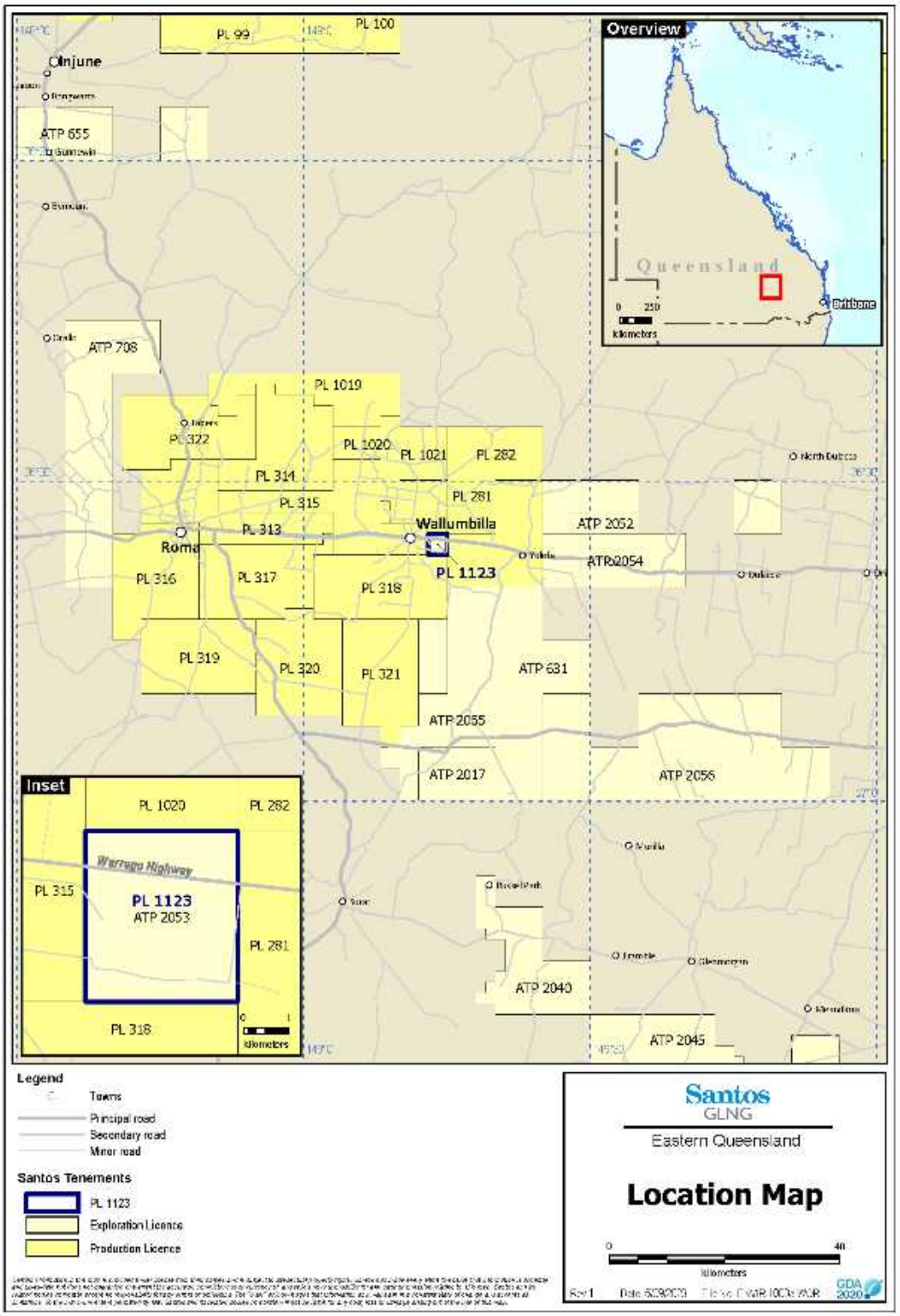


Figure 1: PL 1123 – Regional Location Map – (PL 1123)

1.2 Legislative Requirements

1.2.1 Environmental Protection Act 1994 (EP Act)

1.2.1.1 General Requirements for an EA application (s125 EP Act)

Section 125 of the EP Act specifies the general requirements for an EA application. These are addressed in Table 1.

Table 1: General requirements for an EA application (s125 EP Act)

Section 125 of the EP Act	Relevance to Application
(a) be made to the administering authority	This EA application has been submitted to DETSI who is the administering authority for the EP Act.
(b) be made in the approved form	The application was made using the approved form.
(c) describe all environmentally relevant activities for the application	Refer to Section 2.4.
(d) describe the land on which each activity will be carried out	Refer to Section 3.0.
(e) be accompanied by the fee prescribed under a regulation	The prescribed fee was paid at the time of submission.
(f) if 2 or more entities (joint applicants) jointly make the application—nominate 1 joint applicant as the principal applicant	The approved form nominates the principal applicant.
(g) state whether the application is— *(i) a standard application; or* *(ii) a variation application; or* *(iii) a site-specific application;*	The application is a site-specific application.
(h) state whether the applicant is a registered suitable operator	The approved form identifies the registered suitable operators.
(i) if a development permit under the Planning Act, or an SDA approval under the State Development Act, is required under either of those Acts for carrying out the environmentally relevant activities for the application—describe the permit or approval	N/A – there are no relevant approvals under the Planning Act or State Development Act.
(j) if the application is a standard or variation application—include a declaration that each relevant activity complies with the eligibility criteria	N/A
(k) if the application is a variation application—	N/A

Section 125 of the EP Act	Relevance to Application
(i) for a variation application under section 123(1)—state the standard conditions for the activity or authority the applicant seeks to change; or *(ii) for a variation application under section 123(2)—state the standard conditions that are not the same as the Coordinator-General's conditions;*	
(l) if the application is a variation or site-specific application— *(i) include an assessment of the likely impact of each relevant activity on the environmental values, including—* *(A) a description of the environmental values likely to be affected by each relevant activity;*	Refer to Section 4.0.
(B) details of any emissions or releases likely to be generated by each relevant activity;	Refer to Sections 4.0 and 5.0.
(C) a description of the risk and likely magnitude of impacts on the environmental values;	Refer to Sections 4.0 and 5.0.
(D) details of the management practices proposed to be implemented to prevent or minimise adverse impacts;	Refer to Sections 4.0 and 5.0.
(E) details of how the land the subject of the application will be rehabilitated after each relevant activity ceases;	Refer to Section 4.9.
(ii) include a description of the proposed measures for minimising and managing waste generated by each relevant activity;	Refer to Section 4.8.
(iii) include details of any site management plan that relates to the land the subject of the application;	N/A
(m) if the application is for a prescribed ERA—state whether the applicant wants any environmental authority granted for the application to take effect on a day nominated by the applicant; and	N/A
(n) if the application is a site-specific application for a mining activity relating to a mining lease—be accompanied by a proposed PRC plan; and	N/A

Section 125 of the EP Act	Relevance to Application
(o) include any other document relating to the application prescribed under a regulation	Refer to Sections 4.8.1 and 4.8.2, and the information throughout this document.

1.2.2 Requirements for site specific applications – CSG activities (s126 and 126A EP Act)

Section 126 of the EP Act specifies the requirements for a site-specific application for CSG activities. These are addressed in Table 2.

Section 126A of the EP Act specifies requirements for site-specific applications for resource activities which involve the exercise of underground water rights. These requirements are addressed in section 4.6.2.

Table 2: Requirements for CSG activities (s126 EP Act)

Section 126(1) and (2) of the EP Act	Relevance to Application
(1) A site-specific application for a CSG activity must also state the following— *(a) the quantity of CSG water the applicant reasonably expects will be generated in connection with carrying out each relevant CSG activity;*	The total estimated groundwater abstraction volume for the duration of the Project (with an expected operational life of 30-50 years) is estimated to be 645 ML (KCB, 2025).
(b) the flow rate at which the applicant reasonably expects the water will be generated;	Peak water production is predicted to occur in January 2028 at 0.24 ML/day (7.12 ML/month).
(c) the quality of the water, including changes in the water quality the applicant reasonably expects will happen while each relevant CSG activity is carried out;	Refer to Section 4.8.1.
(d) the proposed management of the water including, for example, the use, treatment, storage or disposal of the water;	Refer to Section 4.8.1.
(e) the measurable criteria (the management criteria) against which the applicant will monitor and assess the effectiveness of the management of the water, including, for example, criteria for each of the following— *(i) the quantity and quality of the water used, treated, stored or disposed of;*	Refer to Section 4.8.1 and Table 25.
(ii) protection of the environmental values affected by each relevant CSG activity;	Refer to Section 4.8.1 and Table 25.

Section 126(1) and (2) of the EP Act	Relevance to Application
(iii) the disposal of waste, including, for example, salt, generated from the management of the water;	No produced water (PW) treatment or disposal of waste products from the treatment of water would occur in the Project Area. With the exception of small volumes of PW to be stored in temporary portable tanks in the Project Area, the majority of PW from the Project Area is proposed to be gathered to the Pickanjinnie and/or Raslie Dams (located on adjacent PL 315). PW from Pickanjinnie / Raslie Dams will then be transferred to the existing water management / processing facilities located on PL 314 (Hub 2) to be processed. On PL 314, the water will be processed through a fines and sludge removal facility before being further processed, or bypassed around, the Roma Reverse Osmosis Plant (ROP) to meet re-use criteria in accordance with *End of Waste Code Irrigation of Associated Water (including coal seam gas water) (ENEW07546918, Version 1.07)* (DETSI, 2025a). Petroleum activities undertaken on PLs 314 and 315 are authorised under existing the Santos EA EPPG00898213 (RSGPA) (refer to Section 4.8.1 for further detail).
(f) the action proposed to be taken if any of the management criteria are not complied with, to ensure the criteria will be able to be complied with in the future.	In the event that any management criteria are not complied with, works/operations that potentially cause the non-compliance would be assessed (and paused if appropriate) and an investigation would commence to identify why the non-compliance has occurred, the effectiveness of existing controls, new controls to be applied where appropriate and any remedial actions to be taken.
(2) The proposed management of the water can not provide for using a CSG evaporation dam in connection with carrying out a relevant CSG activity unless *(a) the application includes an evaluation of—* *(i) best practice environmental management for managing the CSG water; and* *(ii) alternative ways for managing the water; and* *(b) the evaluation shows there is no feasible alternative to a CSG evaporation dam for managing the water.*	As discussed in Section 2.2, for the purposes of efficiency and to minimise land disturbance in the Project Area, gas and PW generated from the Project Area will utilise existing centralised water and gas processing facilities (including compression stations) located on adjoining RSGPA tenures (authorised under EA EPPG00898213). PW is proposed to be transferred to existing approved dams located on adjacent tenures. PW from these dams is then proposed to be transferred to existing approved water treatment facilities located on PL 314, where the water will be processed through a fines and sludge removal facility before being further processed, or bypassed around, the Roma Reverse Osmosis Plant (ROP) to meet re-use criteria in accordance with *End of Waste Code Irrigation of Associated Water* (ENEW07546918, Version 1.07) (DETSI, 2025a). The Roma ROP is located approx. 25 km northwest of the Project Area. Adequate water and brine storage and treatment capacity has been assessed to be available

Section 126(1) and (2) of the EP Act	Relevance to Application
	on adjacent tenures to manage peak water and brine production from the Project. Integration with the RSGPA activities will negate the requirement to locate large water management facilities within the Project Area. Accordingly, this will result in less major infrastructure being required to be located in the Project Area, which will minimise disturbance to remnant native vegetation and assist in minimising disruption to existing land uses i.e. cropping and grazing land. This arrangement represents the best practice environmental management for managing the CSG water and no feasible alternative arrangement is deemed otherwise suitable for the proposed activities. Small volumes of PW may be stored within the Project Area in portable tanks. A proportion of PW stored in tanks on site will be used for on-site activities such as water supply for drilling and hydraulic fracturing purposes, and/or to provide a water source for dust suppression / construction activities (where the water use meets proposed EA conditions and criteria). Approximately 158 ML of water will be required to develop the Project (this represents ~24% of estimated PW volume). Adequate water and brine storage and treatment capacity has been assessed to be available on adjacent tenures to manage peak water and brine production from the Project. Refer to Section 4.8.1 for further detail on produced water management.

1.2.3 Standard Criteria for Decision (s176 EP Act)

Section 176 of the EP Act requires the administering authority, in deciding a variation or site-specific EA application, to consider any relevant regulatory requirements having regard to:

a) the application
b) the standard conditions for the relevant activity or authority
c) any response given for an information request
d) the standard criteria.

The standard criteria (as defined by Schedule 4 of the EP Act) are required to be considered by the administering authority for deciding an application. Refer to Table 3 for consideration of the standard criteria.

The relevant regulatory requirements are contained in section 35 and schedule 8 of the *Environmental Protection Regulation 2019*. These regulatory requirements are addressed in Schedule G.

Proposed EA conditions are attached as Appendix A.

Table 3: Standard Criteria (EP Act)

Schedule 4 EP Act	Relevance
a) the following principles of environmental policy as set out in the Intergovernmental Agreement on the Environment – *(i) the precautionary principle;* *(ii) intergenerational equity;* *(iii) conservation of biological diversity and ecological integrity; and*	The precautionary principle was considered for the application. It is considered that the proposed activities will use 'proven' technology and sufficient scientific data exists that a reverse onus does not exist. The principle of intergenerational equity was considered for the application. It is considered that the proposed activities would not impact the use of environmental values by future generations. The principles of conservation of biological diversity and ecological integrity were considered for the application. The proposed application would not result in impacts to biological diversity or ecological integrity.
b) any Commonwealth or State government plans, standards, agreements or requirements about environmental protection or ecologically sustainable development	The proposed petroleum activities will be undertaken in accordance with the applicable requirements of the following: • EP Act; • *Environment Protection and Biodiversity Conservation Act 1999* (Cth); • *Nature Conservation Act 1992* (Qld); • *Vegetation Management Act 1999* (Qld); • *Environmental Offsets Act 2014* (Qld); • *Fisheries Act 1994* (Qld); and • *Planning Act 2016* (Qld).
d) any relevant environmental impact study, assessment or report	Not applicable – there is no environmental impact study relevant to this application.
e) the character, resilience and values of the receiving environment	Refer to Sections 3.0 to 4.0.
f) all submissions made by the application and submitters	Where required by DETSI, Santos would consider any submissions made on the application.
g) Best Practice Environmental Management (BPEM) for activities under any relevant instrument, or proposed instrument, as follows- *(i) an environmental authority;* *(ii) a transitional environmental program;* *(iii) an environmental protection order;* *(iv) a disposal permit;* *(v) a development approval;*	BPEM of the petroleum activities would be achieved through compliance with the scheduled environmental objectives and proposed conditions of the new EA. Potential impacts to any environmental value will be managed in accordance with the proposed EA conditions as well as the Santos Management System.
h) Financial implications of the requirements under an instrument, or proposed instrument, mentioned in paragraph (g) as they would relate to the type of activity or industry carried out, or	Santos will continue to provide adequate funds, equipment and staffing to comply with the conditions of the amended EA.

Schedule 4 EP Act	Relevance
proposed to be carried out under the instrument;	
i) Public Interest	The proposed EA is considered to be in the public interest. It will facilitate the ongoing production of gas to meet the needs of customers in Queensland and other Australian states / territories, and export markets in Asia and assist in the reduction of fossil fuel emissions by acting as a transitional fuel between coal and renewable energy whilst still maintaining published environmental objectives. Resources produced by Santos will generate taxes and royalties to the Queensland State Government, which provide an ongoing source of revenue to support Government services provided to the general public. Furthermore, in Australia and Queensland, gas plays an important role in domestic energy security and diversification, supporting intermittent renewable energy sources. Santos is a major supplier of natural gas to the domestic energy market, and has operated in Queensland for over 50 years and we're proud of the economic and social benefits being delivered by the projects in the Coopers, Surat and Bowen basins. One such project is the GLNG-GFD Project, which is led by Australian company Santos, in partnership with three of the world's leading energy companies – PETRONAS from Malaysia, Total from France, and KOGAS from South Korea. This project is a pioneering venture which produces natural gas from Queensland's coal seams and converts it into LNG. It involves ongoing gas field development in the Surat and Bowen Basins, a 420-kilometre gas transmission pipeline and a two-train LNG plant on Curtis Island, near Gladstone which has the capacity to produce 7.8 million tonnes of LNG per year. Santos GLNG is at the forefront of making Australia a world-leading LNG producer and will be worth billions of dollars to the Queensland and national economies over many decades. The billions to be paid in royalties will help pay for government frontline services across Queensland. It's one way the GLNG project is bringing renewed opportunities to Queensland. Project construction began in 2011 with the first shipment of LNG in October 2015. The project has taken more than 95 million work hours to date. More than 10,000 people have worked on the project which saw more than $15 billion invested Australia-wide, including $8 billion in Queensland alone of which $710 million was to the Maranoa, Toowoomba and Western Downs districts.

Schedule 4 EP Act	Relevance
	To ensure the delivery of commitments to the domestic and export markets Santos is in the process of optimising activities on existing tenements, along with the active expansion of new fields. This includes the Santos GLNG Project and the Gas Field Development Project which is not a new activity but an extension of the existing work being undertaken by Santos GLNG. One area of expansion is the Roma field which covers approximately 3,000 km^2. Sales gas from the Roma field is transported by pipeline to Gladstone, where it is converted into LNG for export to overseas markets. The major Roma Hub compression facility can produce 145 TJ of gas per day with ongoing development and compression capacity, such as this project, to add to production rates. Santos is committed to meaningfully contributing to the future strength and prosperity of the communities where we operate, building deep, long-lasting relationships with positive intergenerational benefits. We do this through implementing our community investment framework and by providing employment, training, education and enterprise opportunities associated with our industry. As a socially responsible company, our investment in local communities is part of our broader commitment to minimising the impact of our project activities and supporting programs and initiatives that benefit those who live in the areas where we operate. The GLNG community handbook which is a summary of the Santos GLNG Social Impact Management Plan (SIMP) as developed to explain the possible social impacts of our activities and what we are doing about them. Our objective is to work proactively and collaboratively with our host landholders and landowners across all areas of operation. We have a long history of strong and supportive landholder relationships in which we seek to support and enable long-term and intergenerational resilience. We are committed to working with Traditional Owners / clans and Indigenous communities to ensure they are fully informed prior to accessing land and address any issues raised promptly and transparently. We are proud to apply best practice in the assessment, identification and protection of cultural heritage and seek to identify suitable commercial opportunities for Indigenous businesses, as well as opportunities to employ and upskill Indigenous people. Santos recognises the scientific consensus of climate change assessed by the Intergovernmental Panel on Climate Change. We support the objective of the Paris Agreement to limit global temperature

Schedule 4 EP Act	Relevance
	rise to less than 2 degrees Celsius and pursue efforts to limit the temperature rise to 1.5 degrees Celsius. We believe that access to reliable and affordable energy is critical to meeting sustainable development goals and improving living standards and economic prosperity in developed and developing nations. Santos is committed to being part of the solution by supporting the twin objectives of limiting greenhouse gas emissions and providing cleaner fuels to domestic and global markets. Santos has a target of net-zero scope 1 and 2 greenhouse gas emissions by 2040. Our strategy focuses on natural gas as a reliable transition fuel source, and the development of technologies such as clean fuels like hydrogen as the foundation for our decarbonisation pathway. The application is in the public interest.
j) Any relevant site management plan	There are no SMPs applicable to the application.
k) Integrated environmental management system (IEMS) or proposed IEMS	The Santos Management System (SMS) will be implemented for the proposed activities.
l) Other matters prescribed under a regulation	The *Environmental Protection Regulation 2019* prescribes an environmental objective assessment relating to an environmental management decision as an additional matter for the standard criteria. This document has been prepared giving consideration to the above, and Sections 1.0 to 4.0 address the matters raised in the environmental objective assessment.

2.0 Application Description

This application is for a new site-specific EA to authorise petroleum activities under Section 109 of the *Petroleum and Gas (Production and Safety) Act 2004* on PL 1123 once granted. Santos applied for PL 1123 on 16 September 2022.

2.1 Existing Activities

Petroleum exploration activities currently undertaken on ATP 2053 (being proposed PL 1123) are authorised by EA 0002052. Exploration and appraisal activities undertaken by Santos on ATP 2053 to date include:

- drilling, completion and appraisal of 5 CSG wells (RM23-21-1, RM23-43-1, RM23-42-1, RM23-41-1 and RM23-46-1); and
- construction and operation of associated linear infrastructure (gas and water gathering lines, access tracks, power and communications lines).

This application considers total impacts and disturbances associated with 24 existing and proposed CSG wells (i.e. the existing 5 CSG wells form part of the proposed 24 CSG well development). Figure 2 outlines existing (and proposed) infrastructure locations in PL 1123.

2.2 Proposed Activities

The proposed development will initially include:

- progressive drilling (including hydraulic fracture stimulation), completion, and connection of up to 24 CSG exploration, appraisal, and development wells (with some multi-well leases)
- construction and operation of associated linear infrastructure (gas and water gathering lines, access tracks, power and communications lines). This infrastructure will be co-located wherever feasible, and will consist of:
    - buried gas and water gathering lines (these are typically co-located with power and communication lines); and
    - access tracks (typically co-located with gas and water gathering infrastructure) comprised of both new access tracks and the upgrade of existing access tracks.
- tie in of the existing wells to gas and water gathering lines to begin production; and
- other ancillary / incidental activities in support of the above activities.

No compression facilities are proposed, and no regulated structures will be required as part of the proposed activity.

Other activities proposed to be undertaken in the Project Area under the EA include but are not limited to construction and/or operation of the following:

- seismic surveys
- gas and water gathering systems / flowlines / pipelines
- powerlines and communication lines (above and/or below ground)

- access tracks and roads
- small-scale water management infrastructure i.e. portable tanks.
- a temporary worker's camp including a sewage treatment plant (STP) and associated irrigation (<21 EP); and
- other ancillary infrastructure / incidental activities such as laydowns, fencing and borrow pits/quarries.

CSG production may occur from a total of up to 24 CSG wells. For the purposes of minimising land disturbance to the Project Area, some well leases located in PL 1123 may host multiple CSG wells i.e. "multi-well leases". Figure 2 outlines existing (and proposed) infrastructure locations on PL 1123.

CSG and PW generated from the Project Area is proposed to be sent to existing approved centralised CSG and PW processing and storage facilities (including compression stations) located on adjoining Santos operated tenures. This is inclusive of beneficial reuse through existing irrigation schemes authorised under the *End of Waste Code Irrigation of Associated Water (including coal seam gas water) (ENEW07546918, Version 1.07)* (DETSI, 2025a). These surrounding tenures, infrastructure and petroleum activities are authorised under existing Santos EAs and EPBC Act decisions/approvals, those being EAs EPPG00898213 (RSGPA), EPPG00662213 (RSGPAE) and EPPG04323316 (Roma Backbone)), and EPBC approvals 2008/4059 and 2012/6615.

Small volumes of PW may be stored within the Project Area in portable tanks. A proportion of PW stored in tanks on site will be used for on-site activities such as water supply for drilling and hydraulic fracturing purposes, and/or to provide a water source for dust suppression / construction activities (where the water use meets proposed EA conditions and criteria). Approximately 158 ML of water will be required to develop the Project (this represents ~24% of estimated PW volume).

Adequate water and brine storage and treatment capacity has been assessed to be available on adjacent tenures to manage peak water and brine production from the Project. Refer to Section 4.8.1 for further detail on produced water management.

Not all CSG wells will be drilled and operational at once. Project execution and gas production is forecast to begin from late-2025 (pending EPBC and EP Act approvals), with an expected operational life of 30-50 years.

Progressive decommissioning and rehabilitation of wells and associated infrastructure will also occur as required throughout this period in accordance with regulatory requirements and industry standards.

Refer to Appendix B for a detailed description of proposed activities to be undertaken in the Project Area.

2.3 Disturbance Planning

Santos has undertaken significant planning and field surveys to locate existing and proposed infrastructure / disturbance in the Project Area to avoid disturbance to environmental values (EVs).

Santos has also developed a preliminary disturbance footprint (PDF) for the Project Area to locate proposed infrastructure to avoid and minimise disturbance to Matters of National Environmental Significance (MNES), Matters of State Environmental Significance (MNES) and other environmental and landholder values. Santos developed the PDF to refine the layout to avoid, where practical, disturbance to environmental and landholder values. Proposed infrastructure has predominantly been located in cleared agricultural land with only minor disturbance to MNES/MSES values required, and no disturbance to Threatened Ecological Communities (TECs) is proposed.

The PDF is displayed in Figure 2. The majority of existing and proposed disturbance has been located in non-remnant vegetation or previously cleared areas. Where disturbance to remnant and regrowth vegetation will be required, Santos has actively shifted or reduced disturbance widths and areas to mitigate disturbance to sensitivities wherever practicable. More specifically, Santos has minimised disturbance to be limited to:

- 0.30 ha of remnant and regrowth Regional Ecosystem (RE) 11.3.2
- 0.60 ha of general ephemeral wetland habitat (non-remnant) as part of the proposed development; and
- no disturbance to Threatened Ecological Communities (TECs).

Further, to minimise land disturbance, some well leases will host multiple CSG wells, and infrastructure has been placed along existing access tracks and fence lines to avoid disturbance to landholder activities and reduce disturbance to productive land i.e. cropping / grazing land.

The final configuration and location of infrastructure may change due to unforeseen constraints (e.g. cultural heritage sites) or engineering requirements. However, proposed maximum disturbance limits will not change beyond what is proposed in this application without further environmental approvals (e.g. EPBC Act or EP Act approvals).

Ultimately, the proposed development will impact a fraction of land in PL 1123. Existing and proposed disturbance to PL 1123 as part of the proposed development will constitute ~62 ha or ~5% of total land area in PL 1123 (1229 ha), which is almost wholly located on pre-disturbed land due to agriculture.

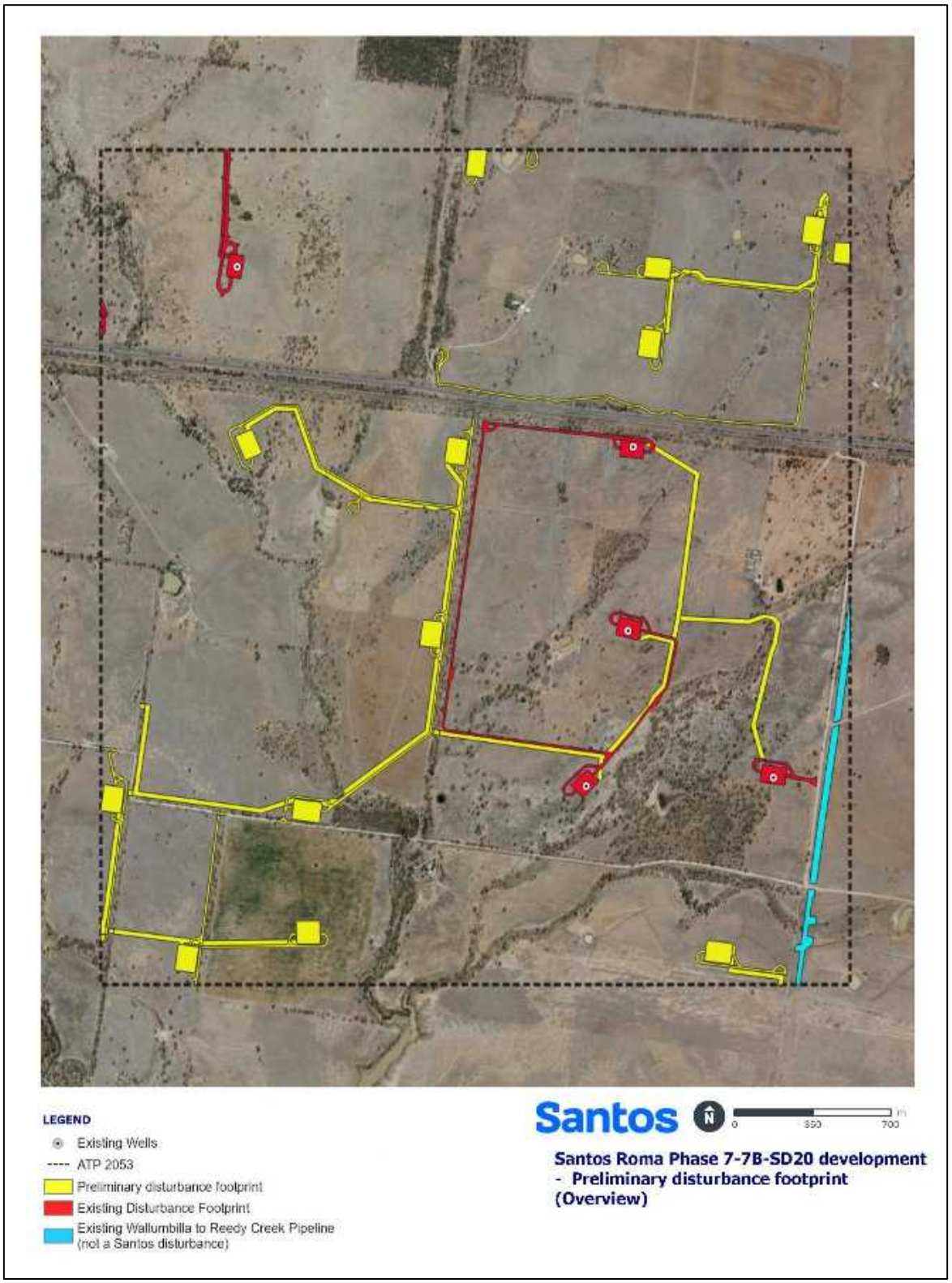


Figure 2: PL 1123 – Preliminary Disturbance Footprint (and Existing Disturbance Footprint)

2.4 Authorised Activities and Proposed EA Conditions

Due to varying joint venture and commercial arrangements, PL 1123 cannot be added to any of the existing adjacent EAs as an authorised tenure.

The holders of Santos operated petroleum tenures surrounding PL 1123 are different to those of PL 1123, and therefore PL 1123 cannot be added as an authorised tenure to their respective EAs.

Santos is therefore seeking a new site-specific EA to authorise petroleum production on proposed PL 1123. The proposed scale and intensity of activities, for inclusion in condition A1(a) of the EA, is detailed in Table 4.

Table 4: Scale and intensity for proposed activities in PL 1123

Petroleum activities and infrastructure	Scale (number of activities)	Intensity (maximum size in total)
Coal seam gas exploration, appraisal, and development wells	24	36 ha
Stimulation activities	All wells are subject to stimulation activities	

Given the proximity of the Project Area to the RSGPA and RSGPAE tenures (refer to Figure 1 and Figure 2), proposed development and operation of the Project Area will be carried out as a single integrated operation with existing authorised RSGPA and RSGPAE petroleum tenures and activities.

Santos is therefore seeking EA conditions consistent with those of the RSGPA EA (EPPG00898213), which are predominately based on streamlined model conditions for petroleum activities (DETSI, 2024).

Further, Santos requests the following Environmentally Relevant Activity (ERA) is authorised on the new EA (refer to Section 4.2 and Table 15 for further information on the requirement for this ERA):

- Schedule 3 – 3 – A petroleum activity that is likely to have a significant impact on a category A or B Environmentally Sensitive Area.

Proposed EA conditions, and a more detailed justification for the conditions, is attached as Appendix A of this report.

3.0 Project Area Description and Relevant Environmental Values

The Project Area is located approximately 43 km east of the town of Roma and 3 km east of the town of Wallumbilla in southern inland Queensland (refer to Figure 1). Further detail on the location, land use and climate of the Project Area is provided in Appendix C.

This section of the report provides a description of the EVs present within the Project Area where relevant to the scope of the EA application and proposed activities. For clarity, the proposed activities are those activities described in Section 2.2.

Desktop and field-based methods were used to assess relevant EVs within the Project Area as follows:

- field-based methods included detailed ecological field surveys undertaken by suitably qualified third-party ecologists (Boobook Ecological Consulting (Boobook)) to ground-truth government mapped vegetation and flora and fauna habitat within the Project Area; and
- desktop assessment methods included database searches and government environmental reports (refer to for Appendix D for further information).

Relevant EVs for this application and the Project Area include:

- land resources;
- Regional Ecosystems (REs);
- environmentally sensitive areas;
- flora and fauna;
- Matters of State Environmental Significance;
- surface waters and wetlands;
- groundwater;
- air quality and noise / vibration;
- waste; and
- rehabilitation.

No European heritage or community values have been identified within the Project Area.

Potential impacts to identified EVs resulting from the proposed activities, and impact mitigation measures to be implemented are described in Section 4.0.

3.1 Land Resources

The Project Area is located within the Southern Downs subregion of the Brigalow Belt bioregion within the Maranoa Region. The landscape is relatively flat with low relief (ranging from 300 – 320m Australian height datum (AHD)), comprising a broad floodplain with meandering drainage lines flanked by slightly elevated areas. Beyond the Project area, to the east, an abrupt north-south trending plateau rises up to 50m above the surrounds.

There is no outcropping rock within the Project Area, and the surface geology consists of Quaternary alluvial sediments (Qa) with an area of unconsolidated colluvial sediments derived from early Cretaceous mudstones of the Doncaster Member (Qs>Kud) in the east associated with the adjacent plateau (Boobook, 2025).

Soils are mapped as a homogenous sodosol (hard pedal brown duplex soils) as shown in Figure 3 (Atlas of Australian Soils, 2021). Field survey identified dark brown clay-loam and sandy clay-loam soils across much of the Project Area, with reddish clay-loams in the east (Boobook, 2025).

The Project Area is located in a Strategic Cropping Area and Strategic cropping land is mapped to be present in the Project Area (State of Queensland, 2025).

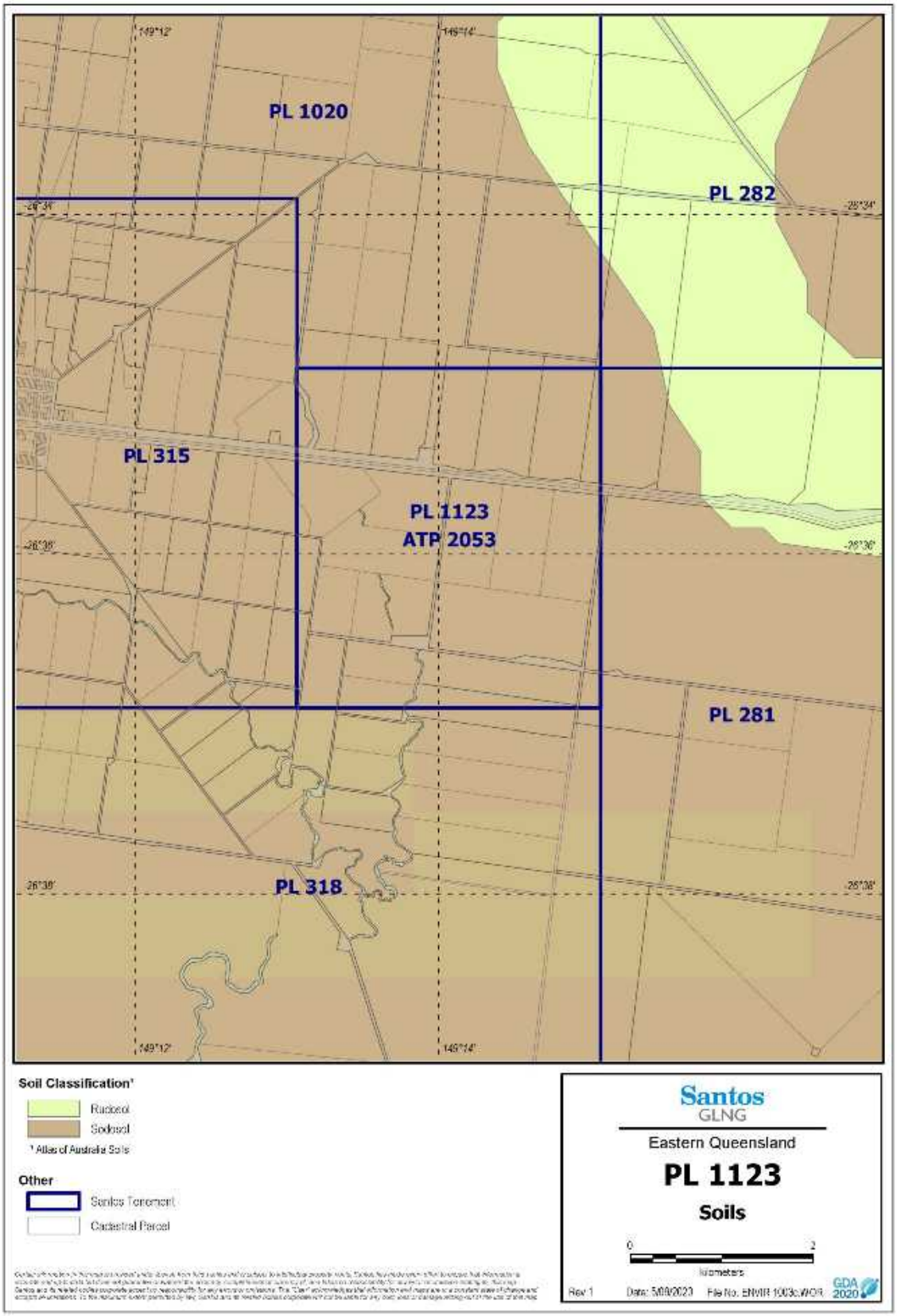


Figure 3: PL 1123 – Mapped Soils

3.2 Regional Ecosystems

Third-party ecological consultants (Boobook Ecological Consulting (Boobook)) undertook an ecological field survey and assessment of the Project Area. A summary of the ecological survey assessment methodology and findings is provided in this section. Refer to the Ecological Assessment Report (EAR) (Boobook, 2025) attached as Appendix D for further detailed information.

Boobook undertook initial desktop and then field-based ground-truthing assessments of vegetation located in the Project Area to confirm RE classification and status. Desktop assessment of REs included review of the Qld Government's (DETSI and Department of Resources (DoR)) RE mapping of the Project Area. No remnant (Category B) vegetation is mapped within the Project Area i.e. the Project Area is entirely mapped by government as non-remnant vegetation. Three areas of vegetation are mapped by DETSI to be VM Act Class Of Concern Category C high value regrowth vegetation consisting of mixed REs 11.3.2/11.3.17/11.3.25 (70/20/10) (Boobook, 2025).

Field assessments included identification and mapping of remnant and regrowth REs across the Project Area. Ground-truthing assessments (and confidence level scoring) of the RE designation was undertaken using the quaternary level of data collection as described by Neldner et al. (2022). Quaternary vegetation assessments were undertaken within 50m x 10m plots for the purpose of typifying the vegetation community under assessment. Plots were chosen within representative areas of each vegetation type encountered. Locations of quaternary assessment sites are displayed in Figure 4.

Vegetation community polygons were verified in accordance with Queensland RE description and biodiversity status as per the Regional Ecosystem Description Database (REDD) and classified as remnant RE, vegetation consistent with RE (regrowth) or non-remnant vegetation. For any identified regrowth (i.e. vegetation floristically equivalent to a RE but not meeting structural thresholds of remnant RE) an ecosystem functionality assessment was conducted. Bio-Condition assessments and scoring, Quaternary level vegetation structure assessments, and fauna habitat assessments were also undertaken at seven representative locations across the Project Area (for remnant and regrowth RE) as displayed on Figure 4. Bio-Condition assessment scores are used to provide an indication of ecosystem function relative to minimally disturbed benchmark sites (Queensland Herbarium data) within the same vegetation type.

Ground-truthing surveys confirmed the Project Area largely consists of non-remnant vegetation (non-remnant derived grassland dominated by introduced pastoral grasses with occasional native trees and shrubs), with most vegetation associated with drainage features. Minor areas of remnant vegetation occur as disturbed, irregular and discontinuous corridors along streams, road easements and fence line corridors. Five remnant REs were identified within the Project Area, these being REs 11.3.2, 11.3.17, 11.3.25, 11.9.7, 11.9.10 (refer to Table 5 for further detail).

Regrowth vegetation comprises Poplar Box (*Eucalyptus populnea*) woodland in riparian corridors, on floodplains and gently undulating country. Vegetation in the southern section of the Project Area is located on Land Zone 3 (Quaternary alluvium) associated with streamlines and alluvial plains (REs 11.3.2, 11.3.17, 11.3.25). Vegetation in the northern section of the Project Area predominantly includes areas located on Land Zone 9 (Undulating country on fine-grained sedimentary rocks) (REs 11.9.7 and 11.9.10), with minor areas of Land Zone 3 (REs 11.3.2 and 11.3.25).

Within the Project Area, Bio-Condition assessment scores for all REs ranged from 0.47 – 0.60, which indicates the significant disturbance and consequent loss of ecosystem integrity relative to Bio-Condition benchmarks of each RE. These scores also reflect landscape level fragmentation of native vegetation i.e. small patch sizes, low connectivity and a low proportion of remnant and regrowth vegetation within the surrounding landscape. Ground-truthed REs identified in the Project Area are detailed in Table 5 and displayed on Figure 4.

Table 5: Ground-truthed REs within the Project Area (~1229 ha)

RE	RE Description	VM Act Status	BD Status	Structural Category	Extent Remnant (ha)	Extent Regrowth (ha)
11.3.2	*Eucalyptus populnea* woodland on alluvial plains	OC	OC	Sparse	19.41	65.38
11.3.17	*Eucalyptus populnea* woodland with *Acacia harpophylla* and/or *Casuarina cristata* on alluvial plains	OC	E	Sparse	10.81	0.00
11.3.25	*Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines	LC	OC	Sparse	20.94	0.00
11.9.7	*Eucalyptus populnea*, *Eremophila mitchellii* shrubby woodland on fine-grained sedimentary rocks	OC	OC	Sparse	0.61	1.30
11.9.10	*Eucalyptus populnea open forest with a secondary tree layer of Acacia harpophylla and sometimes Casuarina cristata on fine-grained sedimentary rocks*	OC	E	Mid-dense	23.96	2.34
				Totals	75.73	69.02

Key: Non VM class and BD status under the *Vegetation Management Act 1999*: NCAP – No Concern at Present, LC – Least Concern, OC – Of Concern, E – Endangered

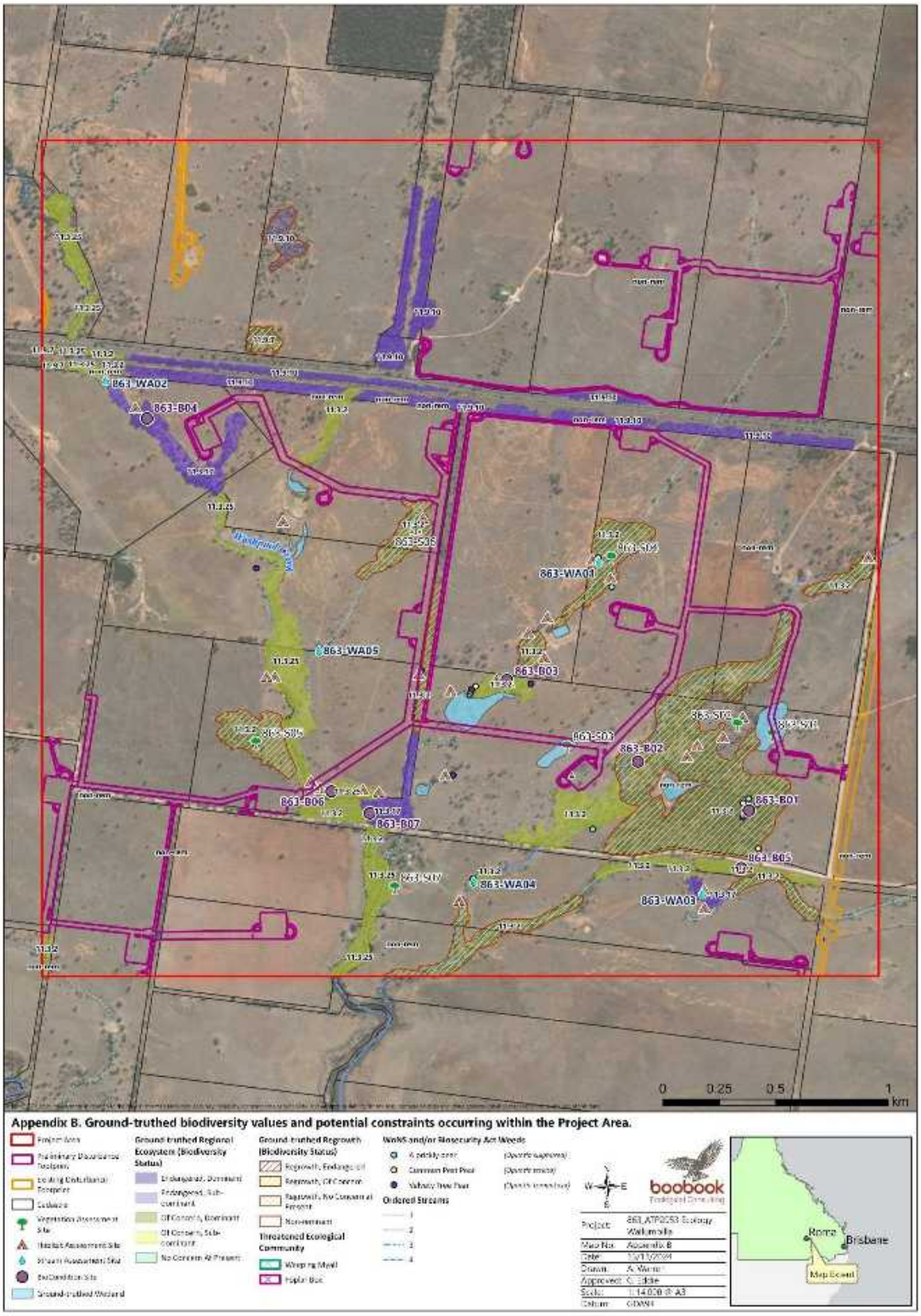


Figure 4: PL 1123 – Ground-truthed REs and Field Survey Sites (adapted from Boobook, 2025)

3.3 Environmentally Sensitive Areas

The following Category B Environmentally Sensitive Areas (ESA) are present within the Project Area:

- areas of ground-truthed Endangered RE (biodiversity status): 11.3.17 and 11.9.10.

The following Category C ESA are present within the Project Area:

- areas of ground-truthed Of Concern RE (biodiversity status): 11.3.2, 11.3.25 and 11.9.7.

3.3.1 Environmentally Sensitive Areas - Essential Habitat

As defined by Section 20AC (1) of the *Vegetation Management Act 1999* (VMA), the Essential Habitat Map is a map certified by the chief executive as the Essential Habitat Map for the State and showing, for the State, areas the chief executive reasonably believes are areas of Essential Habitat for protected wildlife. There is no Essential Habitat mapped within the project area on the Essential Habitat Map.

Further, as defined by Section 20AC (2) of the VMA, Essential Habitat, that is 'protected wildlife habitat', is a category A, B or C area shown on the *Regulated Vegetation Management Map* (RVMM) that has at least 3 essential habitat factors for the protected wildlife that must include any essential habitat factors that are stated as mandatory for the protected wildlife in the essential habitat database; or in which the protected wildlife, at any stage of its life cycle, is located. As per the definition imposed by DETSI on previous EAs '*essential habitat means section 20AC (2) of the VMA validated as 'protected wildlife habitat' from ground-truthing surveys for species of wildlife identified as critically endangered, endangered or vulnerable under the NCA).*

Only Category C (regrowth) Regulated Vegetation is present in the Project Area on the RVMM. Areas of mapped Regulated Vegetation were ground-truthed by Boobook (2025) to be REs 11.3.2, 11.3.25 and 11.9.10. These areas of RE / vegetation may provide potentially suitable habitat for five species (listed as endangered or vulnerable under the NCA) that may occur in the Project Area (Boobook, 2025).

The Project Area is not located within a High-Risk Area as shown on a Protected Plants Flora Survey Trigger Map (Boobook, 2025). There is no state government mapped Essential Habitat for NC Act-listed threatened flora within the Project Area (Boobook, 2025).

ESAs located in the Project Area are detailed in Table 6 and displayed in Figure 5 to Figure 6. Refer to the EAR (Boobook, 2025) attached as Appendix D for further detailed information.

Table 6: Ground-truthed ESAs within the Project Area

ESA Category	ESA Type	RE
Category B	Endangered REs	REs 11.3.17 / 11.9.10
Category C	Of Concern REs	REs 11.3.2 / 11.3.25 / 11.9.7
Category C	Essential Habitat – Protected Wildlife Habitat for Glossy Black-Cockatoo (*Calyptorhynchus lathami*). NCA listed Vulnerable	remnant and regrowth REs 11.3.2 / 11.3.25 / 11.9.10
Category C	Essential Habitat – Protected Wildlife Habitat for Koala (*Phascolarctos cinereus*). NCA listed Endangered	remnant and regrowth REs 11.3.2 / 11.3.25 / 11.9.10
Category C	Essential Habitat – Protected Wildlife Habitat for Yakka Skink (*Egernia rugosa*). NCA listed Vulnerable	remnant and regrowth REs 11.3.2 / 11.9.10
Category C	Essential Habitat – Protected Wildlife Habitat for Grey Snake (*Hemiaspis damelii*). NCA listed Endangered	remnant and regrowth REs 11.3.2 / 11.3.25
Category C	Essential Habitat – Protected Wildlife Habitat for White-throated Needletail (*Hirundapus caudacutus*). NCA listed Vulnerable	remnant and regrowth RE 11.3.2 / 11.3.25 / 11.9.10

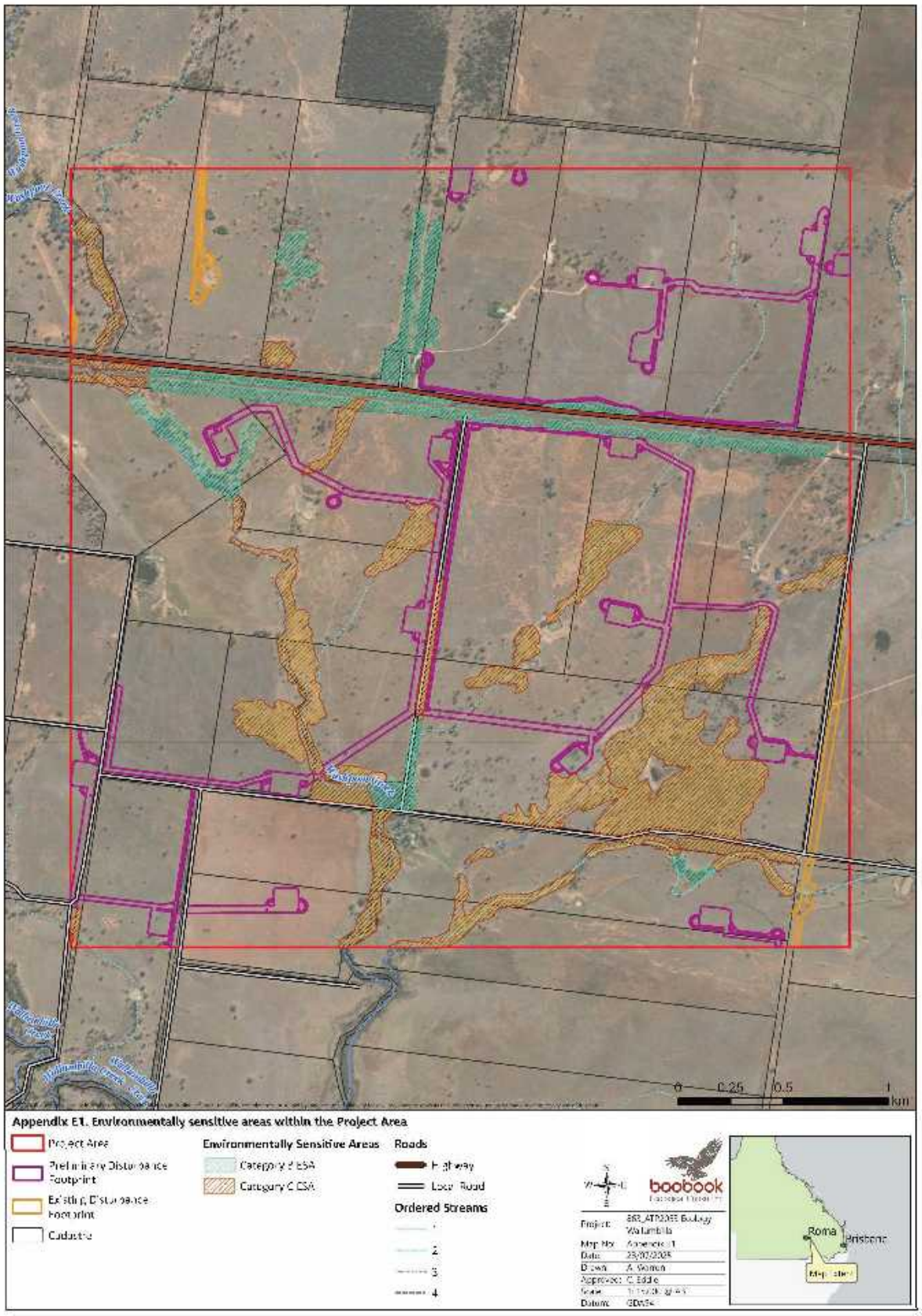


Figure 5: PL 1123 – Ground-truthed ESAs within the Project Area (adapted from Boobook, 2025)

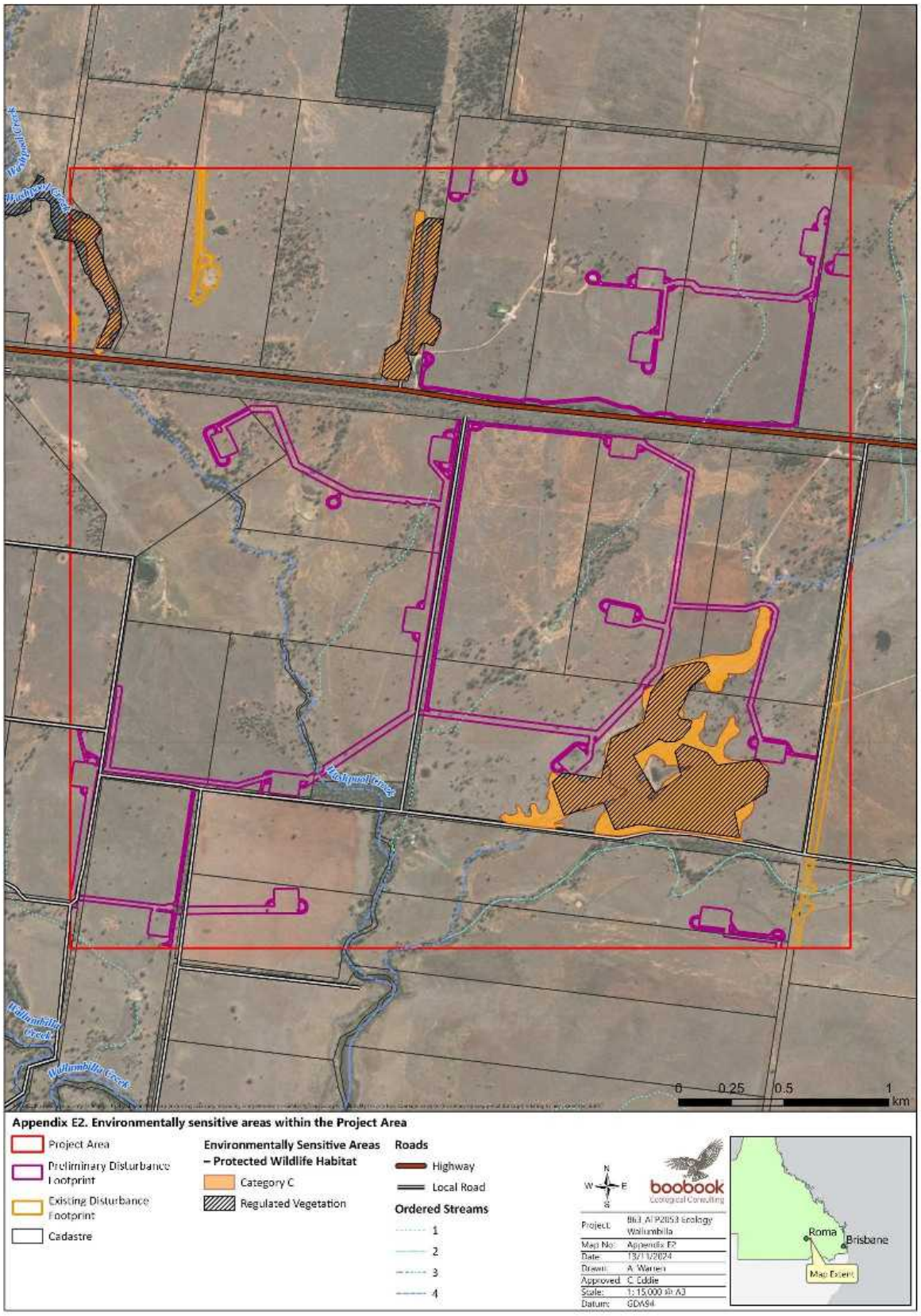


Figure 6: PL 1123 – Ground-truthed ESAs (Regulated Vegetation) within the Project Area

3.4 Threatened Ecological Communities

Several areas of Threatened Ecological Communities (TECs) were identified within the Project Area during field surveys including several small patches of Poplar Box Grassy Woodlands on Alluvial Plains TEC (Poplar Box TEC) and Weeping Myall Woodlands TEC (Weeping Myall TEC).

All areas of TEC within the Project Area are disturbed by grazing and edge effects such as tree death and encroachment by introduced pastoral grasses and other weeds. All Poplar Box TEC within the Project Area was assessed as Moderate Quality (Category C) with low native cover but retaining diverse native understorey plants and more than 10 mature trees per hectare (Boobook, 2025). Ground-truthed areas of TEC within the Project Area are detailed in Table 7 and displayed on Figure 4.

Table 7: Ground-truthed TECs within the Project Area

TEC Description	RE	Extent of TEC within the Project Area (ha)
Poplar Box grassy woodland on alluvial plains	11.3.2	46.71
Weeping Myall Woodlands	11.3.2	7.61
	Total	54.32

3.5 Flora and Fauna

Boobook (2025) undertook desktop-based searches of spatial biological databases (including Atlas of Living Australia, DESI Wildnet) for presence records of flora and fauna species listed under the NCA and EPBC Act. These database searches utilised a 10 km search radius around (and inclusive of) the Project Area). Boobook also utilised the Commonwealth protected matters search tool (PMST) for the purpose of identifying EPBC Act listed species with the predicted potential to occur in or near the Project Area. The searches were conducted using land parcel codes or central coordinates (26.60632S, 149.23120E, datum GDA94) as a geographic reference and including a 10 km buffer. Refer to the EAR (Boobook, 2025) attached as Appendix D for further detailed information.

3.5.1 Flora

The spatial biological database search results did not identify any presence records for NCA or EPBC Act listed threatened flora species located in or within 10 km of the Project Area (Boobook, 2025).

PMST search results (refer to Appendix B in the EAR attached as Appendix D) indicated the potential occurrence of four EPBC Act-listed flora species within the Project Area. As detailed in Table 8, these are also listed flora species under the NCA.

Boobook assessed the likelihood for NCA listed threatened flora species to occur within the Project Area. Refer to Section 3 of the Boobook report attached as Appendix D for further detailed information on the likelihood of occurrence assessment. The results of this assessment, combined with published information and suitably qualified ecologist knowledge of flora distribution and habitat preference in the region, were used to predict habitat suitability for nominated NCA listed threatened flora (of which was limited to one flora species – that being Plains Picris (*Picris barbarorum*), NCA listed Vulnerable). The likelihood of occurrence assessment for NCA and EPBC Act-listed threatened flora within the Project Area is presented in Table 8. Refer to Appendix D (Boobook, 2025) for further information.

Targeted field surveys for NCA threat-listed flora were informed by the spatial biological database / PMST search results and local experience. Field surveys for NCA / EPBC Act listed flora were carried

out within the Project Area at vegetation assessment sites and during random meanders in targeted habitat types (e.g. RE associations for each species), including areas of remnant and non-remnant vegetation. No NCA or EPBC Act threat-listed flora species were detected during field surveys.

Further, the Project Area does not fall within a High-Risk Area on the Protected Plants Flora Survey Trigger Map. Refer to the Boobook (2025) report attached as Appendix D for further detailed information.

No EPBC Act or NCA-listed threatened flora species were detected within the Project Area and no suitable habitat is present for species identified within desktop searches. The Project is therefore unlikely to impact on any threatened flora species, and no impact assessment is required (Boobook, 2025).

Table 8: Assessment of likelihood of occurrence for NCA and EPBC Act-listed threatened flora within the Project Area (adapted from Boobook, 2025)

Common & Scientific Name	EPBC Act Status	NCA Status	Potentially Suitable RE	Likelihood of Occurrence
Vincetoxicum forsteri listed as *Tylophora linearis* Slender Tylophora	E	E	None within the Project Area.	**Unlikely to be present.** There is no suitable habitat (i.e. dry shrubby woodland on land zones 5, 7 or 11) within the Project Area. This species does not occur in the vegetation types and landforms within the Project Area (i.e. grassy woodland on floodplains and low rises, land zones 3 and 9). The closest recorded occurrence is from Glenmorgan, 77 km south-southeast of the Project Area (Boobook, 2025).
Lepidium monoplocoides Winged Pepper-cress	V	C	None within the Project Area.	**Unlikely to be present.** There are no suitable semi-arid, sparsely vegetated areas on heavy clay soils within the Project Area. There are no areas dominated by chenopods, halophytes or Coolibah/Black Box woodland in the Project Area. The Project Area is outside the known range of this species, being over 260 km from the closest records around Yelarbon (Boobook, 2025).
Dichanthium setosum A bluegrass	V	C	None within the Project Area.	**Unlikely to be present.** There is no suitable habitat (i.e. basalt derived heavy clay soils – areas associated with landzone 8) within the Project Area or the vicinity. There are no records of the species within 200km of the Project Area (Boobook, 2025
Cadellia pentastylis Ooline	V	V	None within the Project Area.	**Unlikely to be present.** The Project Area does not include suitable habitat areas of SEVT (RE 11.9.4) or Brigalow dominated woodland on rises, hills and scarps (RE 11.7.1, 11.9.5). The closest specimen records are from around 50 km north of the Project Area (Boobook, 2025).
Picris barbarorum *Plains Picris*	-	V	None within the Project Area.	**Unlikely to be present.** Habitat at the known Sites is native grassland associated with heavy cracking clay soils. This habitat type is absent from the Project Area.

Key to Status: CE/CR = Critically Endangered; E = Endangered; V = Vulnerable; NT = Near Threatened; SL = Special Least Concern; C = Least Concern.

3.5.2 Fauna

The spatial biological database search results predicted twenty-four NCA and EPBC Act-listed threatened fauna species or habitat that might occur in or within 10 km of the Project Area. Wildlife Online and ALA searches (Boobook, 2025) produced records of one EPBC Act-listed threatened fauna species within the 10 km buffered desktop search area this being Koala (*Phascolarctos cinereus*).

Incidental surveys for NCA listed fauna were informed by the spatial biological database / PMST search results and local experience. Surveys were conducted through incidental observations and active searches at assessment sites located across the Project Area. No NCA or EPBC Act listed threatened fauna species were found/recorded present during the field survey.

Further, microhabitat assessments and other field-based habitat observations were conducted within the Project Area at each quaternary vegetation assessment site. Presence/absence, abundance or density of habitat features were recorded within a 50m x 10m plot at each survey site including:

- embedded and loose rocks and boulders (estimated % cover);
- logs (abundance);
- trees >18m height (abundance);
- logs with hollows (abundance);
- trees with hollows (abundance);
- trees and/or logs with loose bark (abundance);
- burrows, sinkholes and tunnel erosion (abundance);
- fallen bark (estimated % cover);
- shrub layer (estimated % cover);
- ground cover (estimated % cover);
- leaf litter (estimated % cover);
- termite mounds (abundance);
- mistletoe (abundance);
- rock structures (caves, overhangs and crevices);
- cliffs, escarpments and steep rocky slopes within 5km (presence);
- watercourses with permanent water, pools and riffles and abundant woody/rock cover (presence);
- cracking clays soils (presence);
- gilgai and ephemeral wetlands (presence); and
- canopy dominated by Myrtaceae species (presence).

In addition, representative fauna habitat features were recorded in non-remnant areas to indicate their type and occurrence throughout the Project Area. In general, fauna habitat features are expected to be most abundant in remnant and regrowth vegetation and these areas were addressed by assessment plots. Fauna habitat features present within the Project Area included hollow-bearing trees (dead and alive), hollow-bearing logs and piles of pushed timber. The locations of fauna habitat assessment sites are shown in Appendix C of the EAR (Boobook, 2025) (attached as Appendix D).

The results of these assessments, combined with published information and suitably qualified ecologist knowledge of fauna distribution and habitat use in the region, were used to predict habitat suitability for nominated listed threatened fauna. The likelihood of occurrence assessment for NCA and EPBC Act-listed threatened fauna within the Project Area is presented in Table 9.

For purposes of brevity, species listed in Table 9 have been limited to those assessed to likely or potentially occur within the Project Area. Refer to Section 3 of the EAR (attached as Appendix D) for further detailed information on the likelihood of occurrence assessment.

Table 9: Assessment of likelihood of occurrence for NCA and EPBC Act-listed threatened fauna within the Project Area (adapted from Boobook, 2025)

Common & Scientific Name	EPBC Act Status	NCA Status	Potentially Suitable RE	Likelihood of Occurrence
Aspidites ramsayi Woma	N/A	NT	Remnant and regrowth: RE 11.3.2, 11.3.17, 11.3.25, 11.9.7, 11.9.10 (i.e. all mapped vegetation within the Project Area).	**Potentially present.** There are several records of this species from the vicinity of the Project Area. The species can persist in disturbed and fragmented habitats providing prey and shelter sites are present (Boobook, 2025).
Calidris acuminata Sharp-tailed Sandpiper	V	SL	Potential habitat comprises mapped wetland areas and artificial wetlands such as dams within the Project Area.	**Potentially present.** Passage migrants are periodically reported from the area. Generally recorded around larger wetlands. However, suitable habitat for short-term visitors exists around dams and floodplain soaks within the Project Area (Boobook, 2025).
Calyptorhynchus lathami lathami Glossy Black-Cockatoo (southeastern subspecies)	V	V	Primary feeding habitat - Remnant and regrowth: RE 11.3.17, 11.9.10. Sparse feed trees may occur in other remnant and regrowth vegetation and other non-remnant areas. Roosting and nesting habitat-remnant only: RE 11.3.2, 11.3.25, 11.9.7.	**Potentially present.** Belah (*Casuarina cristata*) is moderately abundant within the Project Area. No other She-Oak tree species were observed. Potential nest trees (large trees with hollows near food and water sources) occur sparsely in remnant woodland within the Project Area. No evidence of Glossy Black-Cockatoo (chewed cones) was found within the Project Area, but occasional visitors could occur (Boobook, 2025).
Egernia rugosa Yakka Skink	V	V	Remnant and regrowth: RE 11.3.2, 11.3.17, 11.9.7, 11.9.10.	**Potentially present.** Possible shelter habitat features within the Project Area, such as logs, were present but not abundant. The species is known to occur in some areas of disturbed habitat where suitable shelter sites are present. The species has been recorded from similarly fragmented vegetation around 21 km north of the Project Area (Boobook, 2025).
Gallinago hardwickii Latham's Snipe	V	SL	None. Potential habitat comprises mapped wetland areas and artificial wetlands such as dams within the Project Area.	**Potentially present.** Migrating individuals could potentially occur within the Project Area during wet periods. Suitable habitat for short-term visitors exists around dams and

				floodplain soaks within the Project Area (Boobook, 2025).
Hirundapus caudacutus White-throated Needletail	V	V	Remnant and regrowth: RE 11.3.2, 11.3.17, 11.3.25, 11.9.7, 11.9.10 (i.e. all mapped vegetation within the Project Area).	**Likely to be present.** The species occurs in the region and is likely to overfly the Project Area occasionally between September and April, following storm fronts. There are no hills within the Project Area and few large trees and therefore the species is unlikely to roost here. There are no specific habitat features that would attract the species to the Project Area (Boobook, 2025).
Phascolarctos cinereus Koala	E	E	Remnant and regrowth: RE 11.3.2, 11.3.17, 11.3.25, 11.9.7, 11.9.10 (i.e. all mapped vegetation within the Project Area).	**Potentially present.** Riparian remnant and regrowth woodland dominated by *E. camaldulensis* and *E. populnea* provides suitable habitat for transient individuals to move through the Project Area. The landscape is heavily fragmented, however Koala are capable of dispersing over land using scattered paddock trees and corridors along streams. Koala are sparsely distributed in this area but there is a record from similar habitat within 10 km of the Project Area (Boobook, 2025). No scratches or other evidence of Koala were observed during field surveys (Boobook, 2025).
Rostratula australis Australian Painted Snipe	E	E	None. Potential habitat comprises mapped wetland areas and artificial wetlands such as dams within the Project Area.	**Potentially present.** Migrating individuals could potentially occur within the Project Area during wet periods. Suitable habitat for short-term visitors exists around dams and floodplain soaks within the Project Area (Boobook, 2025).
Tachyglossus aculeatus Short-beaked Echidna	N/A	SL	Remnant and regrowth: RE 11.3.2, 11.3.17, 11.3.25, 11.9.7, 11.9.10 (i.e. all mapped vegetation within the Project Area).	**Likely to be present.** The species was not confirmed present within the Project Area. The species is likely to have a patchy occurrence in the Project Area and suitable habitat features such as logs and woody debris were scarce within the Project Area (Boobook, 2025).

Key to Status: CE/CR = Critically Endangered; E = Endangered; V = Vulnerable; NT = Near Threatened; SL = Special Least Concern; C = Least Concern.

3.6 Matters of State Environmental Significance

The DETSI Matters of State Environmental Significance (MSES) report and the EAR (Boobook, 2025) (both reports are attached as Appendix D) identified the following MSES to be present within the Project Area:

- Protected wildlife (fauna) habitat;
- Regulated Vegetation (prescribed REs that are Endangered and Of Concern); and
- Regulated Vegetation (a prescribed RE to the extent the ecosystem is located within a defined distance from the defining banks of a relevant watercourse).

3.6.1 Protected wildlife habitat

Refer to Sections 3.5.1 and 3.5.2 for further detail on potential protected wildlife habitat located in the Project Area.

3.6.2 Regulated Vegetation

Regulated vegetation is an MSES if it is a 'prescribed RE' that:

- is Endangered or Of Concern RE as defined under the *Vegetation Management Act 1999* (VMA); or
- intersects with a wetland identified on the '*vegetation management wetlands map*' as defined under the VMA*;* or
- REs located within the defined distance from the defining banks of a watercourse as identified on the '*vegetation management watercourse map'* as defined under the VMA.

In accordance with Schedule 2 of the *Environmental Offsets Regulation 2014* (EOR), a prescribed RE means an RE, other than an RE mentioned in the VMA at section 8(b) (which are grassland REs), located in a Category B area on the RVMM, to the extent the RE contains remnant vegetation.

Further, as stated in Schedule 2 of the EOR and in Section 2 (Regulated Vegetation) of the *Significant Residual Impact Guideline* (DEHP, 2014), the definition of a prescribed RE is in the EOR, and does not include regrowth vegetation.

Regulated vegetation mapped within the Project Area on the RVMM is entirely Category C (regrowth) (REs 11.3.2/11.3.17/11.3.25, high value regrowth vegetation) and Regulated Vegetation - intersecting a watercourse.

Category C regulated vegetation is not a prescribed RE or MSES PEM because it is not mapped as remnant vegetation (Category B). Therefore, this vegetation is not an MSES PEM for the purposes of SRI assessment under the EOR and *Significant Residual Impact Guideline* (DEHP, 2014).

Further, a prescribed RE is an MSES PEM to the extent the RE is mapped as remnant and is located within a defined distance from the defining banks of a relevant watercourse or relevant drainage feature.

The ecological field surveys, as documented in the EAR (Boobook, 2025), identified minor areas of remnant REs located within the defined distance from the defining banks of a watercourse as identified on the '*vegetation management watercourse map'* within the Project Area. Refer to Section 3.2 (Table 5 and Figure 4) for further detail and the location of REs ground-truthed to be present in the Project Area.

3.7 Surface Water and Wetlands

Santos commissioned expert hydrogeological consultants Klohn Crippen Berger Pty Ltd (KCB) to undertake a third-party Water Resources Impact Assessment Report (WRA) (KCB, 2025) of proposed activities to be undertaken in the Project Area (attached as Appendix E). The following section provides a summary of the findings of the KCB report as they relate to surface water and wetlands, refer to Appendix E (KCB, 2025) for further information.

The Project Area is located in the upper reaches of the Balonne River sub-basin, which is part of the wider Condamine-Balonne Basin). Key watercourses in the Project Area include Washpool Creek and Middle Creek which are tributaries of Wallumbilla Creek. These watercourses have a stream order (SO) of between 1 to 5. The PDF (linear infrastructure only) will cross mapped SO 1 watercourses at five locations, and will cross mapped SO 3 watercourses at two locations.

Watercourse flows in the Project Area are characteristically ephemeral and typically only flow during and immediately following significant rainfall events. Washpool Creek (SO3) is the largest watercourse in the Project Area, and it originates approximately 5 km north of the Project Area, and traverses from the north-western boundary to the south-central boundary, before converging with Wallumbilla Creek approximately 2km south of the Project Area. This is a consequence of the Project Area being in the uppermost reaches of the catchment, with limited runoff area. There are no identified third-party surface water users in the vicinity of the Project Area.

There are no wetlands of high or general ecological significance (HES or GES wetlands) located within the Project Area. Boobook (2025) identified several small ephemeral wetland areas in non-remnant vegetation (cleared paddocks) in the Project area. These areas may provide ephemeral potential habitat for wetland bird species such as Australian Painted Snipe (*Rostratula australis*) and Latham's Snipe (*Gallinago hardwickii*).

There is limited to no groundwater contribution from the regional groundwater system to watercourses as baseflow anticipated in the Project Area. There are no spring vents, spring complexes or watercourse springs recorded in or within a 25 km vicinity of the Project Area.

The EVs applicable to surface waters, as defined by the *Maranoa-Balonne River Basin Environmental Values and Water Quality Objectives* (DESI, 2020) and *Condamine River Basin Environmental Values and Water Quality Objectives* (DESI, 2020) are as follows:

- protection of the aquatic ecosystems;
- primary industries:
    - irrigation;
    - farm supply/use;
    - stock watering;
- human consumer;
- recreation and aesthetics:
    - primary and secondary recreation;
    - visual appreciation;
- drinking water;
- industrial use; and
- cultural, spiritual and ceremonial values.

3.8 Groundwater

As discussed in Section 3.7, Santos commissioned expert hydrogeological consultants KCB to undertake a third-party *Water Resources Impact Assessment* of proposed activities. The content and findings of the KCB report as they relate to groundwater are briefly summarised below. Refer to the KCB (2025) report attached as Appendix E for further information.

3.8.1 Geological Setting and Stratigraphy

The Project Area is located within the geographical extent of the Surat Basin, a basin of Jurassic-Cretaceous age, which is underlain by the Permo-Triassic Bowen Basin. Cenozoic-age formations are present overlying the Surat Basin formations. The Bowen Basin, which contains up to 10km of terrestrial and shallow marine sediments, is elongated, trending north-south, and extending over 160,000 km^2 from central Queensland, south beneath the Surat Basin, into New South Wales where it eventually connects with the Gunnedah and Sydney basins. The Surat Basin underlies approximately 180,000 km^2 of southeast Queensland and is connected to the Eromanga Basin in the west, the Clarence-Moreton Basin in the east and Mulgildie Basin to the northeast.

There are currently no formally recognised sub-basins for either the Bowen or Surat Basins. However, the Bowen and Surat Basins are divided into distinct regions based on the structural features that control both the location and thickness of the sedimentary sequences. The Project Area is located within the Maranoa-Balonne-Condamine subregion, in the centre of the Surat Cumulative Management Area, on the far western flanks of the Taroom Trough. The Surat Basin forms part of the Great Artesian Basin (GAB), which comprises several aquifers and confining aquitards. Aquifers of the Surat Basin are a significant source of water used for stock, public water and domestic supply. Refer to Appendix E for further information on regional geology and hydro-stratigraphy.

The Walloon Coal Measures (WCM) are the main gas bearing units within the Surat Basin and they are the target formation for proposed CSG production in PL 1123 and the broader Roma area (refer to Table 10 and Table 11). The thickness of the coal measures in the Roma area ranges from 100 to 460 m, at depths ranging from 170 to 933 metres below ground level (mbgl). The coal seams are separated by silty and tight sandstone, which restricts leakage between seams. Hydro stratigraphy of the Surat and Bowen Basins is outlined, and a summary of each unit is provided, in Table 11. Refer to Appendix E for further information.

Stratigraphic units of relevance to the Project Area and proposed activities include:

- Quaternary alluvial deposits located along Wallumbilla Creek and major tributaries;
- Cenozoic sediments;
- Cretaceous sediments of Wallumbilla Formation; and
- Jurassic aged sediments of the Gubberamunda Sandstone, Westbourne Formation, Springbok Sandstone, Walloon Coal Measures, Eurombah / Durabilla Formation, Hutton Sandstone, Evergreen Formation and Precipice Sandstone.

Table 10: Stratigraphic column for the Project Area (adapted from KCB, 2025)

Age		Formation			Hydro stratigraphic Description		Relevance to Project Area	
Quaternary		Alluvium			Partial Aquifer		Mapped associated with watercourses	
		Unconsolidated sediments					Deposits across Project area	
		Tertiary Sediments					3 km to the northeast and 8 km to east	
Cretaceous	**Early**	Wallumbilla Formation	Coreena Member		Tight Aquitard	Partial Aquifer	Outcrops 7 km south	
			Doncaster Member			Tight Aquitard	Outcrops within Project area	
		Blythesdale Group	Bungil Formation	Kingull Member	Partial Aquifer		Outcrops 9 km north	Outcrops 20 km northwest
				Minmi Member			Outcrops 2 km north	
				Nullawurt Sandstone Member			Outcrops 14 km northwest	
			Mooga Sandstone		Regional Aquifer		Outcrops 16km north	
			Orallo Formation		Tight Aquitard		Outcrops 26km north	
Jurassic			Gubberamunda Sandstone		Regional Aquifer		Outcrops 31km north	
	Late	Westbourne Formation			Tight Aquitard		Outcrops 33km north	
		Springbok Sandstone			Tight Aquifer		Outcrops 38km north	
	Middle	Walloon Subgroup	Walloon Coal Measures		Productive Coal Seam		Target CSG formation	
			Eurombah/Durabilla Formation		Tight Aquitard		Underlying aquitard of regional relevance	
		Hutton Sandstone	Upper Hutton Sandstone		Partial Aquifer		Underlying aquifer of regional relevance	
			Lower Hutton Sandstone		Tight Aquifer			
	Early	Evergreen Formation	Upper Evergreen FM		Tight Aquitard		Regional Relevance	
			Boxvale Sandstone		Partial Aquifer			
			Lower Evergreen FM		Tight Aquitard			
		Precipice Sandstone			Regional Aquifer		Regional Relevance	

Table 11: Summary description of stratigraphic units for the Project Area (adapted from KCB, 2025)

Unit	Description
Alluvium	Quaternary-age alluvium is mapped as occurring within proposed PL 1123. These alluvial deposits are associated with Washpool Creek, Middle Creek and Wallumbilla Creek and associated major tributaries. The alluvium consists of unconsolidated clay, silt, sand, and gravel. In the Surat CMA, sediments within the major river channels are typically narrow and range in thickness from 14 to 26 metres, with alluvium thickness generally decreasing in the smaller tributaries. No bores within the Project area are screened in the alluvium, thus the alluvial thickness is not known for Washpool Creek, Middle Creek, and Wallumbilla Creek.
Cenozoic Sediments	Thin accumulations of Cenozoic unconsolidated and semi-consolidated residual and colluvial sheetwash sediments occur within, and in the vicinity of the Project area, at thicknesses of less than 50 m.
Cretaceous Sediments – The Wallumbilla Formation	The Wallumbilla Formation is sub-divided in two sequences, the Coreena, and Doncaster Members. The upper Member (Coreena) is siltstone-dominated with minor coal seams. The lower Member (Doncaster) is mudstone dominated. The Coreena Member comprises interbedded siltstone, mudstone and fine to very fine-grained labile sandstone, limestone and coal deposited from shallow marine lagoons, shoreline swamps and estuaries, most likely reflecting a regional marine regression. The siltstone is in part calcareous, grading to silty limestone. The thickness of the Coreena Member averages 70 m and is conformably overlain by the Surat Siltstone. The Doncaster Member comprises dominantly blue-grey mudstone with glauconitic siltstone and fine-grained sandstone. The Doncaster Member accumulated with a rapid marine transgression with deep water conditions in the centre of the basin, grading to shallow marine coastal environments around the margins. Average thickness of the member is between 100 m and 150 m. The Doncaster Member of the Wallumbilla Formation and is a tight aquitard. The Coreena Member is a partial aquifer.
Jurassic Aged Sediments -The Bungil Formation	The Bungil Formation conformably overlies the Mooga Sandstone and outcrops 20 km northwest of the Project area. This unit is comprised of interbedded fine-grained lithic sandstones, siltstones, and mudstones with minor quartzose sandstone present. Day (1964b) identified three members: the Minmi, Nullawurt Sandstone and Kingull members, however, these are not easily recognised in the subsurface (Green et al. 1997, Exon 1976). Deposition of the Bungil Formation represents the initial marine transgression into the Surat Basin. The Bungil Formation is considered as an aquifer.
The Mooga Sandstone	The Mooga Sandstone generally conformably overlies the Orallo Formation, with local disconformities. Deposits generally consist of fine to medium grain size sand, although siltstones, mudstones, and shale are present. The Mooga Sandstone is at the base of the fifth major sedimentary cycle in the Surat Basin and was deposited in southwesterly flowing braided to meandering stream environments. Exon 1976, recognised three major subunits in outcrop. The upper Mooga Sandstone and lower Mooga Sandstone are considered aquifers. The middle Mooga Sandstone consists of siltstones, mudstones, and shale and is considered an aquitard. The Mooga Sandstone is considered a regional aquifer.
The Orallo Formation	The Orallo Formation conformably overlies the Gubberamunda Sandstone. It was deposited in a relatively low energy fluvial environment with local ponding. The Orallo Formation consists of fine to coarse-grained sandstone interbedded with clay, siltstone, silty mudstone, bentonite clay, and coal. The Orallo Formation is considered a tight aquitard.

Unit	Description
Gubberamunda Sandstone	Regionally, the Gubberamunda Sandstone conformably overlies the Westbourne Formation, but locally is disconformable, particularly around the margins of the basin. It was deposited by braided and meandering stream systems draining surrounding highlands. Consistent with a fluvial depositional environment, repeated packages of siltstone and fine to coarse sandstone were deposited. Deposits of carbonaceous shale along with minor coal fragments are typically present. Within the GAB, the Gubberamunda Sandstone is considered a usable aquifer.
Westbourne Formation	The Westbourne Formation conformably overlies the Springbok Sandstone. It was deposited in an environment with characteristics consistent with a low energy, lacustrine deltaic plain. The Westbourne Formation comprises predominately siltstone layers with thick interbeds of fine to medium-grained sandstone and minor mudstone. Small coal fragments, lenses and lamina are common throughout the formation. Within the GAB sequence, the Westbourne Formation is considered an aquitard.
Springbok Sandstone	The Springbok Sandstone overlies the Walloon Coal Measures and was deposited by streams and includes overbank and swamp deposits in the upper part of the unit which indicates streams becoming less energetic with time. The Springbok Sandstone consists mostly of feldspathic sandstones, commonly with calcareous cement. At the basin scale, the sandstones range from very fine to coarse-grained, although some very coarse-grained, poorly sorted pebbly beds also occur. Minor interbedded siltstones, mudstones, and thin coal seams are also present, primarily in the upper part of the unit. Within the GAB, the Springbok Sandstone is considered a usable water source, however it is highly variable in hydraulic properties and yield across the basin. The Springbok Sandstone also has a very high content of mudstone and siltstone at many locations with very low permeability.
The Walloon Coal Measures	The WCM of the Surat Basin are the target gas production formation for Santos PL 1123. Within the WCM, the two coal-dominated formations are the Juandah Coal Measures and the Taroom Coal Measures. A low permeability sandstone, siltstone and mudstone typically forms the base and is known as the Durabilla/Eurombah Formation. The WCM were deposited in a low energy meander-belt river system, with the coal layers deposited mainly in an overbank environment. Comprising of very fine to medium-grained argillaceous, siltstone, mudstone, and coal with minor calcareous sandstone, impure limestone, and ironstone. Typically, the coal layers are positioned in the upper half to three-quarters of the coal measures, with mudstones, siltstones, and lithic sandstones dominant in the lower part. At a regional scale the WCM are considered an interbedded aquitard.
Eurombah/Durabilla Formation	The Eurombah Formation, often referred to as the Durabilla Formation, conformably overlies the Hutton Sandstone. The depositional environment for this unit was fluvial with periods of rapid sedimentation. It is often difficult to differentiate the Eurombah Formation from the WCM. It is more restricted in extent than either the Hutton Sandstone or the WCM. The Eurombah Formation is considered an aquitard, consisting of siltstone, mudstone and fine to medium-grained poorly sorted sandstone, with almost no coal and consequently, little permeability.
The Hutton Sandstone	The Hutton Sandstone was deposited in a non-marine environment by meandering streams on a broad floodplain and consists mainly of sandstone with interbedded siltstone, shale, minor mudstone, and coal. The sandstone is white to light grey, fine to medium-grained, well sorted, generally quartz rich, partly porous with some pebble bands, shale, and siltstone clasts in the lower part. Siltstones and shales are light to dark grey, micaceous, carbonaceous and commonly interlaminated with very fine-grained sandstone. It is highly heterogeneous, with sand bodies limited in vertical and lateral extent.

Unit	Description
The Evergreen Formation	The Evergreen Formation conformably overlies the Precipice Sandstone and separates the Precipice Sandstone from the Hutton Sandstone. The upper and lower Evergreen Formations are considered aquitards and generally consists of mudstones laminated with fine-grained sandstone, siltstone, and shale.
The Precipice Sandstone	The Precipice Sandstone is the basal unit of the Surat Basin, which overlies the Moolayember Formation and sedimentary sequences of the Bowen Basin. Lower and upper subunits are recognised, often separated by a siltstone or shale unit. The layers with the coarsest grain sizes were deposited by transverse bars in a braided stream system and the sediment layers with finer grain sizes were deposited in a lower energy fluviatile meandering system. The lower subunit, also known as the Precipice Braided Stream Facies (or Precipice BSF), consists of white, fine to very coarse-grained, in part pebbly, thin to very thickly bedded, porous, quartz rich sandstone with a white clay matrix.

3.8.2 Aquifer Interconnectivity

The Surat Basin comprises layers of aquifers and aquitards of varying hydraulic properties. The formations predominantly comprise fluvial sedimentary deposits that have formed stratifications of sand, silt and clay within and across hydro-stratigraphic formations. Groundwater flow within the Surat Basin hydro-stratigraphic units is predominantly horizontal, as vertical flow is restricted by the spatial extent and continuity of aquitards, and by lower permeability horizons within the aquifers.

Across the Project Area, there is potential for interaction between the WCM, and the aquifers present at depth, and specifically those immediately above and below the WCM, such as the overlying Springbok Sandstone and underlying Hutton Sandstone (separated from the WCM by the Durabilla / Eurombah Formation). The Durabilla / Eurombah Formation is classed as a tight aquitard and is laterally extensive across the Project area, with a mean thickness of 51 m. This provides a significant vertical barrier between the WCM and underlying Hutton Sandstone. An upper WCM aquitard has been mapped by the Office of Groundwater Impact Assessment (OGIA) (the WCM non-productive zone) as being up to 25 m thick across the Project Area, separating the WCM coal seams from the overlying Springbok Sandstone (which is also classed as a tight aquifer due to its low horizontal permeability and significant proportions of siltstone and mudstone). Refer to Appendix E for further information on aquifer interconnectivity and aquitards relevant to the Project Area.

3.8.3 Groundwater Recharge

Recharge processes within the Surat Cumulative Management Area (CMA) are summarised in the 2021 Underground Water Impact Report (UWIR) (OGIA, 2021). Dominant recharge occurs along the zones of increased permeability in outcrop areas through fractures and permeable beds. Key processes of recharge include localised recharge, preferential pathway flow and diffuse recharge:

- localised recharge occurs beneath drainage features including rivers, and free-draining unconsolidated sedimentary cover, such as alluvium.
- preferential pathway flow arises from changes in permeability within aquifers and in overlying regolith, providing conduits for water to infiltrate. Zones of higher permeability may include fissures, faults, joints, tree roots and high-permeability beds within individual formations and along bedding planes. This mechanism is considered the dominant recharge process in the GAB; and
- diffuse recharge is the process by which high-intensity rainfall events and high-volume infiltrate and sufficiently saturate surficial sediments.

Recharge in the vicinity of the Project Area is expected to occur mainly as diffuse recharge with rainfall infiltration occurring at outcropping hydro-stratigraphic units within, and surrounding, the Project Area. Quaternary and Tertiary aged systems are also likely to be replenished during prolonged wet periods when the ephemeral creek system is flowing (where sufficient saturation and hydraulic head allows water to infiltrate into surficial aquifers).

Estimates of long-term mean recharge rates for the Surat CMA have been made by OGIA as part of the 2016 UWIR (OGIA, 2016) using the chloride mass balance recharge estimation method. From this work, OGIA estimates the majority of surficial recharge to flow towards watercourses and discharge locally to streams and rivers such that only 10% of their recharge reaches the deeper confined aquifer. Refer to KCB (2025) attached as Appendix E for further information on groundwater recharge relevant to the Project Area.

3.8.4 Groundwater Levels, Flow and Elevation

At a regional scale, groundwater flow within the Surat Basin is typically north to south, from the outcrop areas located to the north. Groundwater movement is slow in the GAB with flow velocities estimated to be 1 to 5 m/year. Generally, groundwater flow and movement occur as sub-horizontal flow, with limited vertical leakage across formations, where pressure differences may exist. Vertical flow generally only occurs downward in outcropping areas where recharge occurs. Local groundwater flow conditions may be different from regional flow conditions with potential steeper gradients and increased velocities in response to hydraulic stresses such as groundwater abstraction.

Groundwater levels in the vicinity of the Project Area have been considered using available records from the Queensland Groundwater Database (Queensland Government, 2025). A number of groundwater monitoring bores exist within the proximity of the Project Area; however transient groundwater level records are limited. The majority of monitoring bores are installed as part of the UWIR and other programs such as CSG monitoring program or CSG Net Program operated by the DNRME (KCB, 2025). Refer to Appendix E for detailed information on groundwater levels in the Project Area.

3.8.5 Groundwater Dependent Ecosystems

Surface expression Groundwater Dependent Ecosystems (GDEs) are not present in the Project Area, and there are no GDEs or spring vents or complexes located within the 25 km buffer of the Project Area. The closest watercourse springs are located along the Blyth and Yuleba Creeks (associated with the Mooga Sandstone) more than 20 km to the northeast and northwest of the Project Area, respectively.

Small patches of low confidence (1–80%) potential terrestrial GDEs (TGDEs) are mapped by the Queensland government within the Project Area (summarised in Table 12). Potential TGDEs in this area are indicated to intermittently connect to aquifers with brackish salinity and alkaline pH in unconsolidated Quaternary alluvial. Rooting depths identified for species present in identified RE's based on available literature reviews range to 22.6 m. The potential for groundwater dependence of identified REs in the Project Area was inferred using GDE assessment guidelines. Further, potential TGDEs located along the creek systems in and around the Project Area may be groundwater dependent as they occur within an alluvial system (associated with creeks), and the ecosystem is associated with drainage features. This alluvial system is likely replenished during prolonged wet periods when the ephemeral creek system is flowing.

Limited to no groundwater contribution from the regional groundwater system to watercourses as baseflow is anticipated in the Project Area.

Refer to Appendix E for further information on GDEs/TGDEs relevant to the Project Area.

Table 12: Potential TGDEs located in Project Area (adapted from KCB, 2025)

RE	Land Zone	Description	Rooting Depth
11.3.17	Alluvium (river and creek flats)	*Eucalyptus populnea* woodland with *Acacia harpophylla* and/or *Casuarina cristata* on alluvial plains; not a wetland	12.1 - 22.6 m
11.3.2		*Eucalyptus populnea* woodland on alluvial plains; may contain Palustrine wetlands	
11.3.25		*Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines; riverine wetland	

RE	Land Zone	Description	Rooting Depth
11.9.10	Undulating country on fine grained sedimentary rocks	*Eucalyptus populnea* open forest with a secondary tree layer of *Acacia harpophylla* and sometimes *Casuarina cristata* on fine-grained sedimentary rocks; not a wetland	No information available
11.9.7	Hills and lowlands on Metamorphic rocks	*Eucalyptus populnea, Eremophila mitchellii* shrubby woodland on fine grained sedimentary rocks;	No information available

3.8.6 Groundwater Users and Bores

Groundwater in the Surat CMA has multiple uses, including stock and domestic purposes, agriculture (general agriculture, irrigation, and stock-intensive), town water supplies, and industrial/mining activities. Groundwater abstraction for stock and domestic purposes is likely to be the dominant water use within the vicinity of the Project Area.

There are 427 registered groundwater bores located within a 25 km buffer of the Project Area. Of these bores, 376 are existing bores (which include water supply and monitoring bores), with the remainder either abandoned and destroyed, abandoned but usable or proposed.

Under the Queensland *Water Act 2000*, CSG proponents are required to undertake baseline assessments of water bores located within their petroleum tenures prior to commencement of production. Baseline assessments are undertaken in accordance with the *Baseline Assessment Guideline* (DES, 2017), to obtain information such as: bore status, type and purpose; information related to the construction of the bore, including depth installed, screen interval and source aquifer; groundwater level and quality and field gas measurement; and bore equipment including pump depth, pumping frequency and flow rate.

There is one operational water bore located within the Project Area. This bore is attributed to the Mooga Sandstone. The baseline assessment was undertaken in 2009 for RN 123195 (refer to Table 13). Another groundwater bore (RN208460) was drilled on the tenement in June 2024. This new bore is indicated as “no longer used”. Santos are in the process of revising their Baseline Assessment Plan, as required by the Queensland *Water Act*, with baseline assessment planned to occur in Q4 2025 (prior to commencement of the Project) if it is required.

Table 13: Baseline Assessment Bore Details

RN	Name	Property (Lot Plan)	Easting	Northing	Purpose	Baseline Assessment Date	Aquifer
			GDA 94				
123195	House Bore	123 WV468	722513	7057126	Domestic	4/11/2009	Mooga Sandstone
208460	N/A	126 WAL53678	723709	7056052	Domestic Stock	Q4 2025	Unknown

3.9 Air Quality and Noise

Air quality in the vicinity of the Project Area is representative of a rural area with a low population density and is likely to be largely influenced by activities such as:

- dust from agricultural and oil and gas exploration and production activities, including from stock and vehicle movements, land clearing, and cropping activities;
- particulates from naturally occurring events such as bushfires;
- vehicle and equipment exhaust fumes from roads, agriculture activities, industrial activities and towns; and
- emissions from resources activities operating in the area.

Consistent with the objectives of the *Environmental Protection (Air) Policy 2019* (EPP Air), the EVs relevant to the Project Area are:

- the qualities of the air environment that are conducive to protecting the health and biodiversity of ecosystems;
- the qualities of the air environment that are conducive to human health and well-being;
- the qualities of the air environment that are conducive to protecting the aesthetics of the environment, including the appearance of buildings, structures and other property; and
- the qualities of the air environment that are conducive to protecting agricultural use of the environment.

The existing noise environment for the Project Area is typical of rural areas, with low levels of background noise generally comprised of noises associated with rural based human occupation.

Noise levels in the vicinity of the Project Area are likely to be influenced by the following:

- the use of equipment and machinery during both agricultural activities and oil and gas exploration and production activities in the area;
- traffic noise from project vehicles and other traffic, including heavy transport vehicles associated with the Warrego Highway operating on a 24-hour basis;
- natural sources such as birds, insects, wind and other meteorological events;
- livestock; and
- resource exploration and development activities.

Consistent with the objectives of the *Environmental Protection (Noise) Policy 2019* (EPP Noise), the EVs are:

- the qualities of the acoustic environment that are conducive to protecting the health and biodiversity of ecosystems;
- the qualities of the acoustic environment that are conducive to human health and well being, including by ensuring a suitable acoustic environment for individuals to sleep, study or learn, or be involved in recreation (including relaxation and conversation); and
- the qualities of the acoustic environment which are conducive to protecting the amenity of the community.

Background noise monitoring has not been undertaken for the Project Area. In the absence of background noise monitoring, the deemed background levels nominated in the proposed conditions for the new EA and in Table 2 of the DETSI guideline *'Prescribing noise conditions for environmental authorities for petroleum activities*' (ESR/2016/1935, Version 2.05) (DETSI, 2025) are considered to be representative of the ambient acoustic environment associated with a rural setting.

3.10 Waste

EVs that may be impacted by waste from petroleum activities relate to:

- human health and wellbeing;
- land quality;
- water quality;
- visual amenity; and
- existing ecological processes and biodiversity.

Under Schedule 8, Part 3 of the *Environmental Protection Regulation 2019* (EP Reg), the environmental objective for activities with waste impacts is:

> *Any waste generated, transported, or received as part of carrying out the activity is managed in a way that protects all environmental values.*

Performance outcomes are:

- Waste generated, transported, or received, is managed in accordance with the waste and resource management hierarchy in the *Waste Reduction and Recycling Act 2011*; and
- If waste is disposed of, it is disposed of in a way that prevents or minimises adverse effects on environmental values.

Wastes potentially generated from project activities would include the following:

- batteries and electrical – lead acid batteries, gel type batteries, nickel cadmium batteries and alkaline batteries generated from equipment, vehicles, generators and electronics;
- chemical waste and chemical containers – chemical wastes may include herbicides, pesticides, paints and solvents. Chemical containers are those containing any volume of free chemical that is a regulated waste and may include waste oil containers and aerosol cans containing solvent or paint;
- concrete / aggregate / asphalt – concrete, aggregate and asphalt materials removed from demolished infrastructure that are not suitable for recycling;
- contaminated soil – contaminated soils may be generated where localised spills of hydrocarbons and other contaminants occur;
- cooking oil – waste cooking oil is generated from kitchen facilities at temporary mobile camps;
- drilling fluids and muds – waste drilling fluids, muds and cuttings are generated from the drilling process;
- general recycling – plastic bottles and food containers, glass bottles and jars, milk cartons, aluminum bottles and cans, metal lids from jars, tin cans, aluminum cans, plastic cups, cardboards and paper packaging, folders, envelopes, office paper, magazines, cereal boxes, clean paper towels, steel scraps;
- grease trap waste – grease trap waste is generated from kitchen facilities at temporary mobile camps;
- green waste – green waste produced from vegetation clearing activities;
- hydrostatic test water – spent water used in the hydrostatic testing of pipelines to test pipeline integrity;
- Intermediate bulk containers (IBCs) – containers used for transport of fluids and bulk materials;

- oily filters, rags, and absorbents - Oily filters, rags, and absorbents are generated from routine equipment and vehicle servicing, repair and filter changes;
- oily water – oily water may be produced from servicing equipment, machinery and vehicles;
- pipeline tape wrap – pipeline tape wrap protects the pipeline against corrosion;
- plastic liners - waste plastic liners associated with sumps and turkeys nest dams;
- PW – PW is primarily generated from the operation of wells;
- putrescible and other domestic waste – food scraps, food wrappers, packaging materials, textile materials, plastic wrapping film, plastic bags, facial tissues, ear plugs, pens and pencils, polystyrene, aluminum foil, waxy paper, cardboard, non-recyclable plastics, etc.;
- scrap steel and metal – scrap steel and metal may include steel piping, values and cabling;
- stimulation flowback water – this waste is generated when the fluids used in the stimulation process are brought back to the surface;
- timber – untreated timber derived from packaging and uses that cannot be reused or recycled;
- Triethylene glycol (TEG) / glycol / coolant – is generated from equipment and vehicle fluid changes;
- tyres – tyres and tubes are generated from tyre changes on work and vehicle equipment;
- used spill kits – used spill kits are generated from spill clean-up of chemicals and hydrocarbons;
- waste oil – small quantities of waste oil are generated routinely from vehicle and equipment oil changes; and
- wiring – electrical wiring and equipment not suitable for reuse.

Leftover fracture stimulation fluids would be removed from the Project Area for use on subsequent wells or taken offsite from the Project Area for authorised disposal. Where of an appropriate quality, some PW may be re-used for the purposes of dust suppression, and in drilling and hydraulic fracturing activities.

3.11 Rehabilitation

Rehabilitation and decommissioning of disturbed land would occur progressively in accordance with proposed EA conditions (refer to Schedule J in Appendix A). The objective of rehabilitation and decommissioning is to achieve a post development landform that is:

- safe for humans, native fauna and livestock
- non-polluting; and
- stable and able to sustain appropriate land use.

The rehabilitation works would aim to provide appropriate site conditions to facilitate revegetation.

Consistent with Santos' existing operations currently undertaken on adjacent Santos-operated PLs (e.g. PLs 315, 1020) authorised by EA EPPG0089821, a two-stage rehabilitation program approach would be pursued.

Stage 1 pertains to stabilisation works which would be completed post construction within the footprint of operational assets, predominantly pipeline easements. The land is stabilised to ensure the safe and effective operation of assets and to minimise the risk of erosion, soil loss and weed invasion. Where possible, land would be returned to the landholder for productive use (e.g. grazing and cropping). Stabilisation works would include:

- remediating areas of contaminated land resulting from petroleum activities
- re-establishing surface drainage lines and re-profiling contours for operational use
- establishing a safe landform for humans and livestock in areas of significant cut and fill
- reinstating top soil (where present)
- improving the condition of soil through the appropriate assessment and treatment of soils where required; and
- promoting the establishment of groundcover vegetation.

Stage 2 rehabilitation activities relate to disturbance footprints no longer required for operational purposes. Rehabilitation activities in Stage 2 would return remaining disturbance footprints to an appropriate land use in accordance with landholder needs and applicable regulatory requirements.

Agricultural land uses and natural areas comprising native vegetation are the two most common pre-disturbance land uses to be rehabilitated. Final rehabilitation of natural areas would be undertaken to achieve the final rehabilitation criteria conditions specified in the proposed EA (refer to Schedule J in Appendix A). Where appropriate infrastructure is to be left for the landholder, a written agreement will be submitted to DETSI alongside the Final Rehabilitation Report.

4.0 Potential Impacts, Mitigation Measures and Environmental Risk Assessment

As discussed in Section 1.2, impacts associated with the proposed activities are not new and are consistent with existing authorised petroleum activities and impacts currently being undertaken in the Project Area and surrounding region. Existing petroleum activities in the Project Area and surrounding region are authorised under EAs 0002052 and EPPG0089821.

Further, as discussed in Sections 2.1 to 2.2, Santos has invested significant time into planning and locating existing and proposed infrastructure in the Project Area to avoid unnecessary disturbance to native remnant and regrowth vegetation wherever practicable (given safety and engineering restrictions discussed in Section 2.3).

As can be seen in Figure 2 and Figure 4, the majority of existing and proposed disturbance has been located in non-remnant vegetation or previously cleared areas. Where disturbance to remnant and regrowth vegetation will be required, Santos has actively shifted or reduced disturbance widths and areas to mitigate disturbance to sensitivities wherever practicable. Further, to minimise land disturbance, some well leases will host multiple CSG wells, and infrastructure has been placed along existing access tracks and fence lines to avoid disturbance to landholder activities and reduce disturbance to productive land i.e. cropping / grazing land.

Ultimately, the proposed development will impact a fraction of land in PL 1123. Existing and proposed disturbance to PL 1123 as part of the proposed development will constitute ~62 ha or ~5% of total land area in PL 1123 (1229 ha).

This section provides the following:

- a description of potential impacts to relevant EVs (as described in Section 3.0);
- mitigation and management measures to minimise potential impacts to relevant EVs; and
- an environmental risk assessment; and
- an assessment against Schedule 8 (Parts 1 and 2) of the EP Reg (Environmental Objective Assessment and Performance Outcomes) (attached as Appendix G).

To assess environmental risks associated with the proposed activities, a risk assessment for each relevant environmental value has been completed. The environmental risk assessment is based on risk factors associated with both the initial construction and ongoing operational phases of the proposed activities. Risk assessment of a proposed activity identifies a wide range of risks and potential impacts to relevant EVs as a potential result of carrying out the activity. This does not however mean all identified potential impacts will occur as a result of carrying out the activity.

Once initial unmitigated risks and potential impacts are identified as part of a risk assessment, appropriate control strategies are identified and implemented. Appropriately implemented control strategies will typically mitigate the likelihood of a potential impact occurring, and/or reduce the severity/consequences of the potential impact.

The risk assessment identifies initial (unmitigated) risks associated with the proposed activities for each relevant environmental value. Following identification of appropriate mitigation measures (control strategies), the residual (mitigated) risk posed to each environmental value has also been determined (refer to the risk assessment Table 33 in Appendix F for further detail). The risk assessment has been

undertaken in accordance with the Santos Management System (SMS) Risk Management Standard. The SMS Risk Management Standard is based on accepted principles and applicable Australian standards. Further detail on the Santos risk assessment process is provided in Appendix F.

The results of the risk assessment are summarised in the risk assessment Table 33 in Appendix F and discussed in Sections 4.1 to 4.6.2. The risk assessment identified a range of potential impacts and control strategies associated with the proposed activities. Following consideration of control strategies, a residual risk of 'Low' was assigned to all potential impacts to relevant EVs.

Potential impacts to MSES in context of the *Environmental Offset Act 2014* are discussed in Section 4.4.

4.1 Land Resources

Potential direct and indirect impacts to land resources will be predominantly short-term and associated with the initial limited clearing and construction phases of the project. The proposed activities would result in direct disturbance of land for the construction of well leases, access tracks, gathering infrastructure and other incidental petroleum activities as described in Section 2.2.

Proposed disturbance may temporarily reduce the availability of land for agriculture. However, these impacts would be offset by commercial agreements between Santos and relevant property owners.

Following completion of the construction phase, large sections of land will begin regenerating to achieve stability and groundcover similar to that of surrounding areas. For example, the majority of the gathering line / pipeline construction RoW will be rehabilitated following pipeline installation (with the exception of the retention of basic vehicle access to allow for mandatory routine inspections and maintenance via light vehicles i.e. a simple running track is required to be maintained for light vehicle access).

Disturbed areas no longer required for construction will be progressively rehabilitated / stabilised as construction progresses. Rehabilitation of disturbed areas following construction will typically include:

- contouring to match surrounding landforms;
- re-establishment of surface drainage lines;
- re-spreading of stockpiled topsoil and establishment of groundcover; and
- placement of cleared vegetation as required.

As discussed in Section 2.2 (and as displayed on Figure 2), proposed infrastructure has been predominantly located adjacent to existing landholder fence lines to minimise disturbance to remnant native vegetation, and disruption to existing land uses i.e. cropping and grazing land. Santos also proposes to utilise some multi-well leases to minimise disturbance, maximise gas recovery, and/or accommodate landholder requirements. Further, as discussed in Section 2.2, for the purposes of efficiency and to minimise land disturbance in the Project Area, gas and PW generated from the Project Area will utilise existing centralised water and gas processing facilities (including compression stations) located on adjoining RSGPA tenures (authorised under EA EPPG00898213).

More specifically, gas produced from the Project Area is planned to be transferred to an existing compressor station located on PL 314 via new and existing gas gathering infrastructure e.g. gas pipelines and trunklines. In future, gas from the Project Area may potentially be processed or sent elsewhere, subject to relevant approvals (refer to Figure 1 to Figure 2).

PW is proposed to be transferred to existing approved dams located on adjacent tenures. PW from these dams is then proposed to be transferred to existing approved water treatment facilities located on PL 314, where the water will be processed through a fines and sludge removal facility before being further processed, or bypassed around, the Roma Reverse Osmosis Plant (ROP) to meet re-use criteria in

accordance with *End of Waste Code Irrigation of Associated Water* (ENEW07546918, Version 1.07) (DETSI, 2025a). The Roma ROP is located approx. 25 km northwest of the Project Area. Adequate water and brine storage and treatment capacity has been assessed to be available on adjacent tenures to manage peak water and brine production from the Project.

Integration with the RSGPA activities will negate the requirement to locate gas compression or large water management facilities within the Project Area. Accordingly, this will result in less major infrastructure being required to be located in the Project Area, which will minimise disturbance to remnant native vegetation and assist in minimising disruption to existing land uses i.e. cropping and grazing land.

During construction and operational phases, there is a risk of minor accidental spills or leaks of fuels and chemicals, fuels, and PW to soils. This may have the potential to result in minor localised contamination of soil.

The proposed activities may result in direct and indirect impacts to land resources (as described in Section 3.1), primarily as a result of:

- infrastructure construction (earthworks activities, including grading and trenching);
- vehicle and plant movements;
- minor spills or leaks of fuels and chemicals from vehicles and equipment;
- loss of containment;
- bushfire and flood (natural event); and
- fire (ignition sources resulting from activities).

Santos aims to minimise the operational footprint and significant disturbance associated with its activities as far as reasonably practicable. However, potential direct and indirect impacts to land resource EVs resulting from the proposed activities may include:

- reduction in visual amenity;
- soil erosion, topsoil loss, inversion and compaction;
- disturbance to land use and suitability changes;
- reduction in agricultural productivity; and
- contamination of soil.

Management (control) strategies, risk sources, potential impacts and the level of risk associated with the proposed activities are summarised in Appendix F, Table 33. The results of the risk assessment indicate the residual risk to land resource EVs as a result of the proposed activities is classified as ‘Low’.

4.2 REs, ESAs, and Flora and Fauna

The proposed activities may result in direct and indirect impacts to REs, ESAs, Flora and Fauna (as described in Sections 3.2 to 3.5) primarily as a result of:

- infrastructure construction (earthworks activities, including grading and trenching);
- entrapment in voids (trenches / bell holes / pits);
- vehicle and plant movements; and
- fire (ignition sources resulting from activities).

Santos aims to minimise the operational footprint and significant disturbance associated with its activities as far as reasonably practicable. However, potential direct and indirect impacts to REs / ESAs and Flora and Fauna resulting from the proposed activities may include:

- damage to and/or loss of native riparian vegetation and habitat;
- damage to and/or loss of high value flora;
- introduction and/or spread of weeds, pest plants, animals and pathogens;
- loss of species population, further endangerment and loss in species diversity; and
- disturbance, injury or loss of fauna.

As discussed in Section 2.2, significant pre-planning has been undertaken to locate existing and proposed infrastructure to minimise impacts to environmental and land resource values. Santos developed a PDF for the Project Area to locate proposed infrastructure to trial multiple iterations of proposed infrastructure locations to maximise avoidance and minimise disturbance to REs, ESAs, Flora and Fauna (and MNES, MNES) and other environmental and landholder values (refer to Figure 2). As can be seen in Figure 2 and Figure 4, the majority of existing and proposed disturbance has been located in non-remnant vegetation or previously cleared areas. Where disturbance to remnant and regrowth vegetation will be required, Santos has actively shifted or reduced disturbance widths and areas to mitigate disturbance to sensitivities wherever practicable. Santos also proposes to utilise some multi-well leases to minimise disturbance, maximise gas recovery, and/or accommodate landholder requirements.

More specifically, Santos is proposing to disturb 0.30 ha of remnant and regrowth RE 11.3.2, and 0.60 ha of general ephemeral wetland habitat (non-remnant) as part of the proposed development. No disturbance to TECs is proposed. Proposed disturbance to REs, ESAs and Primary Protection Zones (PPZs), and potential fauna habitat are detailed in Table 14 to Table 16, respectively.

As discussed in Section 3.5.1, no NCA or EPBC Act listed threatened flora species were detected during field surveys and no NCA or EPBC Act flora species are assessed to potentially or likely be present. Further, the Project Area does not fall within a High-Risk Area on the Protected Plants Flora Survey Trigger Map. Refer to Appendix D (Boobook, 2025) for further information.

As discussed in 3.5.2, several fauna species listed under the NCA and EPBC Act are considered to potentially or likely occur, or have potentially suitable habitat located in the Project Area. Potential habitat for these species was predicted and mapped by Boobook (2025) based on known vegetation and habitat feature associations for each species. Minor disturbance to small sections of potentially suitable habitat for relevant listed species is detailed in Table 16.

Proposed impacts to potentially suitable listed fauna habitat are minor i.e. a total of 0.90 ha of disturbance to potential habitat is proposed, and of this, 0.30 ha constitutes disturbance to remnant and regrowth vegetation.

Further, as discussed in Section 2.2, for the purposes of efficiency and to minimise land disturbance in the Project Area, gas and PW generated from the Project Area will utilise existing centralised water and gas processing facilities (including compression stations) located on adjoining RSGPA tenures (authorised under EA EPPG00898213). Integration with the RSGPA activities will negate the requirement to locate gas compression or large water management facilities within the Project Area. Accordingly, this will result in less major infrastructure being required in the Project Area, which will minimise disturbance to native vegetation and assist in minimising disruption to existing land uses.

The proposed activities would result in the direct disturbance of land for the construction of well leases, access tracks, gathering infrastructure and other incidental petroleum activities as described in Section

2.2. Following completion of the construction phase, large sections of land will immediately begin regenerating to achieve stability and groundcover similar to that of surrounding areas. For example, the majority of the gathering line / pipeline construction RoW will be rehabilitated following pipeline installation (with the exception of the retention of basic vehicle access to allow for mandatory routine inspections and maintenance via light vehicles i.e. a simple running track is required to be maintained for light vehicle access).

Management (control) strategies, risk sources, potential impacts and the level of risk associated with the proposed activities are summarised in Appendix F, Table 33. The results of the risk assessment indicate that residual risks to REs / ESAs and Flora and Fauna EVs as a result of the proposed activities are classified as 'Low'.

Table 14: Proposed Disturbance to REs

RE	Remnant / Regrowth	RE Description	VM Act Status	BD Status	VMA Structural Category	Disturbance Area (ha)
11.3.2	Remnant	*Eucalyptus populnea* woodland on alluvial plains	OC	OC	Sparse	0.15
11.3.2	Regrowth	*Eucalyptus populnea* woodland on alluvial plains	OC	OC	Sparse	0.15
Total RE Disturbance Area (ha)						**0.30**

Key: VM class and BD status under the *Vegetation Management Act 1999*: NCAP – No Concern at Present, LC – Least Concern, OC – Of Concern, E – Endangered

Table 15: Proposed Disturbance to ESAs and PPZs

Category	Type	Disturbance Area (ha)[1]
B	PPZ (Endangered REs 11.9.10 / 11.3.17)	13.50
C	Of Concern RE 11.3.2	0.30
	Essential Habitat	0.30
	PPZ (Essential Habitat and Of Concern REs (11.3.2 / 11.3.25))	60.50

[1] *Disturbance areas for ESAs/Essential Habitat//PPZs will be an overestimate of impacts due to overlapping values in the PDF.*

Table 16: Proposed Disturbance to Potentially Suitable Fauna Habitat for NCA / EPBC Act-listed Fauna Assessed as Potentially Present or Likely to Occur Within the PDF (adapted from Boobook, 2025).

Species	EPBC Act Status	NCA Status	Potentially Suitable Habitat REs[1]	Disturbance Area (ha)[2]	Mapped Extent of Habitat within Project Area (ha)
Australian Painted Snipe (*Rostratula australis*)	E	E	General Habitat includes ground-truthed wetlands and dams	General: 0.60	General: 7.31
Glossy Black-Cockatoo (*Calptorhynchus lathami*)	V	V	General: 11.3.2, 11.3.25, 11.9.7 Primary: 11.9.10, 11.3.17	General: 0.30	Primary: 37.12 General: 107.61
Grey Snake (*Hemiaspis damelii*)	E	E	General: 11.3.2, 11.3.17, 11.3.25	General: 0.30	General: 144.72
Koala (*Phascolarctos cinereus*)	E	E	Primary: 11.3.2, 11.3.25, 11.9.7 General: 11.3.17, 11.9.10	Primary: 0.30	Primary: 107.62 General: 37.12
White-throated Needletail (*Hirundapus caudacutus*)	V	V	General: 11.3.2, 11.3.17, 11.3.25, 11.9.7, 11.9.10	General: 0.30	General: 144.72
Woma (*Aspidites ramsayi*)	N/A	NT	General: 11.3.2, 11.3.17, 11.3.25, 11.9.7, 11.9.10	General: 0.30	General: 144.72
Yakka Skink (*Egernia rugosa*)	V	V	Primary: 11.3.2 General: 11.3.17, 11.9.10	Primary: 0.30	Primary: 84.79 General: 37.12
Sharp-tailed Sandpiper (*Calidris acuminata*)	V	SL	General Habitat includes ground-truthed wetlands and dams	General: 0.60	General: 7.31
Latham's Snipe (*Gallinago hardwickii*)	V	SL	General Habitat includes ground-truthed wetlands and dams	General: 0.60	General: 7.31

Key to Status: CE/CR = Critically Endangered; E = Endangered; V = Vulnerable; NT = Near Threatened; SL = Special Least Concern; C = Least Concern.

[1] Identified habitat RE were classified as Primary or General Habitat as follows:

- **Primary habitat** - is an area containing resources that are considered essential for the maintenance of populations of the species (e.g. potential habitat for breeding, roosting, foraging, shelter, for either migratory or non-migratory species). 'Primary Habitat' is defined from known records and/or expert advice (including the findings of preclearance surveys).
- **General habitat** - consists of areas or locations that are used by transient individuals or where species have been recorded but there is insufficient information to assess the area as 'Primary Habitat'. 'General Habitat' may be defined from known records or habitat that is considered to potential support a species according to expert knowledge of habitat relationships, despite the absence of specimen backed records. 'General Habitat' may include areas of suboptimal habitat for species.

[2] Disturbance areas will be an overestimate of impacts due to overlap of potentially suitable habitat areas in the PDF.

4.3 Matters of State Environmental Significance

As discussed in Sections 3.2 and 3.6, Boobook undertook an ecological field survey and assessment of the Project Area. Following completion of the ecological field survey, Boobook compiled an EAR (attached as Appendix D) inclusive of a Significant Residual Impact (SRI) assessment of the proposed activities in accordance with the requirements of the DETSI SRI Guideline (DEHP, 2014).

As discussed in Section 3.6, the DETSI MSES report and EAR (Boobook, 2025) (both reports are attached as Appendix D) identified the following MSES to be present within the Project Area:

- Protected wildlife (fauna) habitat (an area of habitat (e.g. foraging, roosting, nesting or breeding habitat) for an animal that is endangered, vulnerable or a special least concern animal (section 6(4), EO Reg);
- Regulated Vegetation (prescribed REs that are Endangered and Of Concern); and
- Regulated Vegetation (prescribed REs to the extent the ecosystem is located within a defined distance from the defining banks of a relevant watercourse).

EVs analogous to MSES protected wildlife (fauna and flora habitat) (i.e. remnant REs) have been assessed for the Project Area by this risk assessment, and relevant control measures to mitigate potential risks and impacts to remnant REs are detailed in Table 33. The results of the risk assessment indicate that residual risks to MSES (where analogous to REs / ESAs and Flora and Fauna EVs) as a result of the proposed activities are classified as 'Low'.

Refer to Section 4.4 for further information on potential impacts to MSES in the context of assessment against the requirements of the *Environmental Offsets Act 2014 and* the DETSI SRI Guideline (DEHP, 2014).

4.4 Environmental Offsets Act 2014

As per Section 8 of the *Environmental Offsets Act 2014* (EO Act), a significant residual impact (SRI) is generally an adverse impact, whether direct or indirect, of a prescribed activity on all or part of a prescribed environmental matter (PEM) that:

a) remains, or will or is likely to remain, (whether temporarily or permanently) despite on-site avoidance and mitigation measures for the prescribed activity; and

b) is, or will or is likely to be, significant.

The proposed development would constitute a prescribed activity under s9 of the EO Act. In accordance with s207(1)(c) of the EP Act, the administering authority may impose an environmental offset condition on an EA. However, s14(2) of the EO Act states that an offset condition may only be imposed on an EA if the proposed activity will, or is likely to have a SRI on a PEM, and all reasonable on-site mitigation measures for the prescribed activity have been, or will be, undertaken.

The *Queensland Environmental Offsets Policy Significant Residual Impact Guideline* (SRI Guideline) (DEHP, 2014) has been developed to assist in deciding whether or not a prescribed activity will, or is likely to have a SRI on a PEM.

Boobook carried out an SRI assessment for PEMs-MSES potentially impacted by the project in accordance with the criteria provided in the SRI Guideline. The SRI assessment is detailed in the EAR (Boobook, 2025) (attached as Appendix D). The SRI assessment found that, after considering potential impacts, mitigation measures and the state SRI criteria, the proposed development will not have a SRI on any PEMs-MSES values (refer to SRI assessment contained in Table 17).

Table 17: Significant Residual Impact Summary Table (adapted from Boobook, 2025)

Prescribed environmental matter as per EOR	Presence in the Project Area	
Regulated vegetation: Endangered and Of Concern REs	☒	The Project Area does not contain areas of regulated vegetation that is a 'prescribed RE'. DEHP (2014) defines regulated vegetation to be a prescribed RE as per the EOR which does not include regrowth (Category C) vegetation. No remnant or Category B areas are present within the Project Area on the RVMM. As discussed in Section 3.6.2, regulated vegetation mapped within the Project Area on the RVMM consists entirely of three areas of Category C (RE 11.3.2/11.3.17/11.3.25, high value regrowth) vegetation. Therefore, the Project Area contains no prescribed RE or MSES PEM for the purposes of SRI assessment under the EOR and Significant Residual Impact Guideline (DEHP 2014). In conclusion, the proposed activities will not result in an SRI to Regulated Vegetation (Endangered and Of Concern RE).
Regulated vegetation: Prescribed REs within the defined distance of a watercourse	☒	The Project Area does not contain areas of regulated vegetation that is a 'prescribed RE' within the defined distance of a watercourse. DEHP (2014) defines regulated vegetation to be a prescribed RE as per the EOR which does not include regrowth (Category C) vegetation. No remnant or Category B areas are present within the Project Area on the RVMM (accessed 22/07/2025). As discussed in Section 3.6.2, regulated vegetation mapped within the Project Area on the RVMM consists entirely of three areas of Category C (RE 11.3.2/11.3.17/11.3.25, high value regrowth) vegetation. Portions of two Category C areas occur within the defined distance from the defining banks of a watercourse identified on the vegetation management watercourse map. As these areas are mapped as regrowth, they are not prescribed RE. Therefore, the Project Area contains no prescribed RE or MSES PEM for the purposes of SRI assessment under the EOR and Significant Residual Impact Guideline (DEHP 2014). In conclusion, the proposed activities will not result in an SRI to Regulated Vegetation (within the defined distance of a watercourse).
Connectivity areas	☑	The Landscape Fragmentation and Connectivity Tool was utilised to assess the proposed disturbances for potential impacts to Connectivity Areas. The Tool determined no SRI was triggered by the proposed activities. Refer to Section 4.4.1 for further information.
Wetlands and watercourses	☒	The following wetlands or watercourses are not present within the Project Area: • Wetlands in a wetland protection area as shown on the Map of referrable wetlands under schedule 12, part 2 of the *Environmental Protection Regulation 2019;* • Wetlands of high ecological significance (HES) as shown on the Map of referrable wetlands under schedule 12, part 2 of the *Environmental Protection Regulation 200*; or • Wetlands or watercourses in a high ecological value waters as identified under the *Environmental Protection (Water) Policy 2009*, schedule 2.

Prescribed environmental matter as per EOR	Presence in the Project Area	
Designated precinct in a strategic environmental area	☒	The Project Area is not located in a designated precinct in a strategic environmental area.
Protected wildlife habitat	☑	• Based on fauna habitat / RE associations, wildlife habitat for NCA listed species relevant to SRI assessment may be present within the Project Area (refer to Section 3.3.1 and Table 9). • No high-risk areas on the flora survey trigger map exist within the Project Area. Boobook undertook ecological impact assessment against the SRI criteria as per the SRI Guideline (DEHP, 2014) for relevant NCA listed species assessed as likely or potentially occur in the Project Area. No NCA listed flora species were assessed to likely or potentially occur in the Project Area (refer to Section 3.5 for further detail). Following detailed assessment against the NCA SRI criteria, Boobook (2025) concluded the proposed activities are not expected to result in an SRI to protected wildlife species (or their habitat) listed under the NCA. Refer to Section 4.4.2 for further information.
Protected areas	☒	There are no protected areas within the Project Area.
Highly protected zones of State marine parks	☒	The Project Area does not contain highly protected zones of a State marine park.
Fish habitat areas	☒	Areas declared under the *Fisheries Act 1994* to be a fish habitat area are not present within the Project Area.
Waterway providing for fish passage	☑	The Project Area contains watercourses providing potential fish passage, as detailed in Section 3.7. The proposed development would not have an SRI on this PEM because linear infrastructure construction activities located in waterways providing for fish passage would not: • reduce the extent, frequency, or duration of fish passage; • result in a substantial change to the hydrological regime of the watercourse; or • lead to significant changes in water quality parameters within the watercourse. Other measures to be carried out to reduce potential impacts on surface waters where required are detailed in Section 4.4 and Table 33. Proposed EA conditions relating to impacts to surface waters and wetlands are also detailed in the Schedule B EA conditions in Appendix A).
Marine plants	☒	Areas containing marine plants are not present in the Project Area.
Legally secured offset areas	☒	No legally secured offset areas are present within the Project Area.

4.4.1 Connectivity Areas

Boobook (2025) utilised the Landscape Fragmentation and Connectivity Tool to assess the proposed disturbances for potential impacts to Connectivity Areas. The Tool determined no SRI was triggered by the proposed activities. Connectivity areas are areas of remnant vegetation outside urban areas containing prescribed RE that are required for ecosystem functioning. As both test results were negative, the overall result is the impact will not be significant. Results of the connectivity tool are summarised in Table 18. Refer to Boobook (2025) for further information.

Table 18: Connectivity areas that are a RE (not in urban area) within the Project Area (adapted from Boobook, 2025)

Connectivity Test	Regional scale extent of core remnant RE pre-impact	Change threshold for local scale core remnant RE	Change in core local scale remnant RE post-impact	Number of core areas ≥1 ha pre-impact	Number of core areas ≥1 ha post-impact	Test Result
Change in core remnant RE extent at the local scale	4.4%	2%	0%			Not Significant
Loss / fragmentation of core remnant RE at the site (Disturbance Footprint) scale				0	0	Not Significant

4.4.2 Protected Wildlife Habitat

The SRI Guideline provides that a prescribed activity is likely to have a significant impact on protected wildlife habitat if:

- For endangered and vulnerable wildlife habitat (including an area of essential habitat as mapped on the *essential habitat map*), an action is likely to have a significant impact on endangered and vulnerable wildlife if the impact on the habitat is likely to:
  - lead to a long-term decrease in the size of a local population; or
  - reduce the extent of occurrence of the species; or
  - fragment an existing population; or
  - result in genetically distinct populations forming as a result of habitat isolation; or
  - result in invasive species that are harmful to an endangered or vulnerable species becoming established in the endangered or vulnerable species' habitat; or
  - introduce disease that may cause the population to decline, or
  - interfere with the recovery of the species; or
  - cause disruption to ecologically significant locations (breeding, feeding, nesting, migration or resting sites) of a species.

- For special least concern (non-migratory) animal wildlife habitat, an action is likely to have a significant impact on a special least concern (non-migratory) animal wildlife habitat if it is likely that it will result in:
  - a long-term decrease in the size of a local population; or
  - a reduced extent of occurrence of the species; or
  - fragmentation of an existing population; or
  - result in genetically distinct populations forming as a result of habitat isolation; or
  - disruption to ecologically significant locations (breeding, feeding or nesting sites) of a species.

As discussed in Section 3.5, Boobook undertook an ecological assessment of the Project Area to determine likelihood of occurrence and presence of potentially suitable habitat for EPBC Act and NCA listed flora and fauna (protected wildlife habitat) (for species relevant to SRI assessment under the EO Act)in the Project Area.

The Project Area may provide suitable habitat for a range of EPBC Act and NCA listed fauna species assessed as likely to or potentially to occur in the Project Area (refer to Table 9).

All species assessed as likely to or potentially to occur in the Project Area, with the exception of Short-beaked echidna (NCA: SL) and Woma (NCA: NT), are listed under both the EPBC Act and NCA.

Boobook (2025) have prepared an EAR to assess potential impacts posed by the proposed activities to relevant species, communities, and migratory species listed under the NCA and/or EPBC Act. The EAR has been compiled to support this application (for a new site-specific EA under the requirements of the EP Act), and to support a referral for the Project to the Department of Climate Change, Energy, the Environment and Water (DCCEEW) under the requirements of the EPBC Act.

Boobook undertook ecological impact assessment against the Significant Impact (SI) criteria as per the *Matters of National Environmental Significance - Significant Impact Guidelines 1.1 (DoE, 2013)* for EPBC Act listed species assessed as likely or potentially to occur in the Project Area.

Further, Boobook also undertook ecological impact assessment against the SRI criteria as per the SRI Guideline (DEHP, 2014) for relevant EPBC Act and NCA listed species assessed as likely or potentially occur in the Project Area. No EPBC Act or NCA listed flora species were assessed to likely or potentially occur in the Project Area (refer to Section 3.5 for further detail).

Following detailed assessment against the NCA SRI and EPBC Act SI criteria (as summarised in Table 19 and Table 20, respectively), Boobook (2025) concluded the proposed activities are not expected to result in an SI or SRI to relevant species (or their habitat) listed under the EPBC Act and NCA. Refer to the Boobook EAR (2025) for further information.

Table 19: Assessment of potential significant impacts upon NC Act-listed fauna species potentially present within the Project Area (adapted from Boobook, 2025).

Species	Significant Residual Impact Criteria (DEHP 2014)							Significant Residual Impact
	Lead to a long-term decrease in the size of a population.	Reduce the Extent of Occurrence (EoO) of the species.	Fragment an existing population / result in genetically distinct populations forming as a result of habitat isolation.	Cause disruption to ecologically significant locations (breeding, feeding, nesting, migration or resting sites) of a species.	Result in invasive species that are harmful to an endangered or vulnerable species becoming established in the endangered or vulnerable species' habitat.	Introduce disease that may cause the population to decline.	Interfere with the recovery of the species.	
Calyptorhynchus lathami Glossy Black-Cockatoo NC Act: Vulnerable	Unlikely: Loss of 0.30 ha of potential shelter and breeding habitat within remnant woodland. Feed trees occur nearby but are not present in the Disturbance Footprint. This small area would support few potential nesting/roost trees. The species has not been recorded in the Project Area and is likely to occur as an occasional visitor, rather than a resident.	Unlikely: Loss of 0.30 ha of potential shelter and breeding habitat. No nest or roost trees were identified during surveys. This mobile and wide-ranging species is capable of traversing non-remnant areas between nest/roost trees and feed trees.	No: The disturbance will not affect dispersal of this species, which travels long distances between suitable foraging trees.	Unlikely: Loss of 0.30 ha of remnant woodland with potential nesting and roost trees. However, the species has not been recorded in the Project Area and is likely to occur as an occasional visitor, rather than a resident.	None known	None known	Unlikely: Loss of 0.30 ha of remnant eucalypt woodland habitat. However, potential nest trees (large trees with large hollows) are in very low abundance.	No: There will be no decrease in foraging habitat. There may be minimal loss of potential nest sites with disturbance of 0.30 ha of remnant / regrowth potential habitat comprising RE 11.3.2.
Hirundapus caudacutus White-throated Needletail NC Act: Vulnerable	No: The species is an aerial feeding insectivore that forages over a wide range of intact and modified landscapes, with a general preference for wooded areas. It does not breed in Australia during its summer presence.	No: The proposed disturbance is not materially relevant to the species.	No: The proposed disturbance is not materially relevant to the species.	No: No impact on foraging resources is anticipated, no other critical locations are relevant to the species in Australia. The species roosts overnight in tall trees along scarps and is unlikely to roost in the Project Area.	None known	None known	No: The proposed disturbance will not reduce the extent of remnant woodland. The species does not breed in Australia.	No: The proposed disturbance is not materially relevant to the species.
Rostratula australis Australian Painted Snipe NC Act: Endangered	No: No potentially suitable habitat occurs within the Disturbance Footprint (i.e. the Disturbance Footprint lacks small ephemeral soaks in floodplain depressions and artificial wetlands such as farm dams).	No: There will be no disturbance to wetland habitat.	No: There will be no disturbance to wetland habitat. The species is mobile and wide-ranging and occurs only sporadically in the region. The proposed development is unlikely to restrict dispersal in this species.	No: There will be no disturbance to wetland habitat and there is no habitat for this species within the Disturbance Footprint.	None known.	None known.	No: There will be no disturbance to wetland habitat and there is no habitat for this species within the Disturbance Footprint.	No: There will be no disturbance to wetland habitat and there is no habitat for this species within the Disturbance Footprint.
Phascolarctos cinereus Koala NC Act: Endangered	Unlikely: Potential loss of 0.30 ha of eucalypt woodland habitat will not lead to a decrease in size of the local population.	Unlikely: No sign of koala was detected within the Project Area. It is likely that the Project Area would be used by occasional transient individuals. The loss of 0.30 ha of potential habitat in the Disturbance Footprint is unlikely to affect the occurrence of Koala within the Project Area.	No: Koala are capable of crossing gaps between habitat patches and may use isolated paddock trees. The loss of several small areas of habitat, summing to 0.30 ha, will not disrupt habitat corridors through this area and will have negligible effect on Koala dispersal through the Project Area.	Unlikely: The loss of several small areas of eucalypt woodland habitat, summing to 0.30 ha, is unlikely to have measurable impacts on occasional Koala usage of the Project Area. All habitat within the Project Area is already fragmented and disturbed by thinning, grazing, weeds and edge effects. The Disturbance Footprint is a small proportion of this habitat.	None known	None known: chlamydia is present in the Koala population of southern inland Queensland, but this bacterial disease is unlikely to be exacerbated by the proposed development.	Unlikely: The loss of several small areas of potential habitat, totalling 0.30 ha will have minimal effect on the recovery of Koala in this area.	No: The proposed development will result in the loss of up to 0.30 ha of remnant and regrowth eucalypt woodland (RE 11.3.2) spread across several fragments. This small area is unlikely to reduce Koala numbers or to disrupt Koala movement through the area. No evidence of Koala was found within the Project Area and it is likely that Koala occurrence within the Project Area is occasional and transient. It is likely that the 0.30 ha of habitat proposed to be cleared involves the removal of <15 mature trees from the Disturbance Footprint.
Egernia rugosa Yakka Skink NC Act: Vulnerable	Unlikely: Removal of logs and accumulations of woody debris in 0.30 ha of habitat within the Disturbance Footprint could reduce some shelter and breeding habitat for this species. However, these features are scarce within the Project Area (BioCondition scores for woody debris averaged 20% of benchmark values) and low numbers of logs/log piles were recorded in microhabitat assessments.	Unlikely: Loss of 0.3 ha of woodland could potentially impact residents. However, few individuals would occupy this small area. The species was not detected within the Project Area and shelter habitat features were scarce. The disturbance will not affect the broader distribution of the species.	No: The disturbance does not pose a barrier to dispersal of this species.	Unlikely: Removal of logs and large woody debris may reduce shelter and breeding habitat. However, these habitat features are scarce in the Project Area.	None known.	None known.	Unlikely: Loss of 0.3 ha, across several habitat patches could potentially impact on any resident individuals but the disturbance is unlikely to affect overall abundance and occurrence within the region.	No: The presence pf this species was not confirmed within the Project Area. Loss of up to 0.30 ha of remnant and regrowth woodland habitat (RE 11.3.2) could impact on any resident individuals. However, this small area would hold few, if any, individuals and these impacts may be mitigated by preclearing of the route by a fauna spotter.
Hemiaspis damelii Grey Snake NC Act: Endangered	Unlikely: 0.30 ha of potential habitat occurs within the Project Area. Mapped habitat comprises fragmentary areas of riparian woodland.	Unlikely: The Project Area is peripheral to the species distribution. If the species occurs in this area, it is unlikely to be restricted to the mapped habitat.	No: The proposed development will not exacerbate existing fragmentation.	Unlikely: The 0.30 ha of mapped shelter, foraging, breeding and dispersal habitat comprises disturbed alluvial woodland fragments. Similar features occur in the vicinity and this habitat is unlikely to be limiting. Loss if 0.30 ha of habitat is unlikely to contribute to decline.	None known.	None known.	No: Only 0.30 ha of mapped habitat within the Project Area with similar habitat abundant in the vicinity.	No: Presence of this species within the Project Area was not confirmed during the field survey. The Project Area is peripheral to the species distribution and there are no records in the vicinity. Potentially suitable floodplain woodland and ephemeral wetland habitat (RE 11.3.2 and 11.3.25) occurs beyond the Disturbance Footprint.
Tachyglossus aculeatus Short-beaked Echidna NC Act: Special Least Concern	Unlikely: Loss of up to 0.30 ha of woodland habitat comprising regrowth and remnant. Removal of logs and accumulations of woody debris could reduce shelter and breeding habitat for this species. However, these features are scarce within the Project Area (BioCondition scores for woody debris averaged 20% of benchmark values. 1-5 logs with hollows in each 0.5 ha assessment site).	Unlikely: Loss of up to 0.30 ha of regrowth and remnant woodland habitat could potentially impact upon foraging or sheltering resident individuals. However, few individuals would occur in these small peripheral areas. The species was not detected within the Project Area and critical habitat features (e.g. log piles, large logs, rock crevices) were scarce or absent. The disturbance will not affect the broader distribution of the species.	No: The disturbance does not pose a barrier to dispersal of this species.	Unlikely: Removal of some logs and large woody debris may reduce shelter and breeding habitat. However, these habitat features are scarce in the Project Area. Available habitat in the Project Area is 144.72 ha	N/A	N/A	N/A	No: The species was not confirmed present within the Project Area. Loss of up to 0.30 ha of remnant and regrowth woodland habitat (RE 11.3.2) could impact on any resident individuals. However, this small area would hold few, if any, individuals and these impacts may be mitigated by preclearing of the route by a fauna spotter. The species is likely to have a patchy occurrence in the Project Area and suitable habitat features such as logs and woody debris were scarce within the Project Area.

Table 20: Assessment of potential significant impacts upon EPBC Act-listed fauna species within the Project Area (adapted from Boobook, 2025).

Species	Significant Impact Criteria (DoE 2013)									Significant Impact
	Lead to a long-term decrease in the size of a population	Reduce the Area of Occupancy (AoO) of the species	Fragment an existing population into two or more populations	Adversely affect habitat critical to the survival of a species	Disrupt the breeding cycle of a population	Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is	Lead to a long-term decrease in the size of a population	Reduce the Area of Occupancy (AoO) of the species	Fragment an existing population into two or more populations	
Rostratula australis Australian Painted Snipe EPBC Act: Endangered	No. The species is a rare visitor in very low numbers to the region. There are no known important populations of the species in or near the Project Area.	No. The available wetland habitat within the Project Area (0.60 ha) is likely to support only a few individuals during favourable conditions in spring-summer only.	No: The species is mobile and wide-ranging and occurs only sporadically in the region. The proposed development is unlikely to restrict dispersal in this species.	No. Wetlands within the Project Area are very small and highly ephemeral. Although these wetlands may occasionally be used by transitory individuals they do not represent habitat critical to the surveyal of the species.	Unlikely: Breeding has been recorded in all months of the year in response to wetland conditions. The small and highly ephemeral nature of wetlands within the Project Area are unlikely to be attractive for breeding by this species.	No. Wetlands within the Project Area are very small and highly ephemeral. Disturbance will only occur to 0.60 ha of 7.31 ha available wetland habitat within the Project Area. Disturbance to this small area will not cause this species to decline.	None known.	None known.	No. The Project is unlikely to cause harm to any individuals and is therefore unlikely to interfere with recovery of the species.	No: There will be no substantial decrease in available foraging habitat within the Project Area i.e. there will be disturbance to only 0.60 ha of mapped wetland habitat. Total available mapped wetland habitat available within the Project Area is 7.31 ha. There will be no loss if individuals as a result of Project activities.
Phascolarctos cinereus Koala Endangered	Unlikely: Potential loss of 0.30 ha of eucalypt woodland habitat will not lead to a decrease in size of the local population.	Unlikely: No sign of koala was detected within the Project Area. It is likely that this area would be used by occasional transient individuals. The loss of 0.30 ha of potential habitat in the Disturbance Footprint is unlikely to affect the occurrence of Koala within the Project Area.	No: Koala are capable of crossing gaps between habitat patches and may use isolated paddock trees. The loss of several small areas of habitat, summing to 0.30 ha, will not disrupt habitat corridors through this area and will have negligible effect on Koala dispersal through the Project Area.	Unlikely: The loss of several small areas of eucalypt woodland habitat, summing to 0.30 ha, is unlikely to have measurable impacts on occasional Koala usage of the Project Area.	No evidence of Koala was found within the Project Area and it is likely that Koala occurrence within the Project Area is occasional and transient. The breeding cycle is unlikely to be disrupted.	This small area is unlikely to reduce Koala numbers or to disrupt Koala movement through the Project Area. It is likely that the 0.30 ha of habitat proposed to be cleared involves the removal of <15 mature trees from the Disturbance Footprint.	None known	None known: chlamydia is present in the Koala population of southern inland Queensland, but this bacterial disease is unlikely to be exacerbated by the proposed development.	Unlikely: The loss of several small areas of potential habitat, totalling 0.30 ha will have minimal effect on the recovery of Koala in this area.	No: The proposed development will result in the loss of up to 0.30 ha of remnant and regrowth eucalypt woodland (RE 11.3.2) spread across several fragments.
Hemiaspis damelii Grey Snake EPBC Act: Endangered	Unlikely: 0.30 ha of potential habitat occurs within the Project Area. Mapped habitat comprises fragmentary areas of riparian woodland.	Unlikely: The 0.30 ha of mapped habitat includes already fragmented habitat patches.	No: The proposed development will not exacerbate existing fragmentation.	Unlikely: The 0.30 ha of mapped shelter, foraging, breeding and dispersal habitat comprises disturbed alluvial woodland fragments. Similar features occur in the vicinity and this habitat is unlikely to be limiting.	No: Only 0.30 ha of mapped habitat within the Project Area with similar habitat abundant in the vicinity.	Unlikely: The 0.30 ha of mapped shelter, foraging, breeding and dispersal habitat comprises disturbed alluvial woodland fragments. Similar features occur in the vicinity and this habitat is unlikely to be limiting. Loss if 0.30 ha of habitat is unlikely to contribute to decline.	None known.	None known.	No: Only 0.30 ha of mapped habitat within the Project Area with similar habitat abundant in the vicinity.	No: Presence of this species within the Project Area was not confirmed during the field survey. The Project Area is peripheral to the species distribution and there are no records in the vicinity. Potentially suitable floodplain woodland and ephemeral wetland habitat (RE 11.3.2 and 11.3.25) occurs beyond the Disturbance Footprint.
Calidris acuminata Sharp-tailed Sandpiper EPBC Act: Vulnerable	No. The species is an occasional visitor in low numbers to the region. There are no important populations of the species in or near the Project Area.	No. The available wetland habitat within the Project Area (0.60 ha) is likely to support only a few individuals during favourable conditions in spring-summer only.	No: The species is mobile and wide-ranging and occurs only sporadically in the region. The proposed development is unlikely to restrict dispersal of this species.	No. Wetlands within the Project Area are very small and highly ephemeral. Although these wetlands may occasionally be used by transitory individuals they do not represent habitat critical to the surveyal of the species.	No. The species does not breed within Australia. Breeding occurs between June and August in northern Siberia (DCCEEW 2024c).	No. Wetlands within the Project Area are very small and highly ephemeral. Disturbance will only occur to 0.60 ha of 7.31 ha available wetland habitat within the Project Area. Disturbance to this small area will not cause this species to decline.	None known.	None known.	No. The Project is unlikely to cause harm to any individuals and is therefore unlikely to interfere with recovery of the species.	No: There will be no substantial decrease in available foraging habitat within the Project Area i.e. there will be disturbance to only 0.60 ha of mapped wetland habitat. Total available mapped wetland habitat available within the Project Area is 7.31 ha. There will be no loss if individuals as a result of Project activities.
Calyptorhynchus lathami lathami Glossy Black-Cockatoo EPBC Act: Vulnerable	Unlikely: Loss of 0.30 ha of potential shelter and breeding habitat within remnant woodland. Feed trees occur nearby but are not present in the Disturbance Footprint. This small area would support few potential nesting/roost trees. The species has not been recorded in the Project Area and is likely to occur as an occasional visitor, rather than a resident.	Unlikely: Loss of 0.30 ha of potential shelter and breeding habitat. No nest or roost trees were identified during surveys. This mobile and wide-ranging species is capable of traversing non-remnant areas between nest/roost trees and feed trees.	No: The disturbance will not affect dispersal of this species, which travels long distances between suitable foraging trees.	Unlikely: Loss of 0.30 ha of remnant woodland with potential nesting and roost trees. However, the species has not been recorded in the Project Area and is likely to occur as an occasional visitor, rather than a resident.	Unlikely: Loss of 0.30 ha of remnant woodland with potential nesting trees. However, the species has not been recorded in the Project Area and is likely to occur as an occasional visitor, rather than a breeding resident.	Unlikely: Loss of 0.30 ha of potential shelter and breeding habitat within remnant woodland. Feed trees occur nearby but are not present in the Disturbance Footprint.	None known	None known	Unlikely: Loss of 0.30 ha of remnant eucalypt woodland habitat. However, potential nest trees (large trees with large hollows) are in very low abundance.	No: There will be no decrease in foraging habitat. There may be minimal loss of potential nest sites with disturbance of 0.30 ha of remnant / regrowth potential habitat comprising RE 11.3.2.
Gallinago hardwickii Latham's Snipe EPBC Act: Vulnerable	No. The species is an occasional visitor in low numbers to the region. There are no important populations of the species in or near the Project Area.	No. The available wetland habitat within the Project Area (0.60 ha) is likely to support only a few individuals during favourable conditions in spring-summer only.	No: The species is mobile and wide-ranging and occurs only sporadically in the region. The proposed development is unlikely to restrict dispersal of this species.	No. Wetlands within the Project Area are very small and highly ephemeral. Although these wetlands may occasionally be used by transitory individuals they do not represent habitat critical to the surveyal of the species.	No. The species does not breed within Australia. Breeding occurs between May and July in north-eastern Asia (Hansen *et al.* 2020).	No. Wetlands within the Project Area are very small and highly ephemeral. Disturbance will only occur to 0.60 ha of 7.31 ha available wetland habitat within the Project Area. Disturbance to this small area will not cause this species to decline.	None known.	None known.	No. The Project is unlikely to cause harm to any individuals and is therefore unlikely to interfere with recovery of the species.	No: There will be no substantial decrease in available foraging habitat within the Project Area i.e. there will be disturbance to only 0.60 ha of mapped wetland habitat. Total available mapped wetland habitat available within the Project Area is 7.31 ha. There will be no loss if individuals as a result of Project activities.
Hirundapus caudacutus White-throated Needletail EPBC Act: Vulnerable	No: The species is an aerial feeding insectivore that forages over a wide range of intact and modified landscapes, with a general preference for wooded areas.	No: The proposed disturbance is not materially relevant to the species.	No: The proposed disturbance is not materially relevant to the species.	No: No impact on foraging resources is anticipated, no other critical locations are relevant to the species in Australia. The species roosts overnight in tall trees along scarps and is unlikely to roost in the Project Area.	No. It does not breed in Australia during its summer presence.	No: The proposed disturbance is not materially relevant to the species.	None known	None known	No: The proposed disturbance will not reduce the extent of remnant woodland. The species does not breed in Australia.	No: The proposed disturbance is not materially relevant to the species.
Egernia rugosa Yakka Skink EPBC Act: Vulnerable	Unlikely: Removal of logs and accumulations of woody debris in 0.3 ha of habitat within the Disturbance Footprint could reduce some shelter and breeding habitat for this species. However, these features are scarce within the Project Area (BioCondition scores for woody debris averaged 20% of benchmark values) and low numbers of logs/log piles were recorded in microhabitat assessments.	Unlikely: Loss of 0.3 ha of woodland could potentially impact residents. However, few individuals would occupy this small area. The species was not detected within the Project Area and shelter habitat features were scarce. The disturbance will not affect the broader distribution of the species.	No: The disturbance does not pose a barrier to dispersal of this species.	Unlikely: Removal of logs and large woody debris may reduce shelter and breeding habitat. However, these habitat features are scarce in the Project Area.	Unlikely. The species has a patchy occurrence in the region and suitable habitat features such as logs and woody debris were scarce within the Project Area.	Unlikely. The species has a patchy occurrence in the region and suitable habitat features such as logs and woody debris were scarce within the Project Area.	None known.	None known.	Unlikely: Loss of 0.30 ha, across several habitat patches could potentially impact on any resident individuals but the disturbance is unlikely to affect overall abundance and occurrence within the region.	No: The presence pf this species was not confirmed within the Project Area. Loss of up to 0.30 ha of remnant and regrowth woodland habitat (RE 11.3.2) could impact on any resident individuals. However, this small area would hold few, if any, individuals and these impacts may be mitigated by preclearing of the route by a fauna spotter.

4.5 Surface Water and Wetlands

The proposed activities have potential to result in direct and indirect impacts to surface water EVs (as described in Section 3.7) primarily as a result of:

- drilling and hydraulic stimulation / fracturing activities;
- production operations;
- infrastructure construction (earthworks activities including grading and trenching);
- vehicle and plant movements;
- minor spills or leaks of fuels and chemicals from vehicles and equipment;
- loss of containment; and
- flood (natural event).

Santos aims to minimise the operational footprint and significant disturbance associated with its activities as far as reasonably practicable. However, potential direct and indirect impacts to surface water values resulting from the proposed activities may include (adapted from KCB, 2025):

- disturbance to natural drainage patterns;
- degradation of downstream water quality from sediment releases / minor spills or leaks of fuels, chemicals or other fluids (PW / hydrotest water);
- damage to and/or loss of native riparian vegetation and habitat;
- reduction in groundwater quantity and/or availability for other users; and
- contamination of soil and/or watercourses.

As discussed in Section 3.7, Santos commissioned KCB to undertake a WRA (KCB, 2025) of proposed activities located in the Project Area (attached as Appendix E). The following summary is based on the findings of the report as they relate to surface water and wetlands. Refer to Appendix E for further information.

As discussed in Section 3.7, the PDF (linear infrastructure only) will cross mapped SO 1 watercourses at five locations, and will cross mapped SO 3 watercourses at two locations. Drainage features located in the Project Area are mapped as SO 1 to 4, and they are expected to be ephemeral, with streamflow only expected to occur following rainfall events. There is limited to no groundwater contribution from the regional groundwater system to watercourses (as baseflow) in the Project Area.

Further, there are no HES or GES wetlands, spring vents, spring complexes or watercourse springs recorded within or in the vicinity of the Project Area. Boobook (2025) did identify several small ephemeral wetland areas located in non-remnant vegetation (cleared paddocks) in the Project area. These areas are potential ephemeral habitat for wetland bird species such as Australian Painted Snipe (*Rostratula australis*) and Latham's Snipe (*Gallinago hardwickii*).

Proposed linear infrastructure construction activities will be undertaken in compliance with proposed EA conditions relating to impacts to surface waters and wetlands (refer to Schedule B EA conditions in Appendix A).

Further, to ensure no significant impacts to waterways providing for fish passage, linear infrastructure construction activities located in waterways providing for fish passage would not:

- reduce the extent, frequency, or duration of fish passage;
- result in a substantial change to the hydrological regime of the watercourse; or
- lead to significant changes in water quality parameters within the watercourse.

Appropriate erosion and sediment control (ESC) measures will also be implemented where required to mitigate potential sediment impacts to drainage features. The RoW will also be constructed ensure sufficient area is available to construct appropriate erosion and ESC structures (where required). These ESC structures will assist to minimise potential for sedimentation to waters.

Rehabilitation will commence as soon as reasonably practicable following completion of construction activities, including the restoration of natural landform contours to ensure natural surface water flows are maintained.

Other measures to be carried out to reduce impacts on surface waters include:

- watercourse crossings would be designed to ensure fish passage during periods of flow is maintained;
- construction of linear infrastructure within a water course would preferentially be carried out in periods of low or no flow;
- where it is necessary to carry out works in a watercourse during periods of flow, these would be carried out in accordance with the relevant Department of Agriculture, Fisheries and Forestry Waterway Barrier Works Code(s);
- watercourse crossings would be selected at locations where the least impact to riparian flora and fauna will occur (i.e. clearing of vegetation and at narrowest and shallowest locations) where practicable;
- construction or maintenance of linear infrastructure activities in watercourses will comply with the turbidity limit of relevant EA conditions, and water quality monitoring would be carried out downstream of watercourse crossing works where necessary to ensure compliance with water quality limits;
- santos will only construct in ephemeral wetland areas when they are dry, and linear infrastructure RoWs will be reinstated to their natural landform following construction;
- appropriate spill kits would be kept on site and in staff vehicles for use in the event of a spill or leak of hydrocarbons or chemicals; and
- chemicals, fuels or other hazardous substances would be stored and managed in accordance with relevant Australian Standards.

Groundwater impact modelling predicts some drawdown may occur in the Springbok Sandstone due to proposed CSG water extraction. There are no predicted impacts to water resources due to project related groundwater drawdown in the Springbok Sandstone because the Springbok Sandstone is overlain by several tight aquitards such as the Westbourne Formation, the Orallo Formation, and the Doncaster Member. Groundwater modelling demonstrates that drawdown from the Springbok Sandstone does not propagate through to surface formations. The Springbok Sandstone outcrops ~38km north of the Project Area, which is located outside the project's area of influence. Based on the lack of predicted drawdown for the geological units overlying the Springbok Sandstone and surficial Quaternary deposits, and the fact that the Springbok Sandstone outcrops well outside the project's area of lateral drawdown influence, there is no potential for impacts to the surficial hydrological systems as a result of the proposed activities. Refer to Appendix E (KCB, 2025) for further information.

Management (control) strategies, risk sources, potential impacts and the level of risk associated with the proposed activities are summarised in Appendix F, Table 33. The results of the risk assessment indicate that residual risks to surface water EVs as a result of the proposed activities are classified as 'Low'.

4.6 Groundwater

As discussed in Section 3.7, Santos commissioned KCB to undertake a WRA (KCB, 2025) of proposed activities located in the Project Area (attached as Appendix E).

Predicted impacts to groundwater as a result of the Project were estimated using the OGIA groundwater model developed for predicting effects on groundwater due to CSG and coal mine development within the Surat Cumulative Management Area (CMA). Based on the information provided by Santos and for the purpose of assessing potential impact of CSG water extraction on groundwater resources, OGIA have modelled a Project only scenario, which includes only CSG water production from the Project, and a Cumulative scenario, which includes the simulation of all current and proposed CSG and coal mine developments within the Surat CMA.

Potential impacts to water-dependent assets have been considered with respect to the *Water Act 2000* trigger threshold for springs (0.2 m drawdown) and bores (5 m drawdown in consolidated aquifer; 2 m drawdown in unconsolidated aquifer) using the predicted drawdown for both the Project only and Cumulative scenarios:

- For the Project only scenario, the predicted long-term drawdown impacts associated with the Project are limited to the Springbok Sandstone, the WCM and the Durabilla Formation, located at depths greater than 500 mbgl in the Project Area.
- The Cumulative scenario drawdown results indicate drawdown within the Westbourne Formation, Springbok Sandstone, WCM and Durabilla Formation, located at depths greater than 470 mbgl in the Project Area.
- The Cumulative scenario predicts drawdown greater that 0.2 m in outcropping geological units (Bungil Formation, Mooga Sandstone and Orallo Formation) in an area more than 12 km geologically up-dip and to the north of the Project Area. This drawdown is not associated with the proposed Project but is rather associated with the water production from neighbouring CSG developments operating on tenures located closer to these outcropping units.

Given the abovementioned modelling results and assessment findings, the WRA concluded that exceedance of the *Water Act 2000* water level trigger (and Commonwealth Joint Industry Framework (JIF)) GDE risk thresholds is not anticipated for the proposed activities; and:

- Surficial deposits are not recognised to be connected to the Surat Basin units in the Project Area. There is no predicted Project only drawdown in these surficial deposits. The Project was assessed to not have a significant impact on GDEs.
- Bore triggers are not predicted to be exceeded as a result of the Project.
- Notable wetlands, spring vents or spring complexes are not predicted to be impacted. The Project only contribution to the predicted Cumulative scenario drawdown for watercourse springs is assessed to be negligible.
- Proposed activities do not include planned direct abstraction from, or discharges to, watercourses. Impacts on surface water users, EVs and spiritual values are not anticipated.

Management (control) strategies, risk sources, potential impacts and the level of risk associated with the proposed activities are summarised in Appendix F, Table 33. The results of the risk assessment indicate that residual risks to groundwater EVs as a result of the proposed activities are classified as ‘Low’.

4.6.1 Hydraulic Fracture Stimulation

As discussed in Section 2.2, subject to trials and project planning, all wells to be located in the Project Area may be subject to stimulation (i.e. hydraulic fracturing). Hydraulic fracturing is necessary to properly assess the potential of the petroleum resource and inform decision making on future projects, as well as to increase the recovery of the resource.

Potential impacts to groundwater as a result of hydraulic fracture stimulation, and mitigation strategies, are discussed in Section 4.6 and summarised in Table 33, respectively. Moreover, Santos ensures the risk of environmental harm to groundwater formations is negligible by ensuring CSG wells are drilled and hydraulic fracturing processes are undertaken in accordance with the *Code of Practice for the*

construction and abandonment of petroleum wells and associated bores in Queensland Version 2 (Code of Practice) (DNRME, 2019). The purpose of this code is to ensure that all petroleum wells, CSG wells and associated bores are constructed, maintained and abandoned to a minimum acceptable standard resulting in long-term well integrity, containment of petroleum and the protection of groundwater resources.

Further, Santos uses best practice well logging, well design, well completion and well cementing methods to ensure well integrity prior to hydraulic fracturing. This would ensure fracture and production fluids are contained within the well and isolated from the aquifer units during the wells production life and following plugging and abandonment.

The Queensland Government's Gasfields Commission publishes data on well integrity. They have concluded that when such national and international codes are used then the likelihood, and therefore risk, of well integrity failure resulting in underground leakage is assessed to be low to near zero (Queensland Gasfield Commission, 2015). Santos' production wells will be designed to:

- prevent any interconnection between target hydrocarbon-bearing formations and aquifers;
- ensure that gas is contained within the well and associated pipework and equipment without leakage;
- ensure zonal isolation between different aquifers is achieved; and
- not introduce substances that may cause environmental harm.

Santos has prepared a Hydraulic Fracturing Risk Assessment (HFRA) (EHS Support 2021)) and Stimulation Impact Monitoring Program (SIMP) (Santos, 2021) for Santos' production operations throughout Eastern Queensland, including PL 1123. Further, Santos has developed a Chemical Risk Assessment Framework (CRAF) (Santos, 2025) for the Project.

The HFRA is attached to this document as Appendix H. The SIMP is attached as Appendix 4 to the WRA (KCB, 2025) (attached as Appendix E). The CRAF is available upon request by DETSI.

Monitoring of the hydraulic stimulation process (and stimulation fluids) is undertaken throughout the stimulation activities (prior- and post- activities) in accordance with the requirements of the SIMP.

The CRAF has been developed to guide the assessment of risk associated with chemicals used during CSG operations (drilling and completions, and hydraulic fracturing) for the Project. The CRAF incorporates best practice risk assessment methodology for the assessment of potential impacts associated with the use of chemicals to MNES and MSES. The CRAF is based on existing Santos approved chemical risk assessment frameworks and aligns with best practice methodologies.

Further, a Project specific Chemical Risk Assessment Register (CRAR) (EHS Support 2024) has been developed in accordance with the requirements of the CRAF to identify the potential risks and effects of chemicals used during CSG operations (drilling and completions, and hydraulic fracturing) specific to the Project. The CRAF / CRAR assessment process is designed to align with national guidance and other regulatory frameworks and assesses the full lifecycle of chemicals that are stored, transported, handled, used and / or disposed during or following drilling and completions, and hydraulic fracturing activities. The CRAR summarised the potential risks and effects of chemicals used during the life cycle of CSG extraction to MNES / MSES.

The abovementioned assessments indicate the risks associated with hydraulic fracturing operations are manageable.

4.6.2 Underground water rights requirements (s126A EP Act)

Section 126A of the EP Act has specific requirements for application that:

- are carried out on one or more resource tenures for which the relevant tenure is a petroleum lease; and

- involve the exercise of underground water rights or a change to the exercise of underground water rights.

The requirements for section 126A are addressed in Table 21.

Table 21: Exercising underground water rights

Requirement	Reference to Information
A statement that the applicant proposes to exercise underground water rights.	Santos proposed to exercise underground water rights within the Project Area (PL 1123) as authorised under the *Petroleum and Gas (Production and Safety) Act 2004.*
A description of the area/s in which underground water rights are proposed to be exercised.	The areas that may be developed comprise the full extent of the Project Area (PL 1123), notwithstanding specific land access, cultural heritage or environmental constraints that may influence development of certain petroleum activities within the Project Area.
A description of the aquifer/s affected or likely to be affected.	Refer to Sections 3.8.1 and the WRA (KCB, 2025) (attached as Appendix E).
An analysis of the movement of underground water to and from the affected or potentially affected aquifer/s.	Refer to Sections 3.8.2 to 3.8.4 and the WRA (KCB, 2025) (attached as Appendix E).
A description of the area of the aquifer where the water level is predicted to decline because of the exercise of underground water rights.	Refer to Section 3.8 and the WRA (KCB, 2025) (attached as Appendix E).
The predicted quantities of water to be taken or interfered with because of the exercise of underground water rights.	The total estimated groundwater abstraction volume for the duration of the Project (with an expected operational life of 30-50 years) is estimated to be 645 ML (KCB, 2025).
Information on predicted impacts to the quality of groundwater that will, or may, happen because of the exercise of underground water rights.	Refer to Section 4.6 and the WRA in detail (KCB, 2025) (attached as Appendix E). Provided that petroleum wells are designed and construction in accordance with the *Code of Practice for the construction and abandonment of petroleum wells and associated bores in Queensland Version 2* (DNRME, 2019) and measures identified in Section 4.6 and Table 33 are implemented, there is unlikely to be any impact on groundwater quality from the exercise of underground water rights. This is because well integrity measures will ensure that separated hydrostratigraphic units remain isolated. Further, potential impacts to water-dependent assets have been considered with respect to the *Water Act 2000* trigger threshold for springs (0.2 m drawdown) and bores (5 m drawdown in consolidated aquifer; 2 m drawdown in unconsolidated aquifer) using the predicted drawdown for both the Project only and Cumulative scenarios: • For the Project only scenario, the predicted long-term drawdown impacts associated with the Project are limited to the Springbok Sandstone, the WCM and the Durabilla

Requirement	Reference to Information
	Formation, located at depths greater than 500 mbgl in the Project Area. • The Cumulative scenario drawdown results indicate drawdown within the Westbourne Formation, Springbok Sandstone, WCM and Durabilla Formation, located at depths greater than 470 mbgl in the Project Area. • The Cumulative scenario predicts drawdown greater that 0.2 m in outcropping geological units (Bungil Formation, Mooga Sandstone and Orallo Formation) in an area more than 12 km geologically up-dip and to the north of the Project Area. This drawdown is not attributed to the proposed Project, but rather to groundwater extraction associated with neighbouring CSG developments operating on tenures located closer to these outcropping units. Given the abovementioned modelling results and assessment findings, the WRA (KCB, 2025) concluded that exceedance of the *Water Act 2000* water level trigger (and Commonwealth Joint Industry Framework (JIF)) and GDE risk thresholds is not anticipated for the proposed activities; and: • Surficial deposits are not recognised to be connected to the Surat Basin units in the Project Area. There is no predicted Project only drawdown in these surficial deposits. The Project was assessed to not have a significant impact on GDEs. • Bore triggers are not predicted to be exceeded as a result of the Project. • Notable wetlands, spring vents or spring complexes are not predicted to be impacted. The Project only contribution to the predicted Cumulative scenario drawdown for watercourse springs is assessed to be negligible. • Proposed activities do not include planned direct abstraction from, or discharges to, watercourses. Impacts on surface water users, EVs and spiritual values are not anticipated.
Information on the environmental values that will, or may, be affected by the exercise of underground water rights.	**Impact to Water Bores** Refer to Sections 3.8.6 and 4.6. For the Project only scenario, the maximum predicted drawdown in the target formations at the locations of the 368 (existing, abandoned but usable, proposed and potential) water supply bores, is 0.03 m. For the Cumulative scenario, assessment was undertaken using the same approach adopted for the Project only scenario (e.g. *Water Act 2000* trigger thresholds). No bores are indicated to exceed the trigger threshold within a 25 km buffer of the Project Area. The bore triggers are therefore not predicted to be exceeded as a result of Project only or Cumulative scenario activities and predicted impact on groundwater supply bores is assessed as negligible. The contribution of the Project does not result in any additional bores being triggered in the Cumulative scenario. Further, under the Queensland *Water Act 2000*, CSG proponents are required to undertake baseline assessments of water bores located within their petroleum tenures prior to

Requirement	Reference to Information
	commencement of production. Baseline assessments are undertaken in accordance with the *Baseline Assessment Guideline* (DES, 2017), to obtain information such as: bore status, type and purpose; information related to the construction of the bore, including depth installed, screen interval and source aquifer; groundwater level and quality and field gas measurement; and bore equipment including pump depth, pumping frequency and flow rate. There is one operational water bore located within the Project Area. This bore is attributed to the Mooga Sandstone. The baseline assessment was undertaken in 2009 for RN 123195 (refer to Table 13). Another groundwater bore (RN208460) was drilled on the tenement in June 2024. This new bore is indicated as "no longer used". Santos are in the process of revising their Baseline Assessment Plan, as required by the Queensland *Water Act*, with baseline assessment planned to occur in Q4 2025 (prior to commencement of the Project) if it is required. **Impact to GDEs** Refer to Section 3.8.5 and 4.6. No new springs and GDE areas are triggered due to drawdown contribution from the Project, and no material impacts on spring vents, complexes or watercourse springs as a result of Project development are identified. Further, it is considered unlikely that groundwater present in surficial units, that potentially support TGDEs, will be impacted by CSG related drawdown due to the Project. Refer to Appendix E (KCB, 2025) for further information. **Impact to Other Surface Waters** Refer to Sections 3.7 and 4.4. Based on the lack of predicted drawdown for the geological units overlying the Springbok Sandstone and surficial Quaternary deposits, and the fact that the Springbok Sandstone outcrops well outside the project's area of lateral drawdown influence, there is no potential for impacts to the surficial hydrological systems as a result of the proposed activities. Refer to Appendix E (KCB, 2025) for further information.
Information on strategies for avoiding, mitigating or managing the predicted impacts on the environmental values or predicted impacts on the quality of groundwater.	Refer to Section 4.6 and Table 33.

4.7 Air Quality and Noise

The proposed activities may result in impacts to air quality and noise values (as described in Section 3.9), respectively), primarily as a result of:

- infrastructure construction;
- vehicle and plant movements;
- fire (ignition sources resulting from activities); and
- minor exhaust emissions generated from vehicles, equipment and machinery.

Santos aims to minimise the operational footprint and significant disturbance associated with its activities as far as reasonably practicable. However, potential direct and indirect impacts to air quality and noise values resulting from the proposed activities may include:

- air pollution and localised reduction in air quality;
- nuisance caused by vibration, noise and dust generation; and
- disturbance to fauna and livestock.

The majority of these potential air and noise impacts would be temporary and limited to the initial construction period. The proposed activities (and potential noise and air quality impacts) are also consistent with those associated with existing petroleum activities authorised by the nearby Backbone EA (EPPG04323316), RSGPA (EPPG00898213) and RSGPAE (EPPG00662213) EAs, and existing land use (pastoral / grazing / cropping activities).

Construction activities associated with the proposed development would typically occur from 6am to 6pm, seven days per week for a relatively limited period of time i.e. limited to a number of weeks.

Background noise monitoring has not been undertaken for the proposed activities given that the development occurs within the existing operational GLNG-GFD tenure areas (RSGPA and RSGPAE EA tenure areas).

The deemed background noise levels as prescribed in Table 2 of the DETSI guideline *'Prescribing noise conditions for environmental authorities for petroleum activities*' (ESR/2016/1935, Version 2.05) (DETSI, 2025) are considered to be representative of the ambient acoustic environment. The deemed background levels are detailed in Table 22.

Table 22: Deemed Background Noise Levels

Time period	Deemed background noise level (dB(A))
7:00 am – 6:00 pm	35
6:00 pm – 10:00 pm	30
10:00 pm – 6:00 am	25
6:00 am – 7:00 am	30

The primary air pollutants generated during construction and operations would be minor dust and exhaust emissions from operating vehicles, plant and machinery. These sources will be predominately temporary, occurring only during the construction period. These relatively minor dust and exhaust emissions would remain local to the source, and are unlikely to affect air quality EVs of the broader Project Area provided that mitigation and management measures identified in Table 33 are implemented. There are eleven potential sensitive receptors, including five residences located within the Project Area, and six residences located within approximately 1km of the Project Area boundary.

Management (control) strategies, risk sources, potential impacts and the level of risk associated with the proposed activities are summarised in Appendix F, Table 33. The results of the risk assessment indicate that residual risks to air quality and noise EVs as a result of the proposed activities are classified as 'Low'.

4.8 Waste

The proposed activities may result in impacts to EVs (as described in Section 3.9), respectively) due to the generation of waste, primarily as a result of the storage and disposal of:

- general waste;

- waste fuels;
- oils and other chemicals; and
- produced fluids and other process wastes.

Excessive waste generation from the inefficient use of resources, and improper management or storage of wastes generated by petroleum activities, has the potential to impact on EVs. Under Schedule 8, Part 3 of the *Environmental Protection Regulation 2019*, the environmental objective for activities with waste impacts is:

> *Any waste generated, transported, or received as part of carrying out the activity is managed in a way that protects all environmental values.*

Performance outcomes are:

a) waste generated, transported, or received, is managed in accordance with the waste and resource management hierarchy in the *Waste Reduction and Recycling Act 2011*; and

b) if waste is disposed of, it disposed of in a way that prevents or minimises adverse effects on environmental values.

Waste that would potentially be generated by the proposed activities may include the following:

- batteries and electrical – lead acid batteries, gel type batteries, nickel cadmium batteries and alkaline batteries generated from equipment, vehicles, generators and electronics;
- chemical waste and chemical containers – chemical wastes may include herbicides, pesticides, paints and solvents. Chemical containers are those containing any volume of free chemical that is a regulated waste and may include waste oil containers and aerosol cans containing solvent or paint;
- concrete / aggregate / asphalt – concrete, aggregate and asphalt materials removed from demolished infrastructure that are not suitable for recycling;
- contaminated soil – contaminated soils may be generated where localised spills of hydrocarbons and other contaminants occurs;
- cooking oil – waste cooking oil is generated from kitchen facilities at temporary mobile camps;
- drilling fluids and muds – waste drilling fluids, muds and cuttings are generated from the drilling process;
- effluent – treated effluent from the STP;
- general recycling – plastic bottles and food containers, glass bottles and jars, milk cartons, aluminium bottles and cans, metal lids from jars, tin cans, aluminium cans, plastic cups, cardboards and paper packaging, folders, envelopes, office paper, magazines, cereal boxes, clean paper towels, steel scraps;
- grease trap waste – grease trap waste is generated from kitchen facilities at temporary mobile camps;
- green waste – green waste produced from vegetation clearing activities;
- hydrostatic test water – spend water used in the hydrostatic testing of pipelines to test pipeline integrity;
- intermediate bulk containers (IBCs) – containers used for transport of fluids and bulk materials;
- oily filters, rags, and absorbents - Oily filters, rags, and absorbents are generated from routine equipment and vehicle servicing, repair and filter changes;
- oily water – oily water may be produced from servicing equipment, machinery and vehicles;
- pipeline tape wrap – pipeline tape wrap protects the pipeline against corrosion;

- plastic lines - waste plastic liners associated with sumps and turkeys nest dams;
- PW – also known as coal seam gas water, is released from the coal seam and brought to the surface during operation of wells;
- putrescible and other domestic waste – food scraps, food wrappers, packaging materials, textile materials, plastic wrapping film, plastic bags, facial tissues, ear plugs, pens and pencils, polystyrene, aluminium foil, waxy paper, cardboard, non-recyclable plastics, etc.;
- scrap steel and metal – scrap steel and metal may include steel piping, values and cabling;
- stimulation fluids and flowback water – this waste is generated when the fluids used in the stimulation process are brought back to the surface;
- timber – untreated timber derived from packaging and uses that cannot be reused or recycled;
- triethylene glycol (TEG) / glycol / coolant – is generated from equipment and vehicle fluid changes;
- tyres – tyres and tubes are generated from tyre changes on work and vehicle equipment;
- used spill kits – used spill kits are generated from spill clean-up of chemicals and hydrocarbons;
- waste oil – small quantities of waste oil are generated routinely from vehicle and equipment oil changes;
- wellhead separator waste (coal fines) – separators at wellheads separate gas and water and remove other materials; and
- wiring – electrical wiring and equipment not suitable for reuse.

Further, management of PW, residual drilling materials, hydraulic fracturing stimulation fluids and hydrostatic test water and water from LPDs are specifically discussed in Sections 4.8.1 to 4.8.5.

Impacts associated with the generation of waste, primarily as a result of the storage and disposal of waste, have the potential to impact on EVs including on land and biodiversity, visual amenity, soil and water quality and human health. Santos aims to minimise the operational footprint and significant disturbance associated with its activities as far as reasonably practicable. However, potential direct and indirect impacts to EVs resulting from the generation, storage and disposal of waste may include:

- reduction in visual amenity;
- disturbance, injury or loss of fauna and livestock (i.e. fauna/livestock access to waste/contaminants);
- contamination of soil and water resources (groundwater / surface water);
- disturbance to land use and land suitability changes; and
- reduction in agricultural productivity.

Management (control) strategies, risk sources, potential impacts and the level of risk associated with the proposed activities are summarised in Appendix F, Table 33. The results of the risk assessment indicate that residual risks to EVs due to the generation, storage and disposal of waste as a result of the proposed activities are classified as ‘Low’

4.8.1 Produced Water Management

PW (generated as part of CSG production activities) would be managed in accordance with the Queensland Government’s *Coal Seam Water Management Policy 2012* (DETSI, 2025d).

As discussed in Section 2.2, the majority of PW generated from the Project Area will be transferred to existing approved water storages and treatment facilities located adjacent to the Project Area on PLs

314 and 315 via new and existing water gathering and storage infrastructure. Petroleum activities undertaken on PLs 314 and 315 are authorised under existing Santos EA EPPG00898213 (RSGPA).

Table 23 outlines the expected water quality for the Project, based on Myalla (PL 282: neighbours the Project Area diagonally to the northeast) and Washpool Creek (PL 318: neighbours the Project Area to the south) well data. PW quality is slightly alkaline with elevated chloride and sodium concentrations, which contribute to elevated TDS / EC levels (KCB, 2025).

Peak water production is predicted to occur in January 2028 at 0.24 ML/day (7.12 ML/month). The total volume of PW for the duration of the Project is estimated to be 645 ML (KCB, 2025). Adequate water and brine storage and treatment capacity has been assessed to be available on adjacent tenures to manage peak water and brine production from the Project.

Further, Santos have established procedures to prevent uncontrolled discharge of PW (i.e. restriction of production by “turning down” or “shutting-in” wells). Site water balances are undertaken for all project phases at these water management facilities to ensure adequate storage and treatment capacity is available, and this will include consideration of PW transferred from the Project Area.

PW stored within the Project Area will be limited to small volumes held in portable tanks. A proportion of PW stored in tanks on site will be used for on-site activities such as water supply for drilling and hydraulic fracturing purposes, and/or to provide a water source for dust suppression / construction activities (where the water use meets proposed EA conditions and criteria). Approximately 158 ML of water will be re-used in this way, and represents ~24% of estimated PW volume. Design and operation of portable tanks will follow Queensland regulatory conditions and guidelines.

Beneficial use of PW in the Project Area would be carried out to achieve the following outcomes:

- vegetation is not damaged;
- soil quality is not adversely impacted;
- there is no surface ponding or runoff beyond the designated release area;
- there are no aerosols or odours;
- deep drainage below the root zone of any vegetation is minimised; and
- the quality of shallow aquifers is not adversely affected.

Detailed management measures for each component of the PW management system, and measurable criteria for PW management and beneficial use, are outlined in Table 24 and Table 25, respectively.

Requirements for a site-specific application for CSG activities (s126 of the EP Act) are addressed in Section 1.2.2 (requirements for site specific applications). In the event that any management criteria are not complied with, works/operations that potentially cause the non-compliance would be assessed (and paused if appropriate) and an investigation would commence to identify why the non-compliance has occurred, the effectiveness of existing controls, new controls to be applied where appropriate and any remedial actions to be taken.

Produced water quality (Section126(1)(c) of the EP Act)

Material changes to the quality of PW are not reasonably expected to occur while the activity is being carried out. PW quality will be monitored in accordance with relevant EA conditions and the requirements of the SIMP. Further, as per the requirements outlined in the *Petroleum and Gas (Production and Safety) Act 2004*, the volume of PW will be monitored and recorded and provided to the DNRME in accordance with statutory obligations.

Further, to minimise impacts to shallow groundwater quality, as a result of beneficial use activities such as dust suppression and off tenement irrigation, water quality will be monitored to confirm compliance with water quality objectives in the *End of Waste Code Irrigation of Associated Water (including coal*

seam gas water) (ENEW07546918, Version 1.07) (DETSI, 2025a) and *End of Waste Code Associated Water (including coal seam gas water) (ENEW07547018, Version 1.06)* (DETSI, 2025b).

4.8.2 Prioritisation hierarchy for managing and using CSG water and managing saline waste

The objective of the *Coal Seam Water Management Policy 2012* (DETSI, 2025d) is to encourage the beneficial use of CSG water in a way that protects the environment and maximises its productive use as a valuable resource.

The objective of the policy is achieved when CSG water and saline waste is managed consistently with the prioritisation hierarchies and the management criteria as below:

Managing and using CSG water:

- **Priority 1** – CSG water is used for a purpose that is beneficial to one or more of the following: the environment, existing or new water users, and existing or new water-dependent industries.
- **Priority 2** – After feasible beneficial use options have been considered, treating and disposing CSG water in a way that firstly avoids, and then minimises and mitigates, impacts on EVs.

Managing saline/brine waste:

- **Priority 1** – Brine or salt residues are treated to create useable products wherever feasible.
- **Priority 2** – After assessing the feasibility of treating the brine or solid salt residues to create useable and saleable products, disposing of the brine and salt residues in accordance with strict standards that protect the environment.

To meet the objective of the policy, Santos has conducted a detailed assessment of the proposed water management methods to ensure the proposed management options are achievable and realistic.

Accordingly, Santos has adopted the management option, principle and criteria as outlined in Table 24 and Table 25. The proposed management principles align with the DETSI *Information Sheet: CSG water management: measurable criteria* (ESR/2016/1902) (Version 1.03), and the proposed conditions of the EA. Produced water may be used for dust suppression in alignment with proposed EA conditions.

Prioritisation hierarchy for managing saline/brine waste under the policy

CSG brine is the waste that is produced as a result of treating CSG water using RO technologies. Brine is generally unsuitable for release to the environment and must be appropriately managed in a dedicated CSG brine dam. The concentration and composition of salts and minerals in the brine depends on the characteristics of the CSG water and the treatment process.

The volume and concentrations of total dissolved solids (TDS) in CSG water vary significantly across individual fields. DETSI defines brine as water with a TDS concentration greater than 40,000 milligrams per litre which is a category 2 regulated waste.

In 2023, DETSI in collaboration with industry community groups and academia developed a long-term approach for the management of CSG brine 2023-2033 (the action plan). Under the action plan it is recognised that while the most feasible option is encapsulation of brine waste, research and investigation of alternative options for brine management must be continued in keeping with circular economy principles.

Brine will not be stored in the Project Area. As discussed in Section 2.2, the majority of PW (and resulting saline/brine waste) generated from the Project Area will be transferred to existing approved water storages and treatment facilities located adjacent to the Project Area on PLs 314 and 315 via new and existing water gathering and storage infrastructure. Petroleum activities undertaken on PLs 314 and 315 are authorised under existing Santos EA EPPG00898213 (RSGPA).

On PL 314, the water will be processed through a fines and sludge removal facility before being further processed, or bypassed around, the Roma Reverse Osmosis Plant (ROP) to meet re-use criteria in accordance with *End of Waste Code Irrigation of Associated Water (including coal seam gas water) (ENEW07546918, Version 1.07)* (DETSI, 2025a).

Table 23: PL 1123 Expected Water Quality (adapted from KCB, 2025)

Analyte	Dissolved or total	Limit of detection	Min.	P10	Median	P90	Max.	Sample count
Boron (mg/L)	Dissolved	0.05	<0.05	0.563	0.71	0.857	0.92	44
	Total	0.05	<0.05	0.623	0.71	0.827	0.91	44
Calcium (mg/L)	Dissolved	1	3	7	14	41.8	355	59
Chloride (mg/L)	Null	1	848	1,376	2,550	5266	17,600	69
Electrical Conductivity @ 25°C (µS/cm)	Null	1	3,970	5,366	8,140	14300	49,800	69
Fluoride (mg/L)	Null	0.1	0.4	0.73	1.65	3.14	4.10	44
Magnesium (mg/L)	Dissolved	1	<1	1.8	3	10	82	59
pH – Lab (pH Unit)	Null	0.01	7.65	7.756	8.17	8.526	8.84	59
Potassium (mg/L)	Dissolved	1	9	24	55	392.2	2,120	59
Sodium (mg/L)	Dissolved	1	848	1,186	1,760	3340	10,000	59
Sodium Adsorption Ratio	Dissolved	0.01	79	85.08	105	125.4	162	15
	Null	0.01	90.4	95	121	140.7	190	40
Strontium (mg/L)	Dissolved	0.001	1.33	1.779	3.795	17.48	52	44
	Total	0.001	1.33	1.926	4.335	17.06	51	44
Sulfate as SO_4^2 (mg/L)	Dissolved	1	<1	<1	<1	13.6	66	59
Total Dissolved Solids (Calc.) (mg/L)	Null	1	2,580	2,726	3,960	6400	6,820	15
Total Dissolved Solids @ 180°C (mg/L)	Total	5	2,600		2,970		4,510	4
	Total	10	2,840	3,522	5,290	10433	32,600	50
Suspended Solids (mg/L)	Null	5	<5	16.2	142	2888	259,000	65

Table 24: Management of each component of produced water management system

PW management action	Management measures

Storage	• PW may be temporarily stored in portable tanks prior to beneficial use on site, treatment for beneficial use, or transfer off-tenure;
	• tanks would be located away from watercourses and sensitive areas to minimise risk of water reaching watercourses in the event of a release;
	• tanks would be designed in accordance with relevant standards;
	• tanks would be regularly monitored and inspected to ensure sufficient capacity and integrity;
	• in the event of a release, the following measures would be implemented:
	  ○ cause and release location would be identified and actions taken to rectify failure;
	  ○ sampling/monitoring of affected soil and/or water would be carried out where necessary to determine impacts to the receiving environment;
	  ○ soil and/or water would be remediated where necessary; and
	  ○ the administering authority would be notified in accordance with the requirements of the proposed EA conditions.

Transfer	• water gathering lines would be used to transfer PW from wells to tanks and/or trunk lines; and • water gathering lines would be designed and constructed in accordance with APGA *Code of Practice For Upstream Polyethylene Gathering Networks-CSG Industry – Version 6* (APGA, 2024).
Treatment to facilitate beneficial use	• in some cases, PW may be treated to achieve a water quality that is fit for purpose for an identified beneficial use; and • any chemicals used in water treatment processes would be stored, handled and managed in accordance with relevant Australian Standards.
Beneficial use such as: • dust suppression • construction and operational uses • irrigation; and • third party transfer.	• PW may be used for dust suppression, in construction and for operational purposes (i.e. drilling, compaction, etc.). • Criteria for beneficial use would be determined through the application of the *End of Waste Code Irrigation of Associated Water (including coal seam gas water) (ENEW07546918, Version 1.07)* (DETSI, 2025a) and *End of Waste Code Associated Water (including coal seam gas water) (ENEW07547018, Version 1.06)* (DETSI, 2025b) where applicable and/or proposed EA conditions; • dust suppression activities would not occur within or immediately adjacent to watercourses or wetlands, and in accordance with proposed EA conditions; and • the volume of PW applied to land for beneficial uses would be proportionate to the activity requirements and take account of the local conditions (i.e. surface materials, soil saturation and weather) and water quality. Application of water would be managed in accordance with proposed EA conditions.

Table 25: Produced water measurable criteria

Objective	Environmental values	Component	Measurable criteria
PW use	EVs, as defined in the *Environmental Protection (Water) Policy 2019*, potentially relevant to the use of PW within the Project Area include both aquatic	• dust suppression and construction; • irrigation; and	• compliance with EA conditions relating to PW use and storage, including: ○ Schedule B – Water; and

Objective	Environmental values	Component	Measurable criteria
	ecosystem and human use EVs as follows: • protection of slightly to moderately disturbed aquatic waters; • recreation and aesthetics (primary recreation with direct contact); • secondary recreation and visual appreciation with no contact; • suitability for drinking water supplies (only relevant to the Dawson River); • primary industries (irrigation, water for farm use, stock watering, and human consumption of wild or stocked fish or crustaceans); • industrial use; and • cultural and spiritual values.	• third party transfer.	○ Schedule D – Land. • criteria for beneficial use would be determined through the application of the *End of Waste Code Irrigation of Associated Water (including coal seam gas water) (ENEW07546918, Version 1.07)* (DETSI, 2025a) and *End of Waste Code Associated Water (including coal seam gas water) (ENEW07547018, Version 1.06)* (DETSI, 2025b) where applicable and/or proposed EA conditions; and • dust suppression activities would not occur within or immediately adjacent to watercourses or wetlands
PW storage		• tanks	• compliance with EA conditions relating to PW use and storage, including: ○ Schedule B – Water; ○ Schedule D – Land; and • tanks would be designed in accordance with relevant standards. Tanks would be regularly monitored and inspected to ensure sufficient capacity and integrity.

4.8.3 Residual Drilling Material

Residual drilling material (RDM) would be managed using the following measures to reduce the risk of environmental harm:

- RDM would only be disposed of on-site in accordance with proposed EA condition E6, i.e.:
  - by mix-bury-cover method if the residual drilling material meets the approved quality criteria; or
  - by an alternative method and/or quality that is certified by a suitably qualified third party as acceptable for disposal to land and that environmental harm will not result from the proposed disposal;
- cement returns may be stored in cement bins, allowed to harden and then crushed up for mix bury cover, disposal to landfill, or sent to landfill;
- drilling fluids may be permitted to evaporate, or treated and reused for drilling, or if tested and meets general waste conditions disposed of at a suitable facility; and
- sumps and pits would be temporary and small for safe containment of drilling fluids.

4.8.4 Hydraulic Fracturing Stimulation Fluids

Fluids used for hydraulic fracture stimulation would be stored in a fracture fluid tank and either reused during stimulation activities at other wells or removed for disposal by a licenced contractor.

4.8.5 Hydrostatic Test Water and Water from Low Point Drains

Hydrostatic test water from pipelines and water from LPDs may be released to Land in a manner that ensures:

- vegetation is not damaged;
- soil quality is not adversely impacted;
- there is no surface ponding or runoff beyond the designated release area;
- there is no aerosols or odours;
- deep drainage below the root zone of any vegetation is minimised; and
- the quality of shallow aquifers is not adversely affected.

4.9 Rehabilitation

The EVs of the existing environment and pre-disturbed land use of the Project Area are described in the preceding sections. Rehabilitation activities should seek to maintain or enhance, and protect the following EVs:

- the existing primary land use for agriculture
- ecosystem functioning including provision of wildlife habitat and connectivity, and ecosystem services like clean air and water; and
- visual amenity of the landscape.

Rehabilitation works would aim to meet Rehabilitation Acceptance Criteria under the proposed EA conditions. Rehabilitation and decommissioning of disturbed land areas would occur progressively in accordance with proposed EA conditions.

The objective of rehabilitation and decommissioning is to achieve a post development landform that is:

- safe for humans, native fauna and livestock
- non-polluting; and
- stable and able to sustain appropriate land use.

Disturbed areas such as pipeline RoWs would be stabilised post-construction to ensure the safe and effective operation of assets and to minimise the risk of erosion, soil loss and weed invasion. Stabilisation works would include:

- remediating areas of contaminated land resulting from petroleum activities
- re-establishing surface drainage lines and re-profiling contours for operational use
- establishing a safe landform for humans and livestock in areas of significant cut and fill
- reinstating top soil
- soil conditioning where required; and
- promoting the establishment of groundcover vegetation.

Once disturbed areas are no longer required for operations, these would be returned to an appropriate land use in accordance with landholder needs and applicable regulatory requirements. Agricultural land uses and natural areas comprising MSES, ESAs and other forms of vegetation are the two most common pre-disturbance land uses to be rehabilitated. Final rehabilitation of natural areas would be undertaken to achieve the final rehabilitation criteria specified conditions for the proposed EA.

Decommissioning of wells would occur on an ongoing basis as production within the Project Area is exhausted. Wells at the end of their lifecycle would initially be capped to enable future uses such as for other resource activities or monitoring. Only once it is determined that the well has no future use is it plugged and abandoned in accordance with regulatory requirements and the *Code of Practice for the construction and abandonment of petroleum wells and associated bores in Queensland* (DNRME, 2019).

5.0 Greenhouse Gas Emissions Inventory

This section has been compiled to address greenhouse gas (GHG) emission application requirements under the EP Act and in accordance with the DETSI guideline *Greenhouse gas emissions* (ESR/2024/6819, Version 1.01) (DETSI, 2025c).

This application for a new site-specific EA is required to include sufficient information to enable DETSI to consider the potential impacts of each relevant activity for the whole life of the project – which includes the construction, operations and decommissioning phases and ultimately surrender of the EA.

Estimated Scope 3 emissions are not required to be included in applications where projected Scope 1 and Scope 2 emissions are expected to be less than 25,000 tonnes of CO2-e per annum.

The process to address DETSI GHG emission application requirements consists of the following steps:

1. Identify the GHG emissions likely to be generated throughout the life of the project
2. Determine if the application meets the medium to high GHG emission category
3. Identify the management practices proposed to be implemented to prevent or minimise adverse impacts
4. Identify if a GHG abatement plan will be required to accompany the application; and
5. Describe the impacts of climate change on EVs and the risk and likely magnitude of such impacts based on the relative scale of the project's net GHG emissions.

5.1 Greenhouse Gas Emissions Category and Calculation Methodology

Scope 1 and 2 GHG emissions have been quantified for the following activities for the life of the Project – which includes the construction, operations and decommissioning phases and ultimately surrender of the EA.

Scope 1 emissions from the Project are considered direct emissions and are derived from:

- Fuel combustion – diesel use for stationary and transport-related activities
- Flaring – non-routine flaring during well completion and decommissioning activities and flaring associated with gas production,
- Venting – during hydraulic fracture stimulation and work-over activities; and
- Fugitive emissions – including from natural gas exploration, development and production activities, gas gathering pipelines and produced water.

Scope 2 emissions for a facility represent the 'indirect' emissions that are released outside the facility boundary to produce the electricity that is imported into the facility and used. The Scope 2 emissions for this Project relate to emissions associated with the purchase of electricity from the grid primarily during the Operational phase.

Scope 1 emissions (refer to Table 26) from the Project are expected to occur primarily through diesel fuel consumption (27%), flaring (11%), venting (19%) and fugitives (43%).

As per the NGER Determination, *Method 1* emission factors, which are default emission factors derived from the National Greenhouse Accounts methods and based on national average estimates, has been used to determine Scope 1 GHG emissions from the above activities.

Table 26: Scope 1 emissions for the Project

Scope 1 emissions source	Average annual emissions (tCO2e)	Total emissions during 50-year Project life (tCO2e)
Fuel use	178	8,891
Non-routine flaring	71	3,571
Venting	126	6,292
Fugitives	279	13,952
Total	**654**	**32,706**

Scope 2 emissions (refer to Table 27) arise from electricity purchased from the grid representing 100% of Scope 2 emissions.

Table 27: Scope 2 emissions for the Project

Scope 2 emissions source	Average annual emissions (tCO2e)	Total emissions during 50-year Project life (tCO2e)
Purchased electricity	1,282	61,547
Total	**1,282**	**61,547**

Scope 1 and 2 GHG emissions have been quantified for the potential life of the Project for a 50-year period. Emission factors for the above sources have been referenced from the *National Greenhouse and Energy Reporting (Measurement) Determination 2008, Compilation No: 19* (hereafter 'the NGER Determination') – a legislative instrument under the NGER scheme. Energy content factors for the fuel sources have also been referenced from the NGER Determination. Scope 1 emissions primarily arise from fugitive emissions and fuel use, Scope 2 from purchased electricity. Table 28 outlines total Scope 1 and 2 emissions from the Project over the 50-year lifespan.

Table 28: Total Scope 1 and 2 emissions for the life of the Project

Emissions category	Average annual emissions (tCO2)	Total emissions during 50-year Project life (tCO2e)
Scope 1	654	**32,706**
Scope 2	1,282	**61,547**
Total Scope 1 and 2	**1,936**	**94,253**

Table 29 outlines the sources of Scope 1 and 2 emissions for the life of the Project and the associated assumptions used for calculating emissions estimates.

Table 29: Greenhouse gas emissions sources and assumptions

Emissions Source	Description
Scope 1	
Fuel – liquid fuel combustion	Diesel fuel combustion for stationary and transport energy purposes. Energy content (GJ/kL), and emission factors for CO_2, CH_4 and N_2O expressed in kg CO2-e/GJ have been referenced from the NGER Determination.
Flare – Gas exploration and development	Flaring emission from gas exploration have been estimated using Method 1 as per Section 3.44 – Division 3.3.2 – Oil or gas exploration and development of the NGER Determination.
Flare – Gas development and production	Annual production-related flaring has been estimated from 2029 onwards. Gas production during the first two (2) years is expected to be minimal, and the likelihood of considerable flaring occurring during this period is very low. Accordingly, annual production flaring emissions have been estimated from 2029 for the remainder of the Project life. It is noted that production-related flaring emissions fall within the Project Area boundary and are therefore classified as Scope 1 emissions. For the purposes of this GHG assessment, it is assumed that the average quantity of gas flared for each well located in the Project Area is approximately 2.1 t CO_2-e per well per year. This assumption is based on historical emissions released from gas flared at the Roma Hub facility during processing activities.
Venting – well completion	Venting emissions associated with well completion activities were estimated using the Method 1 approach as per Section 3.46AB – Subdivision 3.3.2.3.1 – Fugitive emissions that result from deliberate releases from process vents, system upsets and accidents – well completions of the NGER Determination. CH_4 and CO_2 percentages in the unprocessed gas was based on referencing other similar CSG facilities. Assumption that all well completions would involve hydraulic fracturing and flaring, therefore, the corresponding venting emission factors specified in the NGER Determination were applied to estimate venting emissions from well completion events. Assumption that all 24-wells will be completed within the same year, and accordingly the emissions were estimated based on that assumption.
Venting – well workover	Venting emissions associated with well workovers were estimated using the Method 1 approach as per Section 3.85P – Subdivision 3.3.9A.8 – Natural gas production – emissions that are vented – well workovers of the NGER Determination.

Emissions Source	Description
	CH_4 and CO_2 percentages in the unprocessed gas was based on referencing other CSG facilities. Assumtion that well workovers will not involve any hydraulic fracturing and the relevant venting emission factors for non-hydraulic fracturing workovers specified in the NGER Determination were applied to estimate venting emissions from these activities. Assumption that workovers will occur once every five (5) years for each well and will happen during the same year, and accordingly the emissions were estimated.
Fugitives – gas production	Fugitive emissions from natural gas production were estimated using the Method 1 approach as per Section 3.73A – Subdivision 3.3.6A.1 – onshore natural gas production, other than emissions that are vented or flared – wellheads. CH_4 and CO_2 percentages in the unprocessed gas was based on referencing other similar CSG facilities.
Fugitives – produced water	Fugitive emissions from produced water were estimated using the Method 1 approach as per Section 3.73NA – Division 3.3.6D – produced water from oil and gas exploration and development, crude oil production, natural gas production or natural gas gathering and boosting (other than emissions that are vented or flared). CH_4 and CO_2 percentages in the unprocessed gas was based on referencing other similar CSG facilities.
Fugitives – gas gathering pipelines	Fugitive emissions from natural gas gathering other than emissions that are vented or flared were estimated using the Method 1 approach as per Section 3.73K – Division 3.3.6C – natural gas gathering and boosting (other than emissions that are vented or flared) CH_4 and CO_2 percentages in the unprocessed gas was based on referencing other CSG facilities.
Scope 2	
Purchased Electricity	Scope 2 emissions from electricity purchased from the grid annually for well operating activities at the Project Area were estimated using emission factors published by the Department of Climate Change, Energy, the Environment and Water in *Australia's emissions projections 2025.* Appendix D of the projections report provides annual Scope 2 emission factors for Australia's electricity grid under the baseline scenario for the period 2025–2040. For Queensland, the baseline scenario shows a gradual decrease in Scope 2 emission factors (t CO_2-e/MWhr) as a consequence of increased penetration of renewable energy sources. Queensland's grid emission factor is expected to reduce from 0.65 t CO_2-e/MWhr in 2025 to approximately 0.12 t CO_2-e/MWhr by 2036, after which it stabilises at around 0.10 t CO_2-e/MWhr

Emissions Source	Description
	through to 2040. This trajectory is consistent with Australia's proposed net-zero pathway, where residual emissions from electricity generation progressively decreases as renewable energy generation becomes the dominant source of energy supply. The trajectory published in Appendix D of the projection's guidebook has been used to estimate Scope 2 emissions from the well operating activities at the Project Area.

Emissions context

According to DCCEEW[1], Australia's national greenhouse gas emissions in 2023 (latest available data) were 453.4MtCO2e. Table 30 below compares the annual average Scope 1 and 2 emissions to this national volume.

Table 30: Project annual emissions in context to Australia's annual emissions

Emissions category	Average annual emissions (tCO2)	Project emissions contribution to Australia's annual emissions (%)
Scope 1	654	0.0001
Scope 2	1,282	0.0003
Total Scope 1 and 2	**1,885**	**0.0004**

The global GHG emissions for 2022 (latest year) were 49.3 GtCO2e[2]. Table 31 compares the annual average Scope 1 and 2 emissions to this global volume.

Table 31: Project annual emissions in context to global annual emissions

Emissions category	Average annual emissions (tCO2)	Project emissions contribution to the world's annual emissions (%)
Scope 1	654	0.000001
Scope 2	1,282	0.000003
Total Scope 1 and 2	**1,885**	**0.000004**

[1] Department of Climate Change, Energy, the Environment and Water (DCCEEW), n.d. Australia's National Greenhouse Accounts, *https://ageis.climatechange.gov.au/*, viewed November 2025.
[2] ClimateWatch, 2025. Historical GHG Emissions, https://www.climatewatchdata.org/ghg-emissions?end_year=2022&start_year=1990, viewed November 2025.

At 0.0004% of Australia's annual GHG emissions[1], and 0.000004% of global emissions[2], the net GHG emissions from the Project comprise a nominal amount in the overall scheme of the national and international GHG emissions and whilst these are theoretical calculations for indicative purposes only, will not materially or substantially contribute to Australia's or Queensland's GHG emissions or global emissions levels.

5.2 Proposed Mitigation and Management Practices

Given that only limited Scope 1 and 2 emissions are associated with the Project, the focus for the project is to optimise fuel use and enhance operational efficiency. The reduction initiatives for reducing emissions are outlined in Table 32.

Santos maintains all vehicles and plant to meet Original Equipment Manufacturer (OEM) specifications. This is done to optimise performance and reduce fuel consumption and emissions.

Further, Santos operates in accordance with the following State petroleum industry Codes of Practice:

- *Code of Practice For leak detection, management & reporting for petroleum operating plant Petroleum and Gas Inspectorate Version 6* (available here);
    - This Code of Practice outlines the requirement for Santos to have a leak management program in place to find, classify, report and repair leaks; and
- *Code of Practice For the construction and abandonment of petroleum wells and associated bores in Queensland Petroleum and Gas Inspectorate Version 2* (available here);
    - This Code of Practice outlines the requirement for Santos to construct and maintain petroleum wells in a manner so as to prevent leakage.

Santos also has a Climate Transition Action Plan (CTAP) in place which outlines how it plans to reduce GHG emissions through the energy transition by improving operational efficiency, offering carbon solutions and clean fuels, and by providing lower emission products across the supply chain. The CTAP meets the DETSI GHG abatement hierarchy of first to avoid, reduce, substitute and finally offset.

Table 32: Emissions reductions proposed

Reduction Initiatives	Emission Type	Initiatives Details
All vehicles and plant (internal combustion and electric) will be serviced and maintained in accordance with manufacturer's recommended service schedule.	Scope 1 and 2	Optimises fuel and electricity consumption associated with GHG emissions.
Plan proposed activities (excluding well operation) to reduce operating hours for the Project to as little as practicable.	Scope 1 and 2	Optimises and reduces fuel and electricity consumption associated with GHG emissions.

5.3 Risk Assessment of the likely magnitude of impacts on environmental values

According to the Queensland Government's Future Climate Dashboard, significant climatic changes are projected under the Representative Concentration Pathway (RCP) 4.5 scenario for the and Maranoa region (Appendix I). This moderate emissions scenario indicates that the region will experience notable increases in temperature and changes in precipitation patterns. Under RCP 4.5, the average temperature is expected to rise by 0.74 to 2.3°C by 2050 and 1.1 to 3.1°C by 2070, compared to 1986-2005 data (Queensland Government, 2024).

The region is also projected to see a decrease in average annual rainfall, with more pronounced variability and extended periods of drought, along with an increase in the number of extremely hot days as Australia's climate changes. These climatic changes will likely exacerbate heat stress on local ecosystems, reduce agricultural productivity, and strain water resources. Consequently, comprehensive risk assessments and adaptive strategies are crucial to mitigate these adverse impacts and enhance the region's resilience to climate change (CSIRO, 2024, BOM, 2024).

The Intergovernmental Panel on Climate Change (IPCC) has identified that continued GHG emissions will cause further warming and long-lasting changes on the global climate system in general. To assess the likely magnitude of impact of the project activities on EVs of the region, the Transient Climate Response to Cumulative Carbon Emissions (TCRE) metric has been applied as outlined in the IPCC's Climate Change 2023 Synthesis Report (IPCC, 2023).

The TCRE metric estimates that each trillion tonnes of carbon emitted as CO_2 results in approximately 0.45°C of global mean peak surface temperature change. Using this methodology, the projected emissions from the proposed project activities (total Scope 1 and 2 emissions during 50-year Project life) equate to an infinitesimal temperature increase of approximately 2.31481084E-10°C beyond natural climatic variability.

This rigorous assessment aligns with IPCC and national regulatory guidelines and underscores the negligible environmental impact from the proposed activities. This concludes that the projected impact is negligible and that it poses no threat on EVs, including MSES, or human safety. In summary, despite ongoing and projected climatic changes, impacts from the proposed activities on the climate are insignificant.

6.0 Key References

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7.0 Appendices

Appendix A: Proposed EA Conditions

Due to varying joint venture and commercial arrangements, PL 1123 cannot be added to any of the existing adjacent EAs as an authorised tenure.

The holders of Santos operated petroleum tenures surrounding PL 1123 are different to those of PL 1123, and therefore PL 1123 cannot be added as an authorised tenure to their respective EAs.

Santos is therefore seeking a new site-specific EA to authorise petroleum production on PL 1123.

Given the proximity of the Project Area to the RSGPA and RSGPAE tenures, proposed development and operation of the Project Area will be carried out as a single integrated operation with existing authorised RSGPA and RSGPAE petroleum tenures and activities.

Gas and water generated from the Project Area will utilise existing centralised gas and water processing facilities (including compression stations) located on adjoining RSGPA tenures. Integration with these existing facilities will negate the requirement to locate gas compression and large water management facilities within the Project Area.

Further, due to the use and reliance on co-located infrastructure approved under the existing adjacent EAs, and to ensure consistent operational standards, compliance and reporting requirements across tenures, for the new EA, Santos is seeking EA conditions consistent with those of the RSGPA EA (EPPG00898213), which are predominately based on the Streamlined model conditions for petroleum activities (DETSI, 2024).

Due to the limited scope of activities proposed for PL 1123, there are several RSGPA EA conditions not required, and these conditions have been excluded from proposed EA conditions. Santos also requests addition of a small number of contemporary EA conditions recently approved by DETSI for use in the Santos Towrie (PL 1059) EA (P-EA-100130995).

Further, Santos requests the following prescribed Environmentally Relevant Activity (ERA) is authorised on the new EA (refer to Section 5.2 for further information on the requirement for this ERA):

Schedule 3 – 3 – A petroleum activity that is likely to have a significant impact on a category A or B Environmentally Sensitive Area.

The proposed EA conditions and ERA are deemed appropriate for development of PL 1123; and the proposed development and EA conditions are reflective of standard developments currently operating in the broader Roma region. The environmental values of the project are also similar to or the same as surrounding Roma tenures due to their close geographic proximity.

Further, the conditions of the RSGPA EA are a product of the outcome of a rigorous Environmental Impact Statement (EIS) based EPBC Act approval process, and the granted conditions of approval were designed to regulate impacts associated with more than 6100 CSG wells.

Refer to proposed EA conditions below.

Proposed EA Conditions

Environmentally relevant activity and location details

Proposed ERA	Justification
Schedule 3 – 3 A petroleum activity that is likely to have a significant impact on a category A or B environmentally sensitive area	Proposed activities will disturb 13.5 ha of a Category B ESA (that being the PPZ of Endangered REs 11.9.10 / 11.3.17). Refer to Section 5.2 and Table 13 for further information on the requirement for this ERA.

<table>
<tr><th>#</th><th>Proposed EA Condition</th><th>Justification / Comments</th></tr>
<tr><td colspan="3">Schedule A – General</td></tr>
<tr><td>A1</td><td>This environmental authority authorises the carrying out of the following resource activity(ies):
(a) the petroleum activities listed in Schedule A, Table 1 – Scale and Intensity for the Activities to the extent they are carried out in accordance with the activity's corresponding scale and intensity;
(b) incidental activities that are not otherwise specified relevant activities.
Schedule A, Table 1 – Scale and Intensity for the Activities
<table>
<tr><th>Petroleum activities and infrastructure</th><th>Scale (number of activities)</th><th>Intensity (maximum size in total)</th></tr>
<tr><td>Coal seam gas exploration, appraisal, and development wells</td><td>24</td><td>36 ha</td></tr>
<tr><td>Stimulation activities</td><td colspan="2">All wells are subject to stimulation activities</td></tr>
</table></td><td>This application considers total impacts and disturbances associated with 24 existing and proposed CSG wells (i.e. the existing 5 CSG wells form part of the proposed 24 CSG well development).</td></tr>
<tr><td>A2</td><td>The resource activities in condition (A1) are authorised subject to the conditions of this environmental authority.</td><td></td></tr>
<tr><td>A3</td><td>This environmental authority authorises a relevant act[1] to occur only to the extent that:
a) the relevant act is an ordinary consequence of carrying out the resource activities authorised by this environmental authority in accordance with its conditions; or
b) the relevant act is specifically authorised by the conditions of this environmental authority and carrying out an activity which results in the relevant act does not contravene the conditions of this authority.
[1]See section 493A of the Environmental Protection Act 1994</td><td></td></tr>
<tr><td colspan="3">Monitoring</td></tr>
<tr><td>A4</td><td>All monitoring must be undertaken by a suitably qualified person.</td><td></td></tr>
<tr><td>A5</td><td>If requested by the administering authority in relation to investigating a complaint, monitoring must be commenced within 10 business days.</td><td></td></tr>
<tr><td>A6</td><td>The administering authority must be advised in writing of the results of the investigation (including an analysis and interpretation of the monitoring results) and actions proposed or undertaken to resolve the complaint within five (5) business days of completing the complaint investigation, unless a longer time is agreed to by the administering authority.</td><td></td></tr>
<tr><td>A7</td><td>All laboratory analyses and tests required must be undertaken by a laboratory that has NATA accreditation for such analyses and tests.</td><td></td></tr>
<tr><td>A8</td><td>Notwithstanding condition (A7), where there are no NATA accredited laboratories for a specific analyte or substance, then duplicate samples must be sent to at least two separate laboratories for independent testing or evaluation.</td><td></td></tr>
</table>

A9	Monitoring and sampling must be carried out in accordance with the requirements of the following documents (as relevant to the sampling being undertaken), as amended from time to time: (a) for waters and aquatic environments, the Queensland Government's Monitoring and Sampling Manual 2009 –Environmental Protection (Water) Policy 2009 (b) for groundwater, Groundwater Sampling and Analysis – A Field Guide and any applicable Australian Standard (c) for noise, the latest administering authority's Noise Measurement Manual and any applicable Australian Standard (d) for air, the Queensland Air Quality Sampling Manual and/or Australian Standard 4323.1:1995 Stationary source emissions method 1: Selection of sampling positions, as appropriate for the relevant measurement (e) for soil, the Guidelines for Surveying Soil and Land Resources, 2nd edition (McKenzie et al.2008), and/or the Australian Soil and Land Survey Handbook, 3rd edition (National Committee on Soil and Terrain, 2009) (f) for dust, Australian Standard AS3580.	
Contingency Procedures for Emergency Environmental Incidents		
A10	Petroleum activities involving significant disturbance to land cannot commence until the development of written contingency procedures for emergency environmental incidents which include, but are not necessarily limited to: (a) A clear definition of what constitutes an environmental emergency incident or near miss for the petroleum activity. (b) Consideration of the risks caused by the petroleum activity including the impact of flooding and other natural events on the petroleum activity. (c) Response procedures to be implemented to prevent or minimise the risks of environmental harm occurring. (d) The practices and procedures to be employed to restore the environment or mitigate any environmental harm caused. (e) Procedures to investigate causes and impacts including impact monitoring programs for releases to waters and/or land. (f) Training of staff to enable them to effectively respond. (g) Procedures to notify the administering authority, local government and any potentially impacted landholder.	
Maintenance of Plant and Equipment		
A11	All plant and equipment must be maintained and operated in their proper and effective condition.	
A12	The following infrastructure must be signed with a unique reference name or number in such a way that it is clearly observable: (a) regulated dams and low consequence dams (b) exploration, appraisal and development wells (c) water treatment facilities (d) sewage treatment facilities (e) specifically authorised discharge points to air and waters (f) any chemical storage facility associated with the environmentally relevant activity of chemical storage (g) field compressor stations (h) central compressor stations (i) gas processing facilities; and (j) pipeline compressor stations.	
A13	Measures to prevent fauna being harmed from entrapment must be implemented during the construction and operation of well infrastructure, dams and pipeline trenches.	
Documentation		

A14	A certification must be prepared by a suitably qualified person within 30 business days of completing every plan, procedure, program and report required to be developed under this environmental authority, which demonstrates that: (a) relevant material, including current published guidelines (where available) have been considered in the written document (b) the content of the written document is accurate and true; and (c) the document meets the requirements of the relevant conditions of the environmental authority.	
A15	All plans, procedures, programs, reports and methodologies required under this environmental authority must be written and implemented.	
A16	All documents required to be developed under this environmental authority must be kept for five (5) years.	
A17	All documents required to be prepared, held or kept under this environmental authority must be provided to the administering authority upon written request within the requested timeframe.	
A18	A record of all complaints must be kept including the date, complaint's details, source, reason for the complaint, description of investigations and actions undertaken in resolving the complaint.	
Third Party Audit		
A19	A third-party auditor, nominated by the holder of this environmental authority and accepted by the administering authority, must audit compliance with the conditions of this environmental authority at a minimum frequency of every three (3) years.	
A20	Notwithstanding condition A19, and prior to undertaking the third-party audit, the scope and content of the third-party audit can be negotiated with the administering authority.	
A21	An audit report must be prepared and certified by the third-party auditor presenting the findings of each audit carried out.	
A22	Any recommendations arising from the audit report must be acted upon by: (a) investigating any non-compliance issues identified; and (b) as soon as reasonably practicable, implementing measures or taking necessary action to ensure compliance with the requirements of this environmental authority.	
A23	A written response must be attached to the audit report detailing the actions taken on stated dates: (a) by the holder to ensure compliance with this environmental authority; and (b) to prevent a recurrence of any non-compliance issues identified.	
A24	The audit report required by condition A21 and the written response to the audit report required by condition A23 must be submitted with the subsequent annual return.	
Schedule B - Water		
Contaminant Release		
B1	Contaminants must not be directly or indirectly released to any waters except as permitted under this environmental authority.	
B2	The extraction of groundwater as part of the petroleum activities from underground aquifers must not directly or indirectly cause environmental harm to any watercourse or wetland.	
Works in Watercourses, Wetlands and Lakes		
B3	Only construction or maintenance of linear infrastructure is permitted in or within a general ecologically significant wetland or in a watercourse.	

B4	The construction and/or maintenance of linear infrastructure that will result in significant disturbance in or on the bed and banks of a watercourse or within a general ecologically significant wetland must be conducted in accordance with the following order of preference: (a) conducting works in times when there is no water present; (b) conducting works in times of no flow; (c) conducting works in times of flow but in a way that does not impede low flow.	
B5	The construction and maintenance of linear infrastructure authorised under condition B3 must comply with the water quality limits specified in *Schedule B, Table 1 Release Limits for Construction or Maintenance of Linear Infrastructure.* Refer to Schedule B, Table 1 in the RSGPA EA (EPPG00898213).	
B6	Monitoring must be undertaken at a reasonable frequency to ensure compliance with condition B5.	
B7	A register must be kept of all linear infrastructure construction and maintenance activities in a wetland of other environmental value and watercourses, which must include: (a) location of the activity (e.g., GPS coordinates (GDA94) and watercourse name) (b) estimated flow rate or surface water at the time of the activity (c) duration of work (d) results of impact monitoring carried out under condition B6.	
B8	Petroleum activities must occur outside a wetland of high ecological significance.	
B9	Petroleum activities must not negatively impact a wetland of high ecological significance.	
B10	Linear infrastructure activities, other than linear infrastructure construction and/or maintenance activities, must not change the existing surface water hydrological regime of any general ecologically significant wetland.	
B11	The construction and/or maintenance of linear infrastructure in any general ecologically significant wetland must not: (a) prohibit the flow of surface water in or out of the wetland; (b) impact surface water quality in the wetland unless specifically authorised by this environmental authority; (c) drain the wetland; (d) fill the wetland; (e) impact bank stability; or (f) result in the clearing of riparian vegetation outside of the required footprint.	
B12	Where the petroleum activity(ies) is carried out on floodplains petroleum activity(ies) must be carried out in a way that does not: (a) concentrate flood flows in a way that will or may cause or threaten an adverse environmental impact; or (b) divert flood flows from natural drainage paths and alter flow distribution; or (c) increase the local duration of floods; or (d) increase the risk of detaining flood flows.	
Erosion and Sediment Control		

B13	For activities involving significant disturbance to land, control measures that are commensurate to the site-specific risk of erosion, and risk of sediment release to waters must be implemented to: (a) preferentially divert stormwater around significantly disturbed land, or allow stormwater to pass through the site in a controlled manner and at non-erosive flow velocities; (b) minimise soil erosion resulting from wind, rain, and flowing water; (c) minimise the duration that disturbed soils are exposed to the erosive forces of wind, rain, and flowing water; (d) minimise work-related soil erosion and sediment runoff; and (e) minimise negative impacts to land or properties adjacent to the activities (including roads).	
Well Testing		
B14	Subject to conditions B15 and B16 the injection of CSG water or better quality groundwater is authorised in wells that are not exploration, appraisal or development wells, for the purposes of hydraulic testing, where such hydraulic tests are undertaken for no more than two (2) consecutive days.	
B15	The maximum volume of CSG water or better quality groundwater injected for the purposes of hydraulic testing identified in condition B14 must not exceed 1 ML per hydraulic test.	
B16	Written notification detailing the type and location (GPS coordinates) of any hydraulic testing undertaken in accordance with condition B14 must be provided to the administering authority at least 10 business days prior to the commencement of the hydraulic test.	
Schedule C – Land		
General		
C1	Contaminants must not be directly or indirectly released to land except as permitted under this environmental authority.	
Top Soil Management		
C2	Top soil must be managed in a manner that preserves its biological and chemical properties.	
Land Management		
C3	Land that has been significantly disturbed by the pipeline activities must be managed to ensure that gully erosion or subsidence do not occur on that land.	
Chemical Storage		
C4	Chemicals and fuels stored, must be effectively contained and where relevant, meet Australian Standards, where such a standard is applicable.	
Pipeline Operation and Maintenance		
C5	Contaminants authorised to be released to land under conditions C6, C8, C14 and C20 must be carried out in a manner that ensures: (a) vegetation is not damaged; (b) soil quality is not adversely impacted; (c) there is no surface ponding or runoff beyond the designated release area; (d) there is no aerosols or odours; (e) deep drainage below the root zone of any vegetation is minimised; (f) the quality of shallow aquifers is not adversely affected.	Requested for operational and compliance consistency with surrounding approved Santos operated tenures and infrastructure.
Pipeline Wastewater		

C6	Contaminants that are hydrostatic test water from pipelines and contaminants from low point drains may be released to land in accordance with condition C5.	Requested for operational and compliance consistency with surrounding approved Santos operated tenures and infrastructure. This also aligns with the basis of design for the flowlines.
C7	Produced water may be re-used in: (a) drilling and well hole activities; or (b) stimulation activities.	
C8	Produced water may be released to land for the following purposes: (a) dust suppression; (b) construction and operational purposes for the petroleum activity authorised by this environmental authority; and (c) irrigation.	
C9	Produced water irrigated to land must: (a) not exceed the release limits specified in *Schedule C, Table 1a Irrigation water quality monitoring*; and (b) be monitored at the frequency and for the quality characteristics at the monitoring point specified in *Schedule C, Table 1a - Irrigation water quality monitoring*; or (c) the process under C10 has been completed.	
C10	Produced water for irrigation which does not meet criteria in condition C10 (a) and (b) may be used for irrigation provided a report has been completed which: (a) determines soil structure, stability and productive capacity will be maintained or improved; (b) determines there are no toxic effects to crops; (c) determines yields and produce quality are maintained or improved; (d) states water quality criteria, which has been determined in accordance with the assessment procedures outlined *in Schedule C, Table 1b Assessment procedures for water quality criteria*; and (e) includes a water monitoring program to ensure that condition C10 (a), (b) and (c) are being achieved. Refer to Schedule C, Tables 1a and 1b in the RSGPA EA (EPPG00898213).	
C11	Produced water may be used for domestic, or stock purposes provided the water quality complies with the criteria specified in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ 2000).	
C12	Produced water may be transferred to a third-party to be used for the following purposes, subject to condition C13: (a) dust suppression; (b) construction and operational purposes; or (c) domestic or stock purposes provided the water quality complies with criteria specified in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ 2000).	

C13	If the responsibility of coal seam gas water is given or transferred to a third party in accordance with condition C12, the holder of the environmental authority must ensure that: (a) the responsibility of the coal seam gas water is given or transferred in accordance with a written agreement (the third-party agreement); and (b) the third party is made aware of the General Environmental Duty under section 319 of the *Environmental Protection Act 1994*.	
Sewage Treatment Works		
C14	Greywater or treated sewage effluent from a treatment system with a daily peak design capacity of up to 21 EP may be: (a) released to land by sub-surface or spray irrigation provided it is to a fenced and signed contaminant release area that is: i. a minimum distance of 50 metres from any watercourse, wetland or protected area; and ii. a minimum distance of 100 metres from any potable water supply or stock drinking water supply; and iii. kept vegetated with groundcover that is not a prohibited or restricted pest species; or (b) used for dust suppression, construction and operational purposes subject to condition C16.	Modified from RSGPA EA (EPPG00898213) to be limited to 21 EP and added "operational" to C14(b), but otherwise unchanged.
C15	When circumstances prevent the irrigation of treated sewage effluent to land, the contaminants must be directed to on-site storage or lawfully disposed of off-site.	
C16	Treated sewage effluent may only be used for dust suppression, construction and operational purposes provided that: (a) the treated sewage effluent has not been stored in a dam or tank prior to use; (b) on local government controlled roads, written approval from the relevant Local Government has been given to the holder of this environmental authority; and (c) the treated sewage effluent quality: (i) is monitored at the location and frequency specified in Schedule C, Table 2 – Treated Sewage Effluent Standards for Dust Suppression, Construction and Operational Purposes; and (ii) meets the release limits for each quality characteristic specified in Schedule C, Table 2 - Treated Sewage Effluent Standards for Dust Suppression, Construction and Operational Purposes. Refer to Schedule C, Table 2 in RSGPA EA (EPPG00898213).	
Schedule D – Biodiversity		
Confirming Biodiversity Values		
D1	Prior to undertaking activities that result in significant disturbance to land in areas of native vegetation, confirmation of on-the-ground environmentally sensitive areas and wetlands at that location must be undertaken by a suitably qualified person.	
D2	A suitably qualified person must develop and certify a methodology so that condition D1 can be complied with, and which is appropriate to confirm on-the-ground environmentally sensitive areas and wetlands.	
D3	Where areas mapped as environmentally sensitive areas and wetlands differ from those confirmed under conditions D1 and D2, petroleum activities may proceed in accordance with the conditions of the environmental authority based on the confirmed on-the-ground values.	
D4	All documentation survey information photographs, field data or any material associated with the field validation requirements in D1 must be maintained for the life of the environmental authority to demonstrate to the administering authority that surveys were conducted in a manner consistent with requirements contained in D2.	

<table>
<tr><td>D5</td><td>The location of the petroleum activity must be selected in accordance with the following site planning principles:
(a) maximise the use of areas of pre-existing disturbance
(b) in order of preference, avoid, minimise or mitigate any impacts, including cumulative impacts, on areas of native vegetation or other areas of ecological value
(c) minimise disturbance to land that may result in land degradation
(d) in order of preference, avoid then minimise isolation, fragmentation, edge effects or dissection of tracts of native vegetation; and
(e) in order of preference, avoid then minimise clearing of native mature trees.</td><td></td></tr>
<tr><td>D6</td><td>Petroleum activities must be carried out in accordance with Schedule D, Table 1 – Petroleum Activities in Environmentally Sensitive Areas, Schedule D, Table 2 – Authorised Petroleum Activities and Disturbance and any other relevant conditions of this environmental authority.

Refer to Schedule D, Table 1 in the RSGPA EA (EPPG00898213).

Schedule D, Table 2 – Authorised Petroleum Activities and Disturbance
<table>
<tr><th rowspan="2">ESA/PPZs</th><th rowspan="2">Details of environmental sensitive area</th><th rowspan="2">Authorised Activity</th><th colspan="2">Approximate Location of development (GDA94)</th><th rowspan="2">Maximum extent of impact (hectares)</th></tr>
<tr><th>Longitude</th><th>Latitude</th></tr>
<tr><td rowspan="8">PPZ of Category B ESA</td><td rowspan="8">Endangered Regional Ecosystems (11.9.10 / 11.3.17)</td><td rowspan="25">Access tracks, well leases and associated infrastructure / resource activities.</td><td>149.2343</td><td>-26.5826</td><td rowspan="8">13.5</td></tr>
<tr><td>149.2424</td><td>-26.5904</td></tr>
<tr><td>149.2411</td><td>-26.5918</td></tr>
<tr><td>149.2413</td><td>-26.5935</td></tr>
<tr><td>149.2336</td><td>-26.5935</td></tr>
<tr><td>149.2253</td><td>-26.5921</td></tr>
<tr><td>149.2323</td><td>-26.6049</td></tr>
<tr><td>149.2452</td><td>-26.6137</td></tr>
<tr><td rowspan="9">Category C ESA</td><td>Of Concern RE 11.3.2</td><td>149.2279</td><td>-26.5946</td><td>0.15</td></tr>
<tr><td rowspan="4">Essential Habitat (RE 11.3.2)</td><td>c</td><td>-26.5946</td><td rowspan="4">0.30</td></tr>
<tr><td>149.2321</td><td>-26.5959</td></tr>
<tr><td>149.2331</td><td>-26.5960</td></tr>
<tr><td>149.2327</td><td>-26.6050</td></tr>
<tr><td rowspan="9">PPZ (Essential Habitat and Of Concern REs (11.3.2 / 11.3.25))</td><td>149.2342</td><td>-26.5825</td><td rowspan="9">61.5</td></tr>
<tr><td>149.2424</td><td>-26.5903</td></tr>
<tr><td>149.2417</td><td>-26.5919</td></tr>
<tr><td>149.2177</td><td>-26.5884</td></tr>
<tr><td>149.2415</td><td>-26.5936</td></tr>
<tr><td>149.2333</td><td>-26.5983</td></tr>
<tr><td>149.2438</td><td>-26.5975</td></tr>
<tr><td>149.2418</td><td>-26.6008</td></tr>
</table></td><td>Schedule D, Table 2 included based on the recently approved EA amendment to the Santos Backbone EA (EPPG04323316) based on outcome of SI/SRI assessments undertaken by Boobook (2025). Refer to Section 7.2 for further information.
“Approximate location of development” represents approximate centroid of each disturbance area.</td></tr>
</table>

				149.2419	-26.6042		
				149.2472	-26.6032		
				149.2179	-26.6127		
				149.2452	-26.6137		
				149.2480	-26.6144		

D7	Limited impact camps must not be located within a primary protection zone of Category C ESA (Essential Habitat) or Category C ESA (Nature Refuges).	
D8	Limited impact petroleum activities must not be located within areas that contain commercial species.	
D9	Despite condition D6 decommissioning petroleum activities are authorised within all ESAs other than Category A ESAs, and within all ESA protection zones when conducted in accordance with the land disturbance planning principles provided in condition D5.	
D10	Limited petroleum activities, limited impact camps or limited impact petroleum activities located within a primary protection zone or secondary protection zone of an environmentally sensitive area in accordance with *Schedule D, Table 1 – Petroleum Activities in Environmentally Sensitive Areas*, and activities listed in *Schedule D, Table 2 – Authorised Petroleum Activities and Disturbance* must not negatively affect the adjacent environmentally sensitive area.	
D11	Prior to carrying out limited petroleum activities or limited impact petroleum activities undertaken within environmentally sensitive areas in accordance with *Schedule D, Table 1 – Petroleum Activities in Environmentally Sensitive Areas*, it must be demonstrated, in the following order of preference that: (a) no reasonable or practicable alternative exists for carrying out the limited petroleum activities within the environmentally sensitive area; (b) the limited petroleum activities are preferentially located in pre-existing areas of clearing or significant disturbance; (c) clearance widths for linear infrastructure is minimised to the maximum extent possible, taking into account the following matters: (i) safe vehicle movement; (ii) drainage devices installed are of a type that is appropriate for the track type and location; (iii) erosion and sediment control measures installed are in accordance condition B13 and B3; and (iv) power line stays have been preferentially located within the pipeline right of way where possible. (d) the maximum clearance widths specified in *Schedule D, Table 3 - Authorised Disturbance for Linear Infrastructure* are not exceeded. Refer to Table 3 Authorised Disturbance for Linear Infrastructure in the RSGPA EA (EPPG00898213).	
D12	Significant residual impacts to prescribed environmental matters are not authorised under this environmental authority or the Environmental Offsets Act 2014 unless the impact is: (i) specified in Schedule B, Table 1 - Authorised impacts to MSES; or (ii) the impact(s) to the prescribed environmental matters, to the extent specified in Table 1 – Authorised impacts to MSES, has/have been assessed under the Environmental Protection Biodiversity Conservation Act 1999 (Cth).	Included based on outcome of SI/SRI assessments undertaken by Boobook (2025). Refer to Section 7.2 for further information.
Environmental Offsets		
D13	An environmental offset must be made in accordance with the Environmental Offsets Act 2014 and Queensland Environmental Offsets Policy, for the maximum extent of impact to	Inserted from the recently

<table>
<tr><td></td><td>each prescribed environmental matter requiring an offset as listed in Schedule B, Table 1 - Authorised impacts to MSES, unless the prescribed environmental matters has/have been assessed under the Environmental Protection Biodiversity Conservation Act 1999 (Cth) to the extent specified in Table 1 – Authorised impacts to MSES.
Note: Deemed conditions provided in section 16 of the Environmental Offsets Act 2014 also apply to this authority. Any contravention of a deemed condition will be dealt with under the Environmental Protection Act 1994.</td><td>approved EA amendment to the Santos Backbone EA (EPPG04323316) based on outcome of SI/SRI assessments undertaken by Boobook (2025). Refer to Section 7.2 for further information.</td></tr>
<tr><td>D14</td><td>Prescribed environmental matters - matters of State environmental significance Impacts to Prescribed environmental matters (PEMs) that are Matters of State environmental significance (MSES) as a result of carrying out the activity must only occur within the locations and to the maximum extents stated in Schedule B, Table 1 – Authorised impacts to MSES.</td><td>As above.</td></tr>
<tr><td colspan="3">Prescribed environmental matters - matters of State environmental significance</td></tr>
<tr><td>D15</td><td>Impacts to Prescribed environmental matters (PEMs) that are Matters of State environmental significance (MSES) as a result of carrying out the activity must only occur within the locations and to the maximum extents stated in Schedule B, Table 1 – Authorised impacts to MSES.

Schedule B, Table 1 – Authorised impacts to MSES
<table>
<tr><th>MSES</th><th>Approximate location of impact</th><th>Significant residual impact determined and offset required?</th><th>Maximum extent of impact (hectares)</th></tr>
<tr><td colspan="4">Protected Wildlife Habitat</td></tr>
<tr><td colspan="4">An area of habitat (e.g. foraging, roosting, nesting or breeding habitat) for an animal that is endangered, vulnerable or a special least concern animal (section 6(4), EO Reg)</td></tr>
<tr><td>Calyptorhynchus lathami lathami (Glossy black cockatoo (eastern))
Hirundapus caudactus (White throated needletail)
Phascolarctos cinereus (Koala)
Egernia rugose (Yakka Skink)
Hemiaspis damelii (Grey Snake)
Tachyglossus aculeatus (Echidna)</td><td>Areas of RE 11.3.2 (remnant and regrowth) as follows:
<table>
<tr><th colspan="2">GPS Co-ordinates (GDA94)</th></tr>
<tr><td>Longitude</td><td>Latitude</td></tr>
<tr><td>149.2279</td><td>-26.5946</td></tr>
<tr><td>149.2279</td><td>-26.5946</td></tr>
<tr><td>149.2279</td><td>-26.5946</td></tr>
<tr><td>149.2279</td><td>-26.5946</td></tr>
</table></td><td>No</td><td>0.30</td></tr>
</table></td><td>As above.</td></tr>
</table>

<table>
<tr><td></td><td>
<table>
<tr>
<td>Calidris acuminata (Sharp-tailed Sandpiper)
Gallinago hardwickii (Latham's Snipe)
Rostratula australis (Australian Painted Snipe)</td>
<td>Potential wetland habitat as follows:
<table>
<tr><th colspan="2">GPS Co-ordinates (GDA94)</th></tr>
<tr><td>Longitude</td><td>Latitude</td></tr>
<tr><td>149.2346</td><td>-26.6051</td></tr>
<tr><td>149.2387</td><td>-26.6058</td></tr>
<tr><td>149.2469</td><td>-26.6050</td></tr>
</table>
</td>
<td>No</td>
<td>0.60</td>
</tr>
</table>
* Offsets under the Environmental Offsets Act 2014 are not required. The maximum extent of impact has been assessed under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC 2025/10227).
</td><td></td></tr>
<tr><td colspan="3">Schedule E – Waste</td></tr>
<tr><td colspan="3">General Waste Management</td></tr>
<tr><td>E1</td><td>Measures must be implemented so that waste is managed in accordance with the waste and resource management hierarchy and the waste and resource management principles.</td><td></td></tr>
<tr><td>E2</td><td>All regulated waste must only be removed from the site by a person who holds a current authority to transport such waste under the provisions of the Environmental Protection Act 1994.</td><td></td></tr>
<tr><td>E3</td><td>Waste, including waste fluids, but excluding waste used in closed-loop systems, must be transported off-site for lawful re-use, remediation, recycling or disposal, unless the waste is specifically authorised by conditions C6, C8, C14 and E4, E7, E8 to be disposed of or used on site.</td><td></td></tr>
<tr><td>E4</td><td>Unless otherwise authorised by the conditions of this EA to be released to land, Waste fluids, other than flare precipitant stored in flare pits, or residual drilling material, or drilling fluids stored in sumps, must be contained in either:
(a) an above ground container; or
(b) a structure which contains the wetting front.</td><td></td></tr>
<tr><td>E5</td><td>Vegetation waste may be burned if it relates to a state forest, timber reserve or forest entitlement area administered by the Forestry Act 1959 and a permit has been obtained under the Fire and Rescue Service Act 1990.</td><td></td></tr>
<tr><td>E6</td><td>Following the completion of the petroleum activity(ies), any residual brine and / or solid salt present in any dam must be removed and transported to a facility that can lawfully reuse, recycle or dispose of such waste under the Environmental Protection Act 1994.</td><td></td></tr>
<tr><td colspan="3">Residual Drilling Materials</td></tr>
<tr><td>E7</td><td>If sumps are used to store residual drilling material or drilling fluids, they must only be used for the duration of drilling activities.</td><td></td></tr>
<tr><td>E8</td><td>Residual drilling material can only be disposed of on- site:
(a) by mix-bury-cover method if the residual drilling material meets the approved quality criteria; or
(b) if it is certified by a suitably qualified third-party as being of acceptable quality for disposal to land by the proposed method and that environmental harm will not result from the proposed disposal.</td><td></td></tr>
<tr><td>E9</td><td>Records must be kept to demonstrate compliance with conditions E7 and E8.</td><td></td></tr>
<tr><td colspan="3">Schedule F – Noise</td></tr>
<tr><td>F1</td><td>Petroleum activities must not cause environmental nuisance at a sensitive place, other than where an alternative arrangement is in place.</td><td></td></tr>
</table>

F2	Notwithstanding condition F1, emission of noise from the petroleum activity at levels less than those specified in Schedule F, Table 1 Noise nuisance limits are not considered to be environmental nuisance. Refer to Schedule F, Table 1 Noise nuisance limits in RSGPA EA (EPPG00898213).	
F3	If the noise subject to a valid complaint is tonal or impulsive, the adjustments detailed in *Schedule F, Table 2 Adjustments to be added to noise levels at sensitive receptors* are to be added to the measured noise level(s) to derive LAeq, adj, 15 min. Refer to Schedule F, Table 2 Adjustments to be added to noise levels at sensitive receptors in RSGPA EA (EPPG00898213).	
F4	Notwithstanding condition F2, emission of any low frequency noise must not exceed either F4(a) and F4(b), or F4(c) and F4(d) in the event of a valid complaint about low frequency noise being made to the administering authority: (a) 60 dB(C) measured outside the sensitive receptor; and (b) the difference between the external A-weighted and C-weighted noise levels is no greater than 20 dB; or (c) 50 dB(Z) measured inside the sensitive receptor; and (d) the difference between the internal A-weighted and Z-weighted (Max LpZ, 15 min) noise levels is no greater than 15 dB.	
Schedule G – Air		
G1	Unless venting is authorised under the *Petroleum and Gas (Production and Safety) Act 2004* or the *Petroleum Act 1923*, waste gas must be flared in a manner that complies with all of G1(a) and G1(b) and G3(c), or with G1(d): (a) an automatic ignition system is used, and (b) a flame is visible at all times while the waste gas is being flared, and (c) there are no visible smoke emissions other than for a total period of no more than 5 minutes in any 2 hours, or (d) it uses an enclosed flare.	
Schedule H – Regulated Structures		
Assessment of Consequence Category		
H1	Regulated Structures are not authorised by this environmental authority.	Inserted as Santos is not proposing any regulated structures in PL 1123.
Schedule I – Well Construction, Maintenance and Stimulation Activity		
Drilling Activities		
I1	Oil based or synthetic based drilling muds must not be used in the carrying out of the petroleum activity(ies).	
I2	Drilling activities must not result in the connection of the target gas producing formation and another aquifer.	
I3	Practices and procedures must be in place to detect, as soon as practicable, any fractures that have or may result in the connection of a target gas producing formation and another aquifer as a result of drilling activities.	
Simulation Activities		
I4	Polycyclic aromatic hydrocarbons or products that contain polycyclic aromatic hydrocarbons must not be used in stimulation fluids in concentrations above the reporting limit.	
I5	Stimulation activities must not negatively affect water quality, other than that within the stimulation impact zone of the target gas producing formation.	

I6	Stimulation activities must not cause the connection of the target gas producing formation and another aquifer.	
I7	The internal and external mechanical integrity of the well system prior to and during well stimulation must be ensured such that there is: (a) no significant leakage in the casing, tubing, or packer; and (b) there is no significant fluid movement into another aquifer through vertical channels adjacent to the well bore hole.	
I8	Practices and procedures must be in place to detect, as soon as practicable, any fractures that cause the connection of a target gas producing formation and another aquifer.	
Stimulation Risk Assessment		
I9	Prior to undertaking well stimulation activities, a risk assessment must be developed to ensure that stimulation activities are managed to prevent environmental harm.	
I10	The stimulation risk assessment required must be carried out for every well to be stimulated prior to stimulation activities being carried out at that well and address issues at a relevant geospatial scale such that changes to features and attributes are adequately described and must include, but not necessarily be limited to: (a) a process description of the stimulation activity to be applied, including equipment and a comparison to best international practice; (b) provide details of where, when and how often stimulation is to be undertaken on the tenures covered by this environmental authority; (c) a geological model of the field to be stimulated including geological names, descriptions and depths of the target gas producing formation(s); (d) naturally occurring geological faults; (e) seismic history of the region (e.g. earth tremors, earthquakes); (f) proximity of overlying and underlying aquifers; (g) description of the depths that aquifers with environmental values occur, both above and below the target gas producing formation. (h) identification and proximity of landholders' active groundwater bores in the area where stimulation activities are to be carried out; (i) the environmental values of groundwater in the area; (j) an assessment of the appropriate limits of reporting for all water quality indicators relevant to stimulation monitoring in order to accurately assess the risks to environmental values of groundwater; (k) description of overlying and underlying formations in respect of porosity, permeability, hydraulic conductivity, faulting and fracture propensity; (l) consideration of barriers or known direct connections between the target gas producing formation and the overlying and underlying aquifers; (m) a description of the well mechanical integrity testing program; (n) process control and assessment techniques to be applied for determining extent of stimulation activities (e.g. microseismic measurements, modelling etc); (o) practices and procedures to ensure that the stimulation activities are designed to be contained within the target gas producing formation; (p) groundwater transmissivity, flow rate, hydraulic conductivity and direction(s) of flow; (q) a description of the chemicals used in stimulation activities (including estimated total mass, estimated composition, chemical abstract service numbers and properties), their mixtures and the resultant compounds that are formed after stimulation; (r) a mass balance estimating the concentrations and absolute masses of chemicals that will be reacted, returned to the surface or left in the target gas producing formation subsequent to stimulation; (s) an environmental hazard assessment of the chemicals used including their	

	mixtures and the resultant chemicals that are formed after stimulation including: (i) toxicological and ecotoxicological information of chemicals used; (ii) information on the persistence and bioaccumulation potential of the chemicals used; (iii) identification of the stimulation fluid chemicals of potential concern derived from the risk assessment; (t) an environmental hazard assessment of use, formation of, and detection of polycyclic aromatic hydrocarbons in stimulation activities; (u) if used, identification and an environmental hazard assessment of using radioactive tracer beads in stimulation activities (v) an environmental hazard assessment of leaving stimulation chemicals in the target gas producing formation for extended periods subsequent to stimulation; (w) human health exposure pathways to operators and the regional population; (x) risk characterisation of environmental impacts based on the environmental hazard assessment; (y) potential impacts to landholder bores as a result of stimulation activities; (z) the determination of the likelihood of causing interconnectivity and/or negative water quality as a result of stimulation activities undertaken in close proximity or each other; and (aa) potential environmental or health impacts which may result from stimulation activities including but not limited to water quality, air quality (including suppression of dust and other airborne contaminants), noise and vibration.	
Water Quality Baseline Monitoring		
I11	Prior to undertaking any stimulation activity, a baseline bore assessment must be undertaken of the water quality of: (a) all landholders' active groundwater bores (subject to access being permitted by the landholder) that are spatially within a two (2) kilometre horizontal radius from the location of the stimulation initiation point within the target gas producing formation; and (b) all landholders' active groundwater bores (subject to access being permitted by the landholder) in any aquifer that is within 200 metres above or below the target gas producing formation and is spatially located with a two (2) kilometre radius from the location of the stimulation initiation point; and (c) any other bore that could potentially be adversely impacted by the stimulation activity(ies) in accordance with the findings of the risk assessment required by conditions I9 and I10.	
I12	Prior to undertaking stimulation activities at a well, there must have sufficient water quality data to accurately represent the water quality in the well to be stimulated. The data must include, as a minimum, the results of analyses for the parameters in condition I13.	
I13	Baseline bore and well assessments must include relevant analytes and physicochemical parameters to be monitored in order to establish baseline water quality and must include, but not necessarily be limited to: (a) pH (b) electrical conductivity [µS/m] (c) turbidity [NTU] (d) total dissolved solids [mg/L] (e) temperature [°C] (f) dissolved oxygen [mg/L] (g) dissolved gases (methane, chlorine, carbon dioxide, hydrogen sulfide) [mg/L] (h) alkalinity (bicarbonate, carbonate, hydroxide and total as CaCO3) [mg/L] (i) sodium adsorption ratio (SAR) (j) anions (bicarbonate, carbonate, hydroxide, chloride, sulphate) [mg/L]	

	(k) cations (aluminium, calcium, magnesium, potassium, sodium) [mg/L] (l) dissolved and total metals and metalloids (including but not necessarily being limited to: aluminium, arsenic, barium, borate (boron), cadmium, total chromium, copper, iron, fluoride, lead, manganese, mercury, nickel, selenium, silver, strontium, tin and zinc) [µg/L] (m) total petroleum hydrocarbons [µg/L] (n) BTEX (as benzene, toluene, ethylbenzene, ortho-xylene, para- and meta-xylene, and total xylene) [µg/L] (o) polycyclic aromatic hydrocarbons (including but not necessarily being limited to: naphthalene, phenanthrene, benzo[a]pyrene) [µg/L] (p) sodium hypochlorite [mg/L] (q) sodium hydroxide [mg/L] (r) formaldehyde [mg/L] (s) ethanol [mg/L]; and (t) gross alpha + gross beta or radionuclides by gamma spectroscopy [Bq/L].	
I14	Despite condition I13, baseline bore and well assessment undertaken prior to 07 December 2022 must include the minimum water quality analytes and physico-chemical parameters identified in the Baseline Assessment Guideline (EHP) and any restricted stimulation fluids as defined in the Environmental Protection Act 1994, as amended from time to time, in order to establish baseline water quality.	
Simulation Impact Monitoring Program		
I15	Stimulation Impact Monitoring Program must be developed prior to the carrying out of stimulation activities which must be able to detect adverse impacts to water quality from stimulation activities and must consider the findings of the risk assessment required by conditions (I9) and (I10) that relate to stimulation activities and must include, as a minimum, monitoring of: (a) the stimulation fluids to be used in stimulation activities at sufficient frequency and which sufficiently represents the quantity and quality of the fluids used; and (b) flow back waters from stimulation activities at sufficient frequency and which sufficiently represents the quality of that flow back water; and (c) flow back waters from stimulation activities at sufficient frequency and accuracy to demonstrate that 150 per cent of the volume used in stimulation activities has been extracted from the stimulated well; and (d) all bores in accordance with condition (I11) at the following minimum frequency: (i) monthly for the first six (6) months subsequent to the stimulation activities being undertaken; then (ii) annually for the first five (5) years subsequent to the stimulation activities being undertaken or until analytes and physico-chemical parameters listed in condition (I13) are not detected in concentrations above baseline bore monitoring data on two (2) consecutive monitoring occasions.	
I16	The Stimulation Impact Monitoring Program must provide for monitoring of: (a) analytes and physico-chemical parameters relevant to baseline bore and well assessments to enable data referencing and comparison including, but not necessarily being limited to the analytes and physico- chemical parameters in condition I13; and (b) any other analyte or physico-chemical parameters that will enable detection of adverse water quality impacts and the inter-connection with a non-target aquifer as a result of stimulation activities including chemical compounds that are actually or potentially formed by chemical reactions with each other or coal seam materials during stimulation activities.	
I17	The results of the Stimulation Impact Monitoring Program must be made available to any potentially affected landholders upon request by that landholder.	
Schedule J – Rehabilitation		
Rehabilitation Planning		

J1	A Rehabilitation Plan must be developed by a suitably qualified person and must include the: (a) rehabilitation goals; and (b) procedures to be undertaken for rehabilitation that will: (i) achieve the requirements of conditions (J2) to (J6) inclusive; and (ii) provide for appropriate monitoring and maintenance.	
Transitional Rehabilitation		
J2	Significantly disturbed areas that are no longer required for the on-going petroleum activities, must be rehabilitated within 12 months (unless an exceptional circumstance in the area to be rehabilitated (e.g. a flood event) prevents this timeframe being met) and be maintained to meet the following acceptance criteria: (a) contaminated land resulting from petroleum activities is remediated and rehabilitated; (b) the areas are: (i) non-polluting; (ii) a stable landform; (iii) re-profiled to contours consistent with the surrounding landform (c) surface drainage lines are re-established; (d) top soil is reinstated; and (e) either: (i) groundcover, that is not a prohibited or restricted pest species, is growing; or (ii) an alternative soil stabilisation methodology that achieves effective stabilisation is implemented and maintained.	
Remaining Dams		
J3	Where there is a dam, (including a low consequence dam) that is being or intended to be used by the landholder or overlapping tenure holder, the dam must be decommissioned to no longer accept inflow from the petroleum activity(ies) and the contained water must be of a quality suitable for the intended on- going uses(s) by the landholder or overlapping tenure holder.	
Pipeline Activities		
J4	Pipeline trenches must be backfilled and topsoils reinstated within three months after pipe laying.	
J5	Reinstatement and revegetation of the pipeline right of way must commence within 6 months after cessation of petroleum activities for the purpose of pipeline construction.	
J6	Backfilled, reinstated and revegetated pipeline trenches and right of ways must be: (a) a stable landform (b) re-profiled to a level consistent with surrounding soils (c) re-profiled to original contours and established drainage lines; and (d) vegetated with groundcover which is not a prohibited or restricted pest species, and which is established and growing.	
Final Rehabilitation Acceptance Criteria		
J7	All significantly disturbed areas caused by petroleum activities which are not being or intended to be utilised by the landholder or overlapping tenure holder, must be rehabilitated to meet the following final acceptance criteria measured either against the highest ecological value adjacent land use or the pre- disturbed land use: (a) greater than or equal to 70 per cent of native ground cover species richness (b) greater than or equal to the total per cent ground cover (c) less than or equal to the per cent species richness of prohibited or restricted pest species	

	(d) where the adjacent land use contains, or the pre-clearing land use contained, one or more regional ecosystem(s), then: (i) at least one Regional Ecosystem(s) from the same broad vegetation group, as demonstrated by the predominant species in the ecologically dominant layer, must be present; and, (ii) the Regional Ecosystem present in J7(d)(i) must possess an equivalent or higher conservation value (biodiversity status) than the Regional ecosystem(s) in either the adjacent land or pre-disturbed land.	
Final Rehabilitation Acceptance Criteria in Environmentally Sensitive Areas		
J8	Where significant disturbance to land has occurred in an environmentally sensitive area, the following final rehabilitation criteria as measured against the pre- disturbance biodiversity values assessment (required by conditions D1 and D3) must be met: (a) greater than or equal to 70% of native ground cover species richness (b) greater than or equal to the total per cent ground cover (c) less than or equal to the per cent species richness of Prohibited or restricted pest species (d) greater than or equal to 50% of organic litter cover (e) greater than or equal to 50% of total density of coarse woody material; and (f) all predominant species in the ecologically dominant layer, that define the pre-disturbance regional ecosystem(s) are present.	
Schedule K – Notification		
K1	The administering authority must be notified through the Pollution Hotline as soon as reasonably practicable, but within 48 hours after becoming aware of: (a) any unauthorised significant disturbance to land; or (b) any unauthorised release of contaminants greater than: (i) 200 L of hydrocarbons; or (ii) 200 L of stimulation additives; or (iii) 500 L of stimulation fluids; or (iv). (iv) 1,000 L of brine; or (v) 5,000 L of coal seam gas water; or (vi). (vi) 10,000 L of sewage effluent; (vii) 100,000 L of irrigation-quality coal seam gas water, released inside a designated irrigation area authorised by condition C8(c). (c) a potential or actual loss of structural or hydraulic integrity of a dam; or (d) when the level of the contents of any regulated dam reaches the mandatory reporting level; or (e) when a regulated dam will not have available storage to meet the design storage allowance on the 1 November of any year; or (f) any incident where there is a potential or actual loss of well integrity (e.g. when the annulus pressure during stimulation increases by more than 3.5 MPa from the pressure immediately preceding stimulation); or (g) any detection of restricted stimulation fluids from stimulation fluid monitoring; or (h) any analyses result from baseline bore, well or stimulation impact monitoring that exceeds a water quality objective for the protection of an environmental value of that water resource; or (i) any analyses result from groundwater monitoring that exceeds trigger action investigation levels, if provided in this environmental authority.	
K2	The notification of emergencies or incidents as required by condition K1 must include but not be limited to the following information: (a) the environmental authority number and name of the holder; (b) the tenure type and number where the emergency or incident occurred; (c) the name and telephone number of the designated contact person;	

	(d) the location of the emergency or incident (GDA94); (e) the date and time that the emergency or incident occurred; (f) the date and time the holder of this environmental authority became aware of the emergency or incident; (g) details of the nature of the event and the circumstances in which it occurred; (h) the estimated quantity and type of any contaminants involved in the incident; (i) the actual or potential suspected cause of the emergency or incident; (j) a description of the land use at the site of the emergency or incident (e.g. grazing, pasture, forest etc.) and/or the name of any relevant waters and other environmentally sensitive features; (k) a description of the possible impacts from the emergency or incident; (l) a description of whether stock and/or wildlife were exposed to any contaminants released and measures taken to prevent access for the duration of the emergency or incident; (m) any sampling conducted or proposed, relevant to the emergency or incident; (n) landholder details and details of landholder consultation; (o) immediate actions taken to control the impacts of the emergency or incident and how environmental harm was mitigated at the time of the emergency or incident; and (p) whether further examination/root cause analysis is required and if so, the expected date by when this examination will be completed and reported to the administering authority.	
K3	Within 10 business days following the initial notification under conditions K1 and K2 unless a longer time is agreed to by the administering authority, a written report must be provided to the administering authority, including the following (where relevant to the emergency or incident): (a) the root cause of the emergency or incident; (b) the confirmed quantities and types of any contaminants involved in the incident; (c) results and interpretation of any analysis of samples taken at the time of the emergency or incident (including the analysis results of any impact monitoring); (d) a final assessment of the impacts from the emergency or incident including any actual or potential environmental harm that has occurred or may occur in the longer term as a result of the release; (e) the success or otherwise of actions taken at the time of the incident to prevent or minimise environmental harm; (f) results and current status of landholder consultation, including commitment to resolve any outstanding issues/concerns; and (g) actions and/or procedural changes to prevent a recurrence of the emergency or incident.	

Definitions

Key terms and/or phrases used in this document are defined in this section. Where a term is not defined, the definition in the Environmental Protection Act 1994, its regulations or environmental protection policies must be used. If a word remains undefined it has its ordinary meaning.

Word or Phrase	Definitions
Adjacent Land Use(s)	means the ecosystem function adjacent to an area of significant disturbance, or where there is no ecosystem function, the use of the land. An adjacent land use does not include an adjacent area that shows evidence of edge effect.
Administering Authority	means:

<table>
<tr><td></td><td>a) for a matter, the administration and enforcement of which has been devolved to a local government under section 514 of the Environmental Protection Act 1994 the local government; or
b) for all other matters the Chief Executive of the Department of Environment, Science and Innovation; or
c) another State Government Department, Authority, Storage Operator, Board or Trust, whose role is to administer provisions under other enacted legislation.</td></tr>
<tr><td>Affected Person</td><td>is someone whose drinking water can potentially be impacted as a result of discharges from a dam or their life or property can be put at risk due to dwellings or workplaces being in the path of a dam break flood.</td></tr>
<tr><td>AHD</td><td>means Australian Height Datum and is the datum used for the determination of elevations in Australia. The determination uses a national network of benchmarks and tide gauges and sets mean sea level at zero elevation.</td></tr>
<tr><td>Alternative Arrangement</td><td>means a written agreement about the way in which a particular environmental nuisance impact will be dealt with at a sensitive place and may include an agreed period of time for which the arrangement is in place. An alternative arrangement may include, but is not limited to, a range of nuisance abatement measures to be installed at the sensitive place, or provision of alternative accommodation for the duration of the relevant nuisance impact.</td></tr>
<tr><td>Analogue Site</td><td>means an area of land which contains values and characteristics representative of an area to be rehabilitated prior to disturbance. Such values must encompass land use, topographic, soil, vegetation, vegetation community attributes and other ecological characteristics. Analogue sites can be the pre-disturbed site of interest where significant surveying effort has been undertaken to establish benchmark parameters.</td></tr>
<tr><td>Analytes</td><td>means a chemical parameter determined by either physical measurement in the field or by laboratory analysis.</td></tr>
<tr><td>Annual Exceedance Probability or AEP</td><td>the probability that at least one event in excess of a particular magnitude will occur in any given year.</td></tr>
<tr><td>Appraisal well</td><td>means a petroleum well to test the potential of one (1) or more natural underground reservoirs for producing or storing petroleum. For clarity, an appraisal well does not include an exploration well.</td></tr>
<tr><td>Approved quality criteria</td><td>for the purposes of residual drilling materials, means the residual drilling material meet the following quality standards:
Part A In all cases:
<table><tr><th>Parameter</th><th>Maximum concentration</th></tr><tr><td>pH</td><td>6-10.5 (range)</td></tr><tr><td>Electrical Conductivity</td><td>20 dS/m (20,000 µS/cm)</td></tr><tr><td>Chloride*</td><td>8000 mg/L</td></tr></table>
*Chloride analysis is only required if an additive containing chloride was used in the drilling process.
The limits in Part A must be measured in the clarified filtrate of oversaturated solids prior to mixing.
Part B If any of the following metals are a component of the drilling fluids, then for that metal:
<table><tr><th>Parameter</th><th>Maximum concentration</th></tr><tr><td>Arsenic</td><td>20 mg/kg</td></tr><tr><td>Selenium</td><td>5 mg/kg</td></tr><tr><td>Boron</td><td>100 mg/kg</td></tr><tr><td>Cadmium
Chromium</td><td>3 mg/kg
400 mg/kg</td></tr><tr><td>Copper</td><td>100 mg/kg</td></tr><tr><td>Lead</td><td>600 mg/kg</td></tr></table></td></tr>
</table>

<table>
<tr><td></td><td>The limits in Part B and Part C refer to the post soil/by-product mix. Part C If a hydrocarbon sheen is visible, the following hydrocarbon fractions:
<table>
<tr><th>TPH</th><th>Maximum concentration</th></tr>
<tr><td>C6 – C10</td><td>170 mg/kg</td></tr>
<tr><td>C10 – C16</td><td>150 mg/kg</td></tr>
<tr><td>C16 – C34</td><td>1300 mg/kg</td></tr>
<tr><td>C34 – C40</td><td>5600 mg/kg</td></tr>
<tr><td>Total Polycyclic Aromatic Hydrocarbons (PAHs)</td><td>20 mg/kg</td></tr>
<tr><td>Phenols (halogenated)</td><td>1 mg/kg</td></tr>
<tr><td>Phenols (non-halogenated)</td><td>60 mg/kg</td></tr>
<tr><td>Monocyclic aromatic hydrocarbons (Total sum of benzene, toluene, ethyl benzene, xylenes including otho, para and meta xylenes) and styrene)</td><td>7 mg/kg</td></tr>
<tr><td>Benzene</td><td>1 mg/kg</td></tr>
</table></td></tr>
<tr><td>Areas of Pre-existing Disturbance</td><td>means areas where environmental values have been negatively impacted as a result of anthropogenic activity and these impacts are still evident. Areas of pre-disturbance may include areas where legal clearing, logging, timber harvesting, or grazing activities have previously occurred, where high densities of weed or pest species are present which have inhibited re-colonisation of native regrowth, or where there is existing infrastructure (regardless of whether the infrastructure is associated with the authorised petroleum activities). The term ‘areas of pre-disturbance’ does not include areas that have been impacted by wildfire/s, controlled burning, flood or natural vegetation die-back.</td></tr>
<tr><td>Assessed or Assessment</td><td>by a suitably qualified and experienced person in relation to a consequence assessment of a dam, means that a statutory declaration has been made by that person and, when taken together with any attached or appended documents referenced in that declaration, all of the following aspects are addressed and are sufficient to allow an independent audit of the assessment:
a) exactly what has been assessed and the precise nature of that determination;
b) the relevant legislative, regulatory and technical criteria on which the assessment has been based;
c) the relevant data and facts on which the assessment has been based, the source of that material, and the efforts made to obtain all relevant data and facts; and
d) the reasoning on which the assessment has been based using the relevant data and facts, and the relevant criteria.</td></tr>
<tr><td>Associated Water</td><td>means underground water taken or interfered with, if the taking or interference happens during the course of, or results from, the carrying out of another authorised activity under a petroleum authority, such as a petroleum well, and includes waters also known as produced formation water. The term includes all contaminants suspended or dissolved within the water.</td></tr>
<tr><td>Associated works</td><td>in relation to a dam, means:
a) operations of any kind and all things constructed, erected or installed for that dam; and
b) any land used for those operations.</td></tr>
<tr><td>Australian Standard 2187</td><td>means Australian Standard 2187.0:1998 Explosives—Storage, transport and use, Part 0, Australian Standard 2187.1:1998 Explosives—Storage, transport and use Part 1 and Australian Standard 2187.2:2006 Explosives—Storage</td></tr>
</table>

	and use, Part 2 or any updated versions that becomes available from time to time.
Australian Standard 3580	means any of the following publications: • AS3580.10.1 Methods for sampling and analysis of ambient air - Determination of particulate matter - Deposited matter - Gravimetric method. • AS3580.9.6 Methods for sampling and analysis of ambient air Determination of suspended particulate matter PM10 high volume sampler with size-selective inlet Gravimetric method • AS3580.9.9 Methods for sampling and analysis of ambient air Determination of suspended particulate matter PM10 low volume sampler Gravimetric sampler.
Australian Standard 4323	means Australian Standard 4323.1:1995 Stationary source emissions method 1: Selection of sampling positions.
Authority	means an environmental authority.
Background noise level	means the sound pressure level, measured in the absence of the noise under investigation, as the L A90, T being the A-weighted sound pressure level exceeded for 90 per cent of the measurement time period T of not less than 15 minutes, using Fast response.
Bed and Banks	for a watercourse or wetland means land over which the water of the watercourse or wetland normally flows or that is normally covered by the water, whether permanently or intermittently; but does not include land adjoining or adjacent to the bed or banks that is from time to time covered by floodwater.
Being or intended to be utilised by the landholder or overlapping tenure holder	for significantly disturbed land, means there is a written agreement (e.g. land and compensation agreement) between the landholder or the overlapping tenure holder and the holder of the environmental authority identifying that the landholder or the overlapping tenure holder has a preferred use of the land such that rehabilitation standards for revegetation by the holder of the environmental authority are not required. For dams, means there is a written agreement (e.g. land and compensation agreement) between the landholder or the overlapping tenure holder and the environmental authority holder identifying that the landholder or the overlapping tenure holder has a preferred use for the dam such that rehabilitation standards for revegetation by the holder of the environmental authority are not required.
Beneficial use	means with respect to dams, that the current or proposed owner of the land on which a dam stands, has found a use for that dam that is: • of benefit to that owner in that it adds real value to their business or to the general community, • in accordance with relevant provisions of the Waste Reduction and Recycling Act 2011, • sustainable by virtue of written undertakings given by that owner to maintain that dam, and • the transfer and use have been approved or authorised under any relevant legislation. Or, with respect to coal seam gas water, refer to the Department of Environment and Heritage Protection's Guideline – Approval of Coal Seam Gas Water for Beneficial Use.
Bore	means a water observation bore or a water supply bore that is either sub artesian or artesian.
Brine	means saline water with a total dissolved solid concentration greater than 40 000 mg/l.
BTEX	means benzene, toluene, ethylbenzene, ortho-xylene, para-xylene, meta-xylene and total xylene.

Bund or bunded	in relation to spill containment systems for fabricated or manufactured tanks or containers designed to a recognised standard means an embankment or wall of brick, stone, concrete or other impervious material which may form part or all of the perimeter of a compound and provides a barrier to retain liquid. Since the bund is the main part of a spill containment system, the whole system (or bunded area) is sometimes colloquially referred to within industry as the bund. The bund is designed to contain spillages and leaks from liquids used, stored or processed above ground and to facilitate clean-up operations. As well as being used to prevent pollution of the receiving environment, bunds are also used for fire protection, product recovery and process isolation.
Business day	has the meaning in the Acts Interpretation Act 1954 and Environmental Protection Act 1994 and means a day that is not— • a Saturday or Sunday; or • a public holiday, special holiday or bank holiday in the place in which any relevant act is to be or may be done; or • a business day that occurs during the period starting on 20 December in a year and ending on 5 January in the following year.
Category A Environmentally Sensitive Area	means any area listed in Schedule 19, part 1, section 1 of the Environmental Protection Regulation 2019.
Category B Environmentally Sensitive Area	means any area listed in Schedule 19, part 1, section 2 of the Environmental Protection Regulation 2019.
Category C Environmentally Sensitive Area	means any of the following areas: • Nature Refuges as defined under the Nature Conservation Act 1992; • Koala Habitat Areas as defined under the Nature Conservation (Koala) Conservation Plan 2006; • State Forests or Timber Reserves as defined under the Forestry Act 1959; • Regional parks (resource use area) under the Nature Conservation Act 1992; • An area validated as “Essential Habitat” from ground-truthing surveys in accordance with the Vegetation Management Act 1999 for a species of wildlife listed as endangered or vulnerable under the Nature Conservation Act 1992; • Of Concern Regional Ecosystems that are remnant vegetation identified in the database called ‘RE description database’ containing Regional Ecosystem numbers and descriptions.
Certifying or Certify or Certified or Certification	in relation to a dam, means assessment and approval must be undertaken by a suitably qualified and experienced person in relation to any assessment or documentation required by this Manual, including design plans, ‘as constructed’ drawings and specifications, construction, operation or an annual report regarding regulated structures, undertaken in accordance with the Board of Professional Engineers of Queensland Policy Certification by RPEQs (ID:1.4 (2A))
Certifying or Certify or Certified or Certification	in relation to any matter other than a design plan, ‘as constructed’ drawings or an annual report regarding dams means, a Statutory Declaration by a suitably qualified person or suitably qualified third-party accompanying the written document stating: • The person’s qualifications and experience relevant to the function; • that the person has not knowingly included false, misleading or incomplete information in the document; • that the person has not knowingly failed to reveal any relevant information or document to the administering authority;

	• that the document addresses the relevant matters for the function and is factually correct; and • that the opinions expressed in the document are honestly and reasonably held.
Clearing	for vegetation: a) means remove, cut down, ringbark, push over, poison or destroy in any way including by burning, flooding or draining; but b) does not include destroying standing vegetation by stock or lopping a tree.
Closed-Loop Systems	means using waste on site in a way that does not release waste or contaminants in the waste to the environment.
Coal Seam Gas Water	means underground water brought to the surface of the earth, or moved underground in connection with exploring for, or producing coal seam gas.
Coal seam gas water concentrate	means the concentrated saline water waste stream from a water treatment process that does not exceed a total dissolved solid concentration of 40 000 mg/L.
Commercial species	means species as listed in parts 1, 2 and 3 of Schedule 6 of the Vegetation Management Regulation 2012, which are above the diameters / sizes specified in this Schedule for each listed species.
Consequence	in relation to a structure as defined, means the potential for environmental harm resulting from the collapse or failure of the structure to perform its primary purpose of containing, diverting or controlling flowable substances.
Consequence Category	means a category, either low, significant or high, into which a dam is assessed as a result of the application of tables and other criteria in the Manual for assessing consequence categories and hydraulic performance of structures (ESR/2016/1933).
Construction or Constructed	in relation to a dam includes building a new dam and modifying or lifting an existing dam, but does not include investigations and testing necessary for the purpose of preparing a design plan.
Control Measure	has the meaning in section 31 of the Environmental Protection Regulation 2019 and means a device, equipment, structure, or management strategy used to prevent or control the release of a contaminant or waste to the environment.
Daily Peak Design Capacity	for sewage treatment works, has the meaning in Schedule 2, section 63(4) of the Environmental Protection Regulation 2019 as the higher equivalent person (EP) for the works calculated using each of the formulae found in the definition for EP.
Dam	means a land-based structure or a void that is designed to contains, diverts or controls flowable substances, and includes any substances that are thereby contained, diverted or controlled by that land-based structure or void and associated works. A dam does not mean a fabricated or manufactured tank or container, designed and constructed to an Australian Standard that deals with strength and structural integrity of that tank or container.
Design Plan	is a document setting out how all identified consequence scenarios are addressed in the planned design and operation of a regulated structure.
Design Storage Allowance or DSA	means an available volume, estimated in accordance with the Manual for assessing consequence categories and hydraulic performance of structures (ESR/2016/1933) published by the administering authority, must be provided in a dam as at 1 November each year in order to prevent a discharge from that dam to an annual exceedance probability (AEP) specified in that Manual.
Development Well	means a petroleum well which produces or stores petroleum. For clarity, a development well does not include an appraisal well.
Discharge area	means:

	• that part of the land surface where groundwater discharge produces a net movement of water out of the groundwater; and • identified by an assessment process consistent with the document Salinity Management Handbook • Queensland Department of Natural Resources, 1997, as amended from time to time; or • identified by an approved salinity hazard map held by the administering authority.
Document	has the meaning in the Acts Interpretation Act 1954 and means: • any paper or other material on which there is writing; • any paper or other material on which there are marks; • figures, symbols or perforations having a meaning for a person qualified to interpret them; and • any disc, tape or other article or any material from which sounds, images, writings or messages are capable of being produced or reproduced (with or without the aid of another article or device).
Ecologically Dominant Layer	has the meaning in the Methodology for Surveying and Mapping of Regional Ecosystems and Vegetation Communities in Queensland (Version 3.2 August 2012) and means the layer making the greatest contribution to the overall biomass of the site and the vegetation community (NLWRA 2001). This is also referred to as the ecologically dominant stratum or the predominant canopy in woody ecosystems.
Ecosystem Function	means the interactions between and within living and nonliving components of an ecosystem and generally correlates with the size, shape and location of the vegetation community.
Enclosed Flare	means a device where the residual gas is burned in a cylindrical or rectangular enclosure that includes a burning system and a damper where air for the combustion reaction is admitted.
Environmental Harm	has the meaning in section 14 of the Environmental Protection Act 1994 and means any adverse effect, or potential adverse effect (whether temporary or permanent and of whatever magnitude, duration or frequency) on an environmental value, and includes environmental nuisance. Environmental harm may be caused by an activity a) whether the harm is a direct or indirect result of the activity; or b) whether the harm results from the activity alone or from the combined effects of the activity and other activities or factors.
Environmental Nuisance	has the meaning in section 15 of the Environmental Protection Act 1994 and means unreasonable interference or likely interference with an environmental value caused by a) aerosols, fumes, light, noise, odour, particles or smoke; or b) an unhealthy, offensive or unsightly condition because of contamination; or c) another way prescribed by regulation.
Equivalent Person or EP	has the meaning under section 3 of the Planning Guidelines For Water Supply and Sewerage, 2005, published by the Queensland Government. It is calculated in accordance with Schedule 2, Section 63(4) of the Environmental Protection Regulation 2019 where: • EP = V/200 where V is the volume, in litres, of the average dry weather flow of sewage that can be treated at the works in a day; or • EP = M/2.5 where M is the mass, in grams, of phosphorus in the influent that the works are designed to treat as the inlet load in a day.
Essential Habitat	essential habitat means section 20AC (2) of the Vegetation Management Act 1999 validated as 'protected wildlife habitat' from ground-truthing surveys for

	species of wildlife identified as critically endangered, endangered or vulnerable under the Nature Conservation Act 1992.
Evaporation dam	means an impoundment, enclosure or structure that is designed to be used to hold CSG water for evaporation.
Exploring for petroleum	means carrying out an activity for the purpose of finding petroleum or natural underground reservoirs as per section 14 of the Petroleum and Gas (Production and Safety) Act 2004 for example including: • conducting a geochemical, geological or geophysical survey; • drilling a well; • carrying out testing in relation to a well; • taking a sample for chemical or other analysis.
Exploration Well	means a petroleum well that is drilled to: • explore for the presence of petroleum or natural underground reservoirs suitable for storing petroleum; or • obtain stratigraphic information for the purpose of exploring for petroleum. For clarity, an exploration well does not include an appraisal or development well.
Fill	means any kind of material in solid form (whether or not naturally occurring) capable of being deposited at a place but does not include material that forms a part of, or is associated with, a structure constructed in a watercourse or wetland including a bridge, road, causeway, pipeline, rock revetment, drain outlet works, erosion prevention structure or fence.
Flare Pit	has the meaning in the Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933), and means containment area where any hydrocarbon that is discovered in an over-pressured reservoir during a drilling operation is diverted to, and combusted, The flare pit is only used during the drilling and work over process on a petroleum well.
Flare Precipitant	means waste fluids which result from the operation of a flare.
Floodplain	has the meaning in the Water Act 2000 and means an area of reasonably flat land adjacent to a watercourse that: • is covered from time to time by floodwater overflowing from the watercourse; and • does not, other than in an upper valley reach, confine floodwater to generally follow the path of the watercourse; and • has finer sediment deposits than the sediment deposits of any bench, bar or in-stream island in the watercourse.
Flowable substance	means matter or a mixture of materials which can flow under any conditions potentially affecting that substance. Constituents of a flowable substance can include water, other liquids fluids or solids, or a mixture that includes water and any other liquids fluids or solids either in solution or suspension.
Fuel burning or combustion equipment	means a permanent fuel burning or combustion equipment which is in isolation, or combined in operation, or which are interconnected, is, or is capable of burning more than 500 kg of fuel in an hour.
GDA	means Geocentric Datum of Australia.
Geophysical survey	means a systematic collection of geophysical data.
Great Artesian Basin (GAB) spring	means an area protected under the Environment Protection and Biodiversity Conservation Act 1999 because it is considered to be a Matter of National Environmental Significance and identified as a: • community of native species dependent on natural discharge of groundwater from the Great Artesian Basin; or

	• Great Artesian Basin spring; or • Great Artesian Basin discharge spring wetland. A GAB spring includes a spring vent, spring complex or watercourse spring and includes the land to which water rises naturally from below the ground and the land over which the water then flows. Note: The Australian Government's Protected Matters Search Tool should be used to get an indication of whether the area of interest may contain an MNES spring. Note: The GAB springs dataset can be requested from the Queensland Government Herbarium.
Greywater	means wastewater generated from domestic activities such as laundry, dishwashing, and bathing. Greywater does not include sewage.
Groundwater Dependent Ecosystems (GDE)	means ecosystems which require access to groundwater on a permanent or intermittent basis to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services. For the purposes of the environmental authority, groundwater dependent ecosystems do not include those mapped as "unknown".
Growing	means to increase by natural development, as any living organism or part thereof by assimilation of nutriment; increase in size or substance.
High value regrowth	vegetation means vegetation located — (a) on freehold land, indigenous land, or land subject of a lease issued under the Land Act 1994 for agriculture or grazing purposes or an occupation licence under that Act; and (b) in an area that has not been cleared (other than for relevant clearing activities) for at least 15 years, if the area is — (i) an endangered regional ecosystem; or (ii) an of concern regional ecosystem; or (iii) a least concern regional ecosystem.
Holder	means any person who is the holder of, or is acting under, that environmental authority.
Hydraulic fracturing	means a technique used to create cracks in underground coal seams to increase the flow and recovery of gas or oil out of a well. It involves pumping a fluid, comprised largely of water and sand, under pressure, into a coal seam. This action fractures the coal seam which provides a pathway that increases the ability for gas to flow through the coal.
Hydraulic performance	means the capacity of a regulated dam to contain or safely pass flowable substances based on the design criteria specified for the relevant consequence category in the Manual for assessing consequence categories and hydraulic performance of structures (ESR/2016/1933).
Hydraulic testing	means the testing of a geological formation to evaluate the hydrogeological characteristics of the formation.
Impulsive noise	means sound characterised by brief excursions of sound pressure (acoustic impulses) that significantly exceed the background sound pressure. The duration of a single impulsive sound is usually less than one second.
Incidental activity	for this environmental authority means an activity that is not a specified relevant activity and is necessary to carry out the activities listed in Schedule A, Table 1 – Scale and Intensity for the Activities.
Infrastructure	means plant or works including for example, communication systems, compressors, powerlines, pumping stations, reservoirs, roads and tracks, water storage dams, evaporation or storage ponds and tanks, equipment, buildings and other structures built for the purpose and duration of the conduct of the petroleum activity(ies) including temporary structures or

	structures of an industrial or technical nature, including, for example, mobile and temporary camps. Infrastructure does not include other facilities required for the long-term management of the impact of those petroleum activities or the protection of potential resources. Such other facilities include dams other than water storage dams (e.g. evaporation dams), pipelines and assets, that have been decommissioned, rehabilitated, and lawfully recognised as being subject to subsequent transfer with ownership of the land.
LAeq, adj, 15 mins	means the A-weighted sound pressure level of a continuous steady sound, adjusted for tonal character, that within any 15 minute period has the same square sound pressure as a sound level that varies with time.
LA 90, adj, 15 mins	means the A-weighted sound pressure level, adjusted for tonal character, that is equal to or exceeded for 90 per cent of any 15 minutes sample period equal, using Fast response.
Lake	means: • a lagoon, swamp or other natural collection of water, whether permanent or intermittent; and • the bed and banks and any other element confining or containing the water.
Land degradation	has the meaning in the Vegetation Management Act 1999 and means the following: • soil erosion • rising water tables • the expression of salinity • mass movement by gravity of soil or rock • stream bank instability • a process that results in declining water quality.
Landholders' Active Groundwater Bores	means bores that are able to continue to provide a reasonable yield of water in terms of quantity for the bores authorised purpose or use. This term does not include monitoring bores owned by the administering authority of the Water Act 2000.
Limited impact camps	mean accommodation camps that: • are temporary (no more than 6 months); • are located within pre-existing areas of clearing or significant disturbance; • are up to 2 ha or located within well sites; and • may involve sewage treatment works that are no release works or release works that involve an irrigation release within pre-existing areas of clearing or significant disturbance.
Limited Impact Petroleum Activities	means petroleum activities that are located within areas that are not a regional ecosystem and: • are single well sites (includes observation, pilot, injection and production wells) greater than 1 ha; or • are multi-well sites greater than 1 ha; and • may involve construction of new access tracks that are required as part of the construction or servicing a petroleum activity that can be lawfully carried out within an ESA or its protection zone; and • may involve upgrading or maintenance of existing roads or tracks; and • may include power and communication lines; and • may include gas gathering lines from a well site to the initial compression facility; and

	• may include water gathering lines from a well site to the initial water storage or dam.
Limited Petroleum Activities	mean any low impact petroleum activity, and: • single well sites (includes observation, pilot, injection and production wells) up to 1 ha and associated infrastructure (water pumps and generators, sumps, flare pits or dams) located on the well site or up to 1.25 ha if the well pad includes the use of a tank (minimum 1ML) for above ground fluid storage, • multi-well sites up to an additional (in addition to single well site above) 0.25 ha per additional well and associated infrastructure (water pumps and generators, sumps, flare pits, dams or tanks) located on the well site to a maximum of 3 ha, • construction of new access tracks that are required as part of the construction or servicing a petroleum activity that can be lawfully carried out within an ESA or its protection zone upgrading or maintenance of existing roads or tracks, • power and communication lines, • gas gathering lines from a well site to the initial compression facility, • water gathering lines from a well site to the initial water storage or dam, • camps within well site that may involve sewage treatment works that are a no release works. • activities necessary to achieve compliance with the conditions of the EA in relation to another limited petroleum activity (e.g. sediment and erosion control measures, rehabilitation), • geophysical, geotechnical, geological, topographic and cadastral surveys (including seismic, sample /test / geotechnical pits, core holes).
Linear infrastructure	means powerlines, communication, pipelines, roads and access tracks.
Long term noise event	is a noise exposure, when perceived at a sensitive receptor, persists for a period of greater than five (5) days, even when there are respite periods when the noise is inaudible within those five (5) days.
Lopping	a tree, means cutting or pruning its branches, but does not include — • removing its trunk; and • cutting or pruning its branches so severely that it is likely to die.
Low Consequence Dam	means any dam that is not a high or significant consequence category as assessed using the Manual for assessing consequence categories and hydraulic performance of structures (ESR/2016/1933).
Low flow	means flow up to the one month average recurrence interval.
Low impact petroleum activities	means petroleum activities which do not result in the clearing of native vegetation, earthworks or excavation work that cause either, a significant disruption to the soil profile or permanent damage to vegetation that cannot be easily rehabilitated immediately after the activity is completed. Examples of such activities include but are not necessarily limited to: • chipholes • coreholes • geophysical surveys • seismic surveys • soil surveys • topographic surveys • cadastral surveys • ecological surveys

	• installation of environmental monitoring equipment (including surface water).
Map of Queensland wetland environmental values	means the statutory map under the Environmental Protection (Water and Wetland Biodiversity) Policy 2019. It identifies wetlands of high ecological significance (HES) and general ecological significance (GES) across the state.
Max LpZ, 15 min	means the maximum value of the Z-weighted sound pressure level measured over 15 minutes.
Max LpA, 15 min	means the absolute maximum instantaneous A-weighted sound pressure level, measured over 15 minutes.
Mandatory Reporting Level or MRL	means a warning and reporting level determined in accordance with the criteria in the Manual for assessing consequence categories and hydraulic performance of structures (ESR/2016/1933) published by the administering authority.
Manual	in reference to dams means the Manual for assessing consequence categories and hydraulic performance of structures (ESR/2016/1933) published by the administering authority, as amended from time to time.
Medium term noise event	is a noise exposure, when perceived at a sensitive receptor, persists for an aggregate period not greater than five (5) days and does not re-occur for a period of at least four (4) weeks. Re- occurrence is deemed to apply where a noise of comparable level is observed at the same receptor location for a period of one hour or more, even if it originates from a difference source or source location.
Methodology	means the science of method, especially dealing with the logical principles underlying the organization of the various special sciences, and the conduct of scientific inquiry.
Mix-bury-cover method	means the stabilisation of residual drilling solids in the bottom of a sump by mixing with subsoil and which occurs in accordance with the following methodology: • the base of the subsoil and residual solid mixture must be separated from the groundwater table by at least one metre of a continuous layer of impermeable subsoil material (kw = 10– 8 m/s) or subsoil with a clay content of greater than 20per cent; and • the residual solids is mixed with subsoil in the sump and cover; and • the subsoil and residual solids is mixed at least three parts subsoil to one part waste (v/v); and • a minimum of one metre of clean subsoil must be placed over the subsoil and residual solids mixture; and topsoil is replaced.
Month	has the meaning in the Acts Interpretation Act 1954 and means a calendar month and is a period starting at the beginning of any day of one (1) of the 12 named months and ending: • immediately before the beginning of the corresponding day of the next named month; or • if there is no such corresponding day—at the end of the next named month.
NATA accreditation	means accreditation by the National Association of Testing Authorities Australia.
Oil based drilling mud	means mud where the base fluid is a petroleum product such as diesel fuel.
Overburden pressure	means the pressure or stress imposed on a layer of soil or rock by the weight of overlying material. The overburden pressure at a depth z is given by p(z) = p0 + g ∫0≈ p(z) dz where p(z) is the density of the overlying rock at depth z

	and g is the acceleration due to gravity. p0 is the datum pressure, like the pressure at the surface.
Pipeline Waste Water	means hydrostatic testing water, flush water or water from low point drains.
Pre-disturbed land use	means the function or use of the land as documented prior to significant disturbance occurring at that location.
Predominant species	has the meaning in the Methodology for Surveying and Mapping of Regional Ecosystems and Vegetation Communities in Queensland (Version 3.2 August 2012) and means a species that contributes most to the overall above-ground biomass of a particular stratum.
Prescribed Environmental Matter	has the meaning in section 10 of the Environmental Offsets Act 2014.
Primary protection zone	means an area within a 200 metre buffer from the boundary of any Category A, B or C Environmentally Sensitive Area.
Produced Water	has the meaning in Section 15A of the Petroleum and Gas (Production and Safety) Act 2004 and means CSG water or associated water for a petroleum tenure.
Prohibited or Restricted Pest Species	means any pest that is: a) a plant or animal, other than a native species of plant or animal, that is i. invasive biosecurity matter under the Biosecurity Act 2014 (Qld); or Notes — 1 See the Biosecurity Act 2014, schedule 1, part 3 or 4 or schedule 2, part 2; and 2 See the note to the Biosecurity Act 2014, schedules 1 and 2. ii. controlled biosecurity matter or regulated biosecurity matter under the Biosecurity Act 2014 (Qld) iii. tramp ants listed in schedule 1 and schedule 2 of the Biosecurity Act 2014 (Qld) b) pest declared under a local law by the local government for the Land to be a pest because the pest is causing, or has the potential to cause, an adverse environmental, economic or social impact in all or part of the local government area.
Regional ecosystem(s)	has the meaning in the Methodology for Surveying and Mapping of Regional Ecosystems and Vegetation Communities in Queensland (Version 3.2 August 2012) and means a vegetation community in a bioregion that is consistently associated with a particular combination geology, landform and soil. Regional ecosystems of Queensland were originally described in Sattler and Williams (1999). The Regional Ecosystems Description Database (Queensland Herbarium 2013) is maintained by Queensland Herbarium and contains the current descriptions of regional ecosystems.
Regulated structure	means any structure in the significant or high consequence category as assessed using the Manual for assessing consequence categories and hydraulic performance of structures (ESR/2016/1933) published by the administering authority. A regulated structure does not include: • a fabricated or manufactured tank or container, designed and constructed to an Australian Standard that deals with strength and structural integrity of that tank or container; • a sump or earthen pit used to store residual drilling material and drilling fluid only for the duration of drilling and well completion activities; • a flare pit.
Rehabilitation or rehabilitated	means the process of reshaping and revegetating land to restore it to a stable landform and in accordance with the acceptance criteria and, where relevant, includes remediation of contaminated land. For the purposes of pipeline rehabilitation, rehabilitation includes reinstatement, revegetation and restoration.

Reinstate or reinstatement	for pipelines, means the process of bulk earth works and structural replacement of pre-existing conditions of a site (i.e. soil surface typography, watercourses, culverts, fences and gates and other landscape(d) features) and is detailed in the APGA Code of Environmental Practice: Onshore Pipelines Revision 4 (2017).
Remnant vegetation	means vegetation, part of which forms the predominant canopy of the vegetation — • covering more than 50 per cent of the undisturbed predominant canopy; and • averaging more than 70 per cent of the vegetation's undisturbed height; and • composed of species characteristic of the vegetation's undisturbed predominant canopy cover.
Reporting limit	means the lowest concentration that can be reliably measured within specified limits of precision and accuracy during routine laboratory operating conditions. For many analytes, the reporting limit is selected as the lowest non-zero standard in the calibration curve. Results that fall below the reporting limit will be reported as "less than" the value of the reporting limit. The reporting limit is also referred to as the practical quantitation limit or the limit of quantitation. For polycyclic aromatic hydrocarbons, the reporting limit must be based on superultra trace methods and, depending on the specific polycyclic aromatic hydrocarbon, will range between 0.005 ug/L – 0.02 ug/L.
Residual drilling material	means waste drilling materials including muds and cuttings or cement returns from well holes and which have been left behind after the drilling fluids are pumped out.
Resource activity(ies)	has the meaning in section 107(d) of the Environmental Protection Act 1994.
Restoration	means the replacement of structural habitat complexity, ecosystem processes, services and function from a disturbed or degraded site to that of a predetermined or analogue site. For the purposes of pipelines, restoration applies to final rehabilitations after pipeline decommissioning.
Restricted stimulation fluids	means fluids used for the purpose of stimulation, including fracturing, that contain the following chemicals in more than the maximum amounts prescribed under section 70 of the Environmental Protection Regulation 2019: • petroleum hydrocarbons containing benzene, ethylbenzene, toluene or xylene; or • chemicals that produce, or are likely to produce, benzene, ethylbenzene, toluene or xylene as the chemical breaks down in the environment. The amount of any chemical is not measured in relation to water included in the restricted stimulation fluid. For clarity, the term restricted stimulation fluids only applies to fluids injected down well post-perforation.
Revegetation or revegetating or revegetate	means to actively re-establish vegetation through seeding or planting techniques in accordance with site specific management plans.
Secondary Protection Zone	in relation to a Category A or Category B ESA means an area within 100 metres from the boundary of the primary protection zone.
Sensitive Place	means: • a dwelling (including residential allotment, mobile home or caravan park, residential marina or other residential premises, motel, hotel or hostel); • a library, childcare centre, kindergarten, school, university or other educational institution;

	• a medical centre, surgery or hospital; • a protected area; • a public park or garden that is open to the public (whether or not on payment of money) for use other than for sport or organised entertainment; • a work place used as an office or for business or commercial purposes, which is not part of the petroleum activity(ies) and does not include employees accommodation or public roads; and • for noise, a place defined as a sensitive receptor for the purposes of the Environmental Protection (Noise) Policy 2019.
Sensitive receptor	is defined in Schedule 2 of the Environmental Protection (Noise) Policy 2019, and means an area or place where noise is measured.
Short term noise event	is a noise exposure, when perceived at a sensitive receptor, persists for an aggregate period not greater than eight hours and does not re-occur for a period of at least seven (7) days. Re- occurrence is deemed to apply where a noise of comparable level is observed at the same receptor location for a period of one hour or more, even if it originates from a different source or source location.
Significantly disturbed or significant disturbance or significant disturbance to land or areas	has the meaning in Schedule 12, section 4 of the Environmental Protection Regulation 2008. Land is significantly disturbed if – a) it is contaminated land; or b) it has been disturbed and human intervention is needed to rehabilitate it: i. to a condition required under the relevant environmental authority; or ii. if the environmental authority does not require the land to a particular conditions – to the condition it was in immediately before the disturbance
Site	means the relevant petroleum activity(ies) to which the environmental authority relates.
Specified relevant activities	for this environmental activity means an activity that: a) but for being carried out as a resource activity, would otherwise be an activity prescribed under section 19 of the Environmental Protection Act 1994 as an environmentally relevant activity; or b) stimulation activities; or c) extracting material other than by dredging.
Spillway	means a weir, channel, conduit, tunnel, gate or other structure designed to permit discharges from the dam, normally under flood conditions or in anticipation of flood conditions.
Stable	has the meaning in Schedule 8 of the Environmental Protection Regulation 2019 and for a site, means the rehabilitation and restoration of the site is enduring or permanent so that the site is unlikely to collapse, erode or subside.
Stimulation	means a technique used to increase the permeability of a natural underground reservoir, including for example, hydraulic fracturing/hydrofracking, fracture acidizing and the use of proppant treatments.
Stimulation fluid	means the fluid injected into an aquifer to increase the permeability of a natural underground reservoir. For clarity, the term stimulation fluid only applies to fluids injected down well post- perforation.
Stimulation impact zone	means a 100 metre maximum radial distance from the stimulation target location within a gas producing formation.
Structure	for the purposes of Schedule H means a dam or levee.

Suitably qualified person	means a person who has professional qualifications, training, skills or experience relevant to the nominated subject matter and can give authoritative assessment, advice and analysis to performance relative to the subject matters using the relevant protocols, standards, methods or literature.
Suitably Qualified and Experienced Person	in relation to regulated structures means a person who is a Registered Professional Engineer of Queensland (RPEQ) under the provisions of the Professional Engineers Act 2002, and has demonstrated competency and relevant experience: • for regulated dams, an RPEQ who is a civil engineer with the required qualifications in dam safety and dam design • for regulated levees, an RPEQ who is a civil engineer with the required qualifications in the design of flood protection embankments. Note: It is permissible that a suitably qualified and experienced person obtain subsidiary certification from an RPEQ who has demonstrated competence and relevant experience in either geomechanics, hydraulic design or engineering hydrology.
Suitably qualified third-party	means a person who: a) has qualifications and experience relevant to performing the function including but not limited to: i. a bachelor's degree in science or engineering; and ii. 3 years' experience in undertaking soil contamination assessments; and b) is a member of at least one organisation prescribed in Schedule 14 of the Environmental Protection Regulation 2019; and not be an employee of, nor have a financial interest or any involvement which would lead to a conflict of interest with the holder(s) of the environmental authority.
Sump	means a pit in which waste residual drilling material or drilling fluids are stored only for the duration of drilling activities.
Synthetic based drilling mud	means a mud where the base fluid is a synthetic oil, consisting of chemical compounds which are artificially made or synthesised by chemically modifying petroleum components or other raw materials rather than the whole crude oil.
Third party auditor	means a suitably qualified person who is either a certified third-party auditor or an internal auditor employed by the holder of the environmental authority and the person is independent of the day to day management and operation of the petroleum activity(ies) covered by this environmental authority.
Topsoil	means the surface (top) layer of a soil profile, which is more fertile, darker in colour, better structured and supports greater biological activity than underlying layers. The surface layer may vary in depth depending on soil forming factors, including parent material, location and slope, but generally is not greater than about 300 mm in depth from the natural surface.
Total density of coarse woody material	means the total length of logs on the ground greater than or equal to 10 cm diameter per hectare and number of logs on the ground greater than or equal to 10cm diameter per hectare.
Transmissivity	means the rate of flow of water through a vertical strip of aquifer which is one unit wide and which extends the full saturated depth of the aquifer.
Valid complaint	means a complaint the administering authority considers is not frivolous, nor vexatious, nor based on mistaken belief.
Vegetation Management Act 1999 (VM Act) Class	has the meaning provided in Division 7A of the Vegetation Management Act 1999. The VM Act class for each Regional Ecosystem is provided in the Vegetation Management Regulation 2012.
Void	means any constructed, open excavation in the ground.

Waste and Resource Management Hierarchy	has the meaning provided in section 9 of the Waste Reduction and Recycling Act 2011 and is the following precepts, listed in the preferred order in which waste and resource management options should be considered: a) AVOID unnecessary resource consumption; b) REDUCE waste generation and disposal c) RE-USE waste resources without further manufacturing d) RECYCLE waste resources to make the same or different products e) RECOVER waste resources, including the recovery of energy f) TREAT waste before disposal, including reducing the hazardous nature of waste g) DISPOSE of waste only if there is no viable alternative.
Waste and Resource Management Principles	has the meaning provided in section 4(2)(b) of the Waste Reduction and Recycling Act 2011 and means the: a) polluter pays principle b) user pays principle c) proximity principle d) product stewardship principle.
Waste Fluids	has the meaning in section 13 of the Environmental Protection Act 1994 in conjunction with the common meaning of “fluid” which is “a substance which is capable of flowing and offers no permanent resistance to changes of shape”. Accordingly, to be a waste fluid, the waste must be a substance which is capable of flowing and offers no permanent resistance to changes of shape.
Watercourse	has the meaning in Schedule 4 of the Environmental Protection Act 1994 and means: 1) a river, creek or stream in which water flows permanently or intermittently a) in a natural channel, whether artificially improved or not; or b) in an artificial channel that has changed the course of the watercourse. 2) Watercourse includes the bed and banks and any other element of a river, creek or stream confining or containing water.
Waters	includes all or any part of a creek, river, stream, lake, lagoon, swamp, wetland, unconfined surface water, unconfined water in natural or artificial watercourses, bed and bank of any waters, non-tidal or tidal waters (including the sea), stormwater channel, stormwater drain, roadside gutter, stormwater run-off, and underground water.
Well Integrity	means the ability of a well to contain the substances flowing through it.
Well infrastructure	means infrastructure required for the construction and completion of a well including but not limited to cellar pits, dams and drill sumps.
Well site	means a maximum area of land disturbance for the purposes of constructing, installing and operating an exploration, appraisal or development well or such wells as part of a multi-well arrangement and includes well lease infrastructure.
Wetland	for the purpose of this environmental authority, wetland means: • areas shown on the Map of Queensland wetland environmental values, which is a state-wide statutory map under the Environmental Protection (Water and Wetland Biodiversity) Policy 2019; and • areas defined under the Queensland Wetlands Program as permanent or periodic / intermittent inundation, with water that is static or flowing fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six (6) metres, and possess one or more of the following attributes:

	○ at least periodically, the land supports plants or animals that are adapted to and dependent on living in wet conditions for at least part of their life cycle, or ○ the substratum is predominantly undrained soils that are saturated, flooded or ponded long enough to develop anaerobic conditions in the upper layers, or ○ the substratum is not soil and is saturated with water, or covered by water at some time. The term wetland includes riverine, lacustrine, estuarine, marine and palustrine wetlands; and it does not include a Great Artesian Basin Spring or a subterranean wetland that is a cave or aquifer.
Wetlands of General Ecological Significance	"Wetlands of General Ecological Significance" or general ecologically significant wetland" is a wetland that meets the definition of a wetland and that is shown as a wetland of 'general ecological significance' on the Map of Queensland wetland environmental values.
Wetland of High Ecological Significance	otherwise known as "high conservation value wetland" is a wetland that meets the definition of a wetland and that is shown as a High Ecological Significance wetland on the Map of Queensland wetland environmental values.
Year	means a period of 12 months.
80th percentile	in relation to release limits means that not more than one (1) of the measured values is to exceed the stated release limit for any five (5) consecutive samples where: • the consecutive samples are taken over a five (5) month period; and • the consecutive samples are taken at approximately equal periods.
95th percentile	in relation to release limits means calculating the 95th percentile of all samples recorded over each 24 hour period for the duration of the release the result of which cannot exceed limits.

END OF ENVIRONMENTAL AUTHORITY

Appendix B: Detailed Description of Proposed Activities

Description of Proposed Activities

The following sections describe the proposed activities and infrastructure to be located and operated in the Project Area, respectively.

Seismic Surveys

Seismic acquisition is a method of investigating subsurface geological structures to identify locations to conduct drilling activities. Seismic data is collected by recording acoustic (sound) waves that are reflected from geological interfaces at depths of up to several thousand metres below surface. Seismic survey data is collected via use of “geophones” or “nodes” placed at regular intervals along “seismic lines”. Seismic lines are regularly ‘offset’ and ‘weaved’ around obstacles to:

(a) avoid the need to disturb terrain and long-lived perennial vegetation or other sensitivities such as watercourses; and

(b) reduce the ‘linearity’ and visual impact of seismic lines.

Seismic line preparation generally involves ‘walking’ a bulldozer with its front blade in the up position along seismic lines to gently flatten terrain and ground vegetation. Minor vegetation slashing can sometimes also be required. However, a range of methods can be utilised depending on the nature of data to be collected and sensitivity of the land to be surveyed. No seismic line preparation is typically undertaken in sensitive land systems.

Petroleum Exploration, Appraisal and Production wells

Well Lease Establishment

All CSG wells would be constructed on a prepared lease area which would accommodate the necessary drilling and well completion equipment and support infrastructure.

Single well leases will typically be no more than 1.25 hectares (ha) in size. Where additional area is needed to accommodate infrastructure such as a water balance tank or cut and fill lease construction, single well leases may be up to 1.5 ha in size. As discussed in Sections 2.1 and 2.2, Santos also proposes to utilise some multi-well leases to minimise disturbance, maximise gas recovery, and/or accommodate landholder requirements. Multi-well leases would be up to 2.5-3 ha in size, resulting in a larger footprint per lease area, but a reduced overall footprint per well given fewer single well leases would be required.

Where practicable, minimum disturbance leases would be used. These consist of the use of matting placed directly onto slashed vegetation to form a temporary hardstand surface (as opposed to a traditional lease, which involves clearing all vegetation and compacting / preparing the soil to form a hardstand surface).

More specifically, where a traditional lease is required, lease establishment involves:

- surveying and pegging the pad boundary
- constructing a diversion bund if required due to slope or proximity to watercourses
- clearing vegetation that is unable to be avoided
- removing and stockpiling topsoil
- levelling the pad by cutting and filling using material from borrow pit if required
- excavating and capping the rig hardstand
- capping and compacting the lease footprint
- excavating sump pit if required

- installing fencing and gate
- installing cellar and conductor on well centre
- installing pads for ancillary equipment and infrastructure (such a tanks and flowlines); and
- setting up drill rig and associated equipment.

Key equipment required on the lease during drilling includes:

- drill rig and associated equipment
- gas generator
- chemical and fuel storage
- mud pit or tank for drilling fluids
- flare and flare sump for disposal of gas during drilling and appraisal; and
- water storage (tank or small dam) for initial water supply and storage of PW during construction.

Drilling, Casing, and Cementing

There is potential for up to 24 wells to be constructed within the Project Area. All wells will be constructed in accordance with the *Code of Practice for the construction and abandonment of petroleum wells and associated bores in Queensland Version 2* (DNRME, 2019).

Drilling would occur on a 24-hour basis for approximately 1-3 weeks per well. The time to complete each well depends on the depth of the well, the geology of the area and the type of rig being used.

A variety of rotary and air drilling techniques are used to drill the well. Drilling fluids are continuously circulated down the drill pipe to lubricate and cool the drill bit and remove drill cuttings from the bore. Drilling fluid and cuttings are collected in surface tanks or in pits and removed from the well lease area for reuse, recycling or authorised disposal.

Through multiple cycles of drilling, installing casing and cementing casing, the well is isolated from surrounding formations. Santos would test and prove the integrity of the well prior to commencing gas extraction. The well casing within the coal seam is perforated to allow material from the coal seam to enter the well and go to surface. The wellhead is installed and completed with a pump and surface facilities.

Hydraulic Fracture Stimulation

Subject to trials and project planning, all wells to be located in the Project Area may be subject to stimulation (i.e. hydraulic fracturing) subject to trials to determine suitability of the process at the expected depth range. Hydraulic fracturing is necessary to properly assess the potential of the petroleum resource and inform decision making on future projects, as well as to increase the recovery of the resource.

Hydraulic fracturing involves pumping a fluid under pressure into the reservoir to open and connect fractures within the reservoir rock, thereby increasing the opportunity for the resource to move within the reservoir rock and flow toward the well. A proppant within the fluids holds the fractures open after the activity ceases. Approximately 99.5% of the material pumped into the well is water and sand. The remaining 0.5% is made up of minor quantities of additives used to:

- enhance fracture initiation
- help lubricate the flow of proppant (i.e., sand) into the fractures
- prevent microbial or chemical reactions following introduction of the fluids; and

- prevent formation of scale deposits that may affect the well or pumps.

Santos does not propose to use any restricted stimulation fluids as defined by proposed EA conditions and Section 206 of the EP Act and Section 70 of the EP Reg.

After the fracture process is completed and fluids that return to surface when the pressure is released are captured in tanks or lined pits for reuse, recycling or are transported to a licenced water management facility for treatment and/or disposal.

Hydraulic fracturing is a predominantly physical process in which hydraulic pressure is applied to a fluid to increase the effective permeability of the formation rock. The process creates narrow pathways (fractures) in the target formation to improve its ability to transmit gas back to and then out of the well.

After a pre-fracturing assessment and hydraulic fracturing design, onsite activities include site setup, perforation of the well casing and cement into discrete targeted sections of the cased bore (to access most viable gas bearing formation), injection of hydraulic fracturing fluid and flowback of the injected fluid. These processes are described in the following sections.

Pre-fracturing Assessment and Design

Operators investigate the subsurface conditions, including hydrogeological and mechanical properties of the target and surrounding geological units, to design the hydraulic fracturing program to strategically identify and reduce the possible risks involved (IESC, 2014).

To understand the geological formation and priorities for the hydraulic fracturing program, key aspects of subsurface characterisation (Beckwith, 2010) include:

- describing all geological units
- assessing target formation permeability
- analysing subsurface distribution of stresses and faults; and
- assessing fluid loss characteristics.

The hydraulic fracturing program is designed after the subsurface characterisation is complete. Part of this design is the prediction of fracture growth within the target zone. Specific hydraulic fracture simulation software is used to predict the geometry of fractures (fracture length, conductivity, and height), while the orientation is determined from the in-situ stress field (IESC, 2014). Typical inputs to numerical models include volume and properties of the fluid and proppant, closure stress, pressures within pores, permeability, mechanical properties, and layer geometry.

Several considerations influence the final design for each stimulation treatment, including:

- depth and thickness of the formation target
- lithology of formation target and bounding layers
- minimum and maximum horizontal stress across all layers (target and bounding)
- thickness of the seals above and below the target reservoir formation
- porosity and permeability of the formation
- pore fluid saturations (percentage of formation pore volume occupied by oil, gas, or water)
- pore fluid properties (e.g., density, water salinity)
- well performance data, including flow rates, formation pressure and produced fluid properties
- formation boundaries (as identified from seismic data)

- bulk rock density, elastic properties, and compressibility
- natural fracture networks; and
- stress field analysis to determine the maximum principal stress direction and the minimum principal stress direction.

Site Set Up

The well lease provides a stable working platform suitable for safely undertaking hydraulic fracturing operations. The lease area provides adequate space for the hydraulic fracturing vehicles and equipment, generators, fuel and chemical storage, casing and pipe storage and associated portable buildings. The well lease area generally incorporates the following standard features:

- a compacted and stable hard stand area
- an access road or track with clear entry and exit points for vehicles
- mobile wastewater treatment systems for the disposal of ablutions waste from well site offices and accommodation
- water storage tanks or ponds for hydraulic fracturing make up water and flowback fluid; and
- proppant and chemical storage for drilling and/or hydraulic fracturing operations.

Well Perforation

Holes are created in the well casing pipe at locations, which align to the centre of the coal seams targeted for gas production (these are referred to as 'perforations'). A section of the casing pipe typically less than one metre long is selected for perforation to allow the well to discretely access the coal seam. They are generally aligned slightly below the midpoint of the coal seam being fractured to accommodate the tendency for upward propagation of the fracture (in the direction of least stress).

The perforations, or holes, are created by blasting a jet of water or fine sand/water mix at high pressure at the pipe wall or using small explosives. The perforations penetrate the steel casing and the cement grout layer, and into the coal seam by up to half a metre.

Acid Injection

If the coal seam cleats are found to be naturally filled with calcite mineral (calcium carbonate) then a dilute acid mix is injected through the perforation holes into the coal seam to dissolve the calcite away prior to hydraulic fracturing. This is found to be necessary for less than 10% of gas wells only. It is carried out after completion of the well casing and directly prior to hydraulic fracturing operations, typically completed by the fracturing spread.

The selected coal seam can be pressurised with a 15% solution of hydrochloric acid (with preservatives), with typical volumes pumped of approximate $1m^3$. Hydraulic fracturing can then be carried out.

Hydraulic Fracturing Fluid

Hydraulic fracturing fluid generally consists of three parts: base fluid (the largest constituent by volume), additives and proppant. Base fluid (water) and proppant (sand) make up around 99% of the hydraulic fracturing fluid, with additives making up the remaining 1%. The purpose of the proppant is to keep the fractures open once the pump pressure is released which improves the productive potential of the well.

Each chemical additive serves a specific, engineered purpose such as:

- viscosity: gelling agents and crosslinkers are added to the water to provide viscosity to enable the proppant material such as sand or ceramic beads to be transported down the well and into the created fractures

- breakers: added to reduce the viscosity of the fluid when flowing back the well, enhancing recovery of fracturing fluid and additives to surface
- friction reduction: to reduce the force required to pump the fluid, friction reducers are added, making the fluid more 'slippery' and easier to pump at the high pressures and rates required to create the fracture network
- biocide: biocides or disinfectants are added to reduce the amount of naturally occurring microbes or organisms present in the water which can impact fluid stability and to ensure they will not enter and contaminate the reservoir
- scale and corrosion: scale and corrosion inhibitors are added to prevent deposition of mineral scales and to prevent corrosion of the steel casing or tubing; and
- surface tension: surfactants or surface tension modifiers are added to assist the back flow of fluids from the formation.

Stimulation Process

Several steps are involved in the hydraulic stimulation process to pump the designed fracture treatment. These include:

- diagnostic Fracture Injection Test to validate and update the proposed stimulation design. This involves injecting a small volume of water, shutting down the surface pumps and monitoring pressure decline to evaluate near wellbore entry friction, fracture gradient, fluid leak off, and minimum horizontal stress. This stage is typically only performed in the exploratory / appraisal stages of development, or until localised fracture characteristics are defined
- drift run to check there are no obstructions in the wellbore
- in the case of Plug and Perforation stimulation conveyance method, perforation of stimulation stage one (deepest stage) to gain access to the reservoir from the wellbore
- in the case of coiled tubing stimulation conveyance method, all stimulation stages are perforated before the fracturing crew and equipment arrive at the wellsite
- main stimulation treatment consisting of pad volume injection, slurry stage injection(s) with increasing proppant concentrations, and flush stage to displace last slurry stage through the perforations and into the fracture
- mechanical isolation of the completed fracture stimulation stage
- perforate the next stage to be hydraulically stimulated and repeat the processes above until the final fracture stimulation stage is completed
- remove all mechanical isolation devices by milling out the mechanical isolations; and
- flowback well to clean up fracture stimulation fluids and monitor hydrocarbon production.

A CSG well typically takes 1 to 2 days to complete hydraulic stimulation operations. Hydraulic fracture stimulation initial fluid flowback may occur for a period of 1 to 30 days, depending on the reservoir and clean up profile before the well is connected into the gathering network.

Injection and Isolation of Hydraulic Fracturing Fluid

Once the well has been perforated in the depth interval that is to be hydraulically fractured, fluid injection is performed.

Hydraulic fracturing fluid is injected into the well at the surface through the wellhead. The perforation zones are isolated by either a coiled tubing unit with packers, a bridge or frac plug set by a wireline operator, or by a baffle and ball-drop system.

Following isolation of the perforated zone, injection of fluid commences. The hydraulic fracturing fluid is forced into fractures and remains within the target reservoir. The bore design and construction, comprising multiple physical barriers such as cement and steel casing, ensure that the hydraulic fracturing fluid does not encounter overlying strata, including aquifers. The integrity of these barriers is tested before hydraulic fracturing activities are undertaken.

The injection pressure, injection rates, slurry volumes, fluid viscosity, additive concentrations and proppant concentration are monitored in real-time during each injection. Downhole pressure information is also recorded and reviewed during the hydraulic fracture stimulation operation. Down-hole pressures are calculated based on wellhead pressure, fluid density, casing diameter and the depth to the target formation. When a coiled tubing unit is used as part of the operation pressure is monitored: inside the casing above the top packer of the tool, inside the coiled tubing delivering the fluid and inside the wellhead at surface.

Once the entire hydraulic fracturing operation is complete for a well, completions rig or coiled tubing unit will generally mill out the bridge plugs or baffles that were installed for the hydraulic fracturing operation, to clear them from the well.

Return of Injected Fluid and Water (Flowback Fluid)

Once the injection process is complete, the internal pressure of the rock formation typically causes fluid to return or ‘flowback’ to the surface through the gas well. Flowback fluid contains the dissociation or broken-down products of the injected chemicals plus naturally occurring geogenic compounds.

The volume of the injected fluids which is recovered as flowback is variable depending on the formation, treatment execution, and fluid type used. Immediately after stimulation, typically a range of 0 - 20% of the stimulation volume is recovered within a few days of the completion of the fracturing operation. The well then continues to flowback once connected into the gathering network, where 100% of the stimulation volume is commonly recovered. The flowback water is typically temporarily stored tanks before treatment for reuse or disposal.

Flowback Fluid Management

The recovered fluid, or flowback, may be treated and stored for reuse in the next hydraulic fracturing event. Flowback fluid unable to be reused would be disposed of at a licensed facility or transferred to one of Santos’ engineered wastewater treatment facilities for treatment and management under existing approvals for those facilities.

Well Workover Operations

Maintenance activities termed ‘well workover operations’ are performed periodically to maintain or increase productivity. Workover operations are carried out on production wells by re-entering the well to perform pump repairs, well deepening, isolation of intervals or re-perforation.

Decommissioning and Rehabilitation

Decommissioning of wells would occur on an ongoing basis as production within the Project Area is exhausted. Wells at the end of their lifecycle would initially be capped to enable future uses such as for other resource activities or monitoring. Only once it is determined that the well has no future use is it plugged and abandoned in accordance with regulatory requirements and the *Code of Practice for the construction and abandonment of petroleum wells and associated bores in Queensland* (DNRME, 2019).

Gathering Lines

Santos would construct gas and water gathering lines (i.e. flowlines and pipelines) to transport produced gas and water from the production wells to gas compression and water management facilities located on adjoining Santos operated tenures. Gathering infrastructure would typically be constructed in 20-35 m wide Right of Way (RoW) corridors, and linear infrastructure would be co-located to reduce disturbance wherever feasible. The width of RoWs is influenced by the number of linear services co-located and the nature of the topography (and other considerations such as the size of areas needed to install erosion-sediment controls).

Gathering lines are typically constructed of high-density polyethylene (HDPE). Low point drains (LPDs) and high point vents (HPVs) would be installed at intervals along the gathering lines to allow drainage of condensate from gas, and the release of minor entrained gas from PW as required.

Gathering lines would be designed and constructed to comply with *Australian Standards AS2885 – Pipelines Gas and Liquid Petroleum* and the Australian Pipelines and Gas Association (APGA) *Code of Practice For Upstream Polyethylene Gathering Networks-CSG Industry – Version 6* (APGA, 2024).

Gathering lines would be constructed using a combination of conventional earthmoving equipment and specialist pipeline trenching and lifting equipment. Gathering lines are constructed using a standard construction methodology including:

- clearing and grading
- trenching and padding
- pipe stringing, laying, and welding
- backfilling and reinstating natural ground level; and
- installing marker signs as required.

Once installed, the construction RoW corridor would be rehabilitated back to the minimum width required for operations. Groundcover would be re-established along the operational RoW.

Access Tracks

Roads and access tracks would be required for construction and operational activities. Access tracks would have a typical disturbance width of 10-15m, and linear infrastructure would be co-located to reduce disturbance wherever feasible. The width of roads and co-located RoWs is influenced by the number of linear services co-located and the nature of the topography (and other considerations such as the size of areas needed to install erosion-sediment controls).

Access tracks would be built to allow servicing of well leases and access to other infrastructure (e.g. mobile camps). Wherever practicable, Santos would use existing access tracks and upgrade these if required. Where new access tracks are needed, Santos would aim to co-locate these with gathering lines and/or in already disturbed areas, where practicable to reduce clearing impacts.

- construction activities associated with roads and access tracks include:
- upgrading and/or widening of existing roads
- excavation and filling
- preparation of sub grade; and
- installation of drainage.

Other Incidental Petroleum Activities

Ancillary infrastructure and incidental petroleum activities would be required to support construction and operation activities. These include, but are not limited to:

- laydown, stockpile, storage, and vehicle cleaning areas
- a temporary workers camp including an STP and associated irrigation (<21 EP)
- low hazard dams and storage tanks
- power and communication lines
- borrow pits
- fencing
- environmental monitoring equipment and management controls
- geophysical, geotechnical, geological, topographic, cadastral, and ecological surveys; and
- supporting infrastructure, such as energy supply, water supply and communications.

Appendix C: Project Area Description

Project Area Description and Context

The Project Area is located approximately 43 km east of the town of Roma and 3 km east of the town of Wallumbilla in southern inland Queensland (refer to Figure 1). Further, the Project Area is located in the Maranoa Regional Council Local Government Area (LGA).

The Project Area covers a total area of approximately 1229 ha and will wholly replace all existing blocks of ATP 2053 (as detailed in Table 1 and Figure 1).

The Project Area is bounded by the RSGPA and RSGPAE and shares its boundaries with existing Santos operated PLs 281, 282, 315, 318 and 1020 (as shown in Figure 1).

Table 1: Graticular Block Summary

Block Name	Block Number	Sub-Block
CHAR	2295	E
CHAR	2295	D
CHAR	2295	K
CHAR	2295	J

Further, the Project Area overlaps the following property lot and plans:

- 105 WV68
- 109 RP189184
- 120 WAL53367
- 121 WAL53367
- 122 WAL53367
- 123 WV468
- 124 WAL53367
- 125 WAL53367
- 126 WAL53678
- 127 WAL53678
- 128 WAL53382
- 129 WAL53372
- 130 WAL53382
- 131 WAL53678
- 134 WAL53372
- 135 WAL53381
- 137 WAL53372
- 138 WAL53372
- 159 WV1423
- 162 WV233
- 163 WV322
- 238 WAL53372
- 421 WV898
- 426 WAL53597
- 43 WAL53326
- 51 SP269504
- 56 WAL53326
- 57 WAL53328
- 61 WAL53328
- 631 WV449
- 7 WAL53372

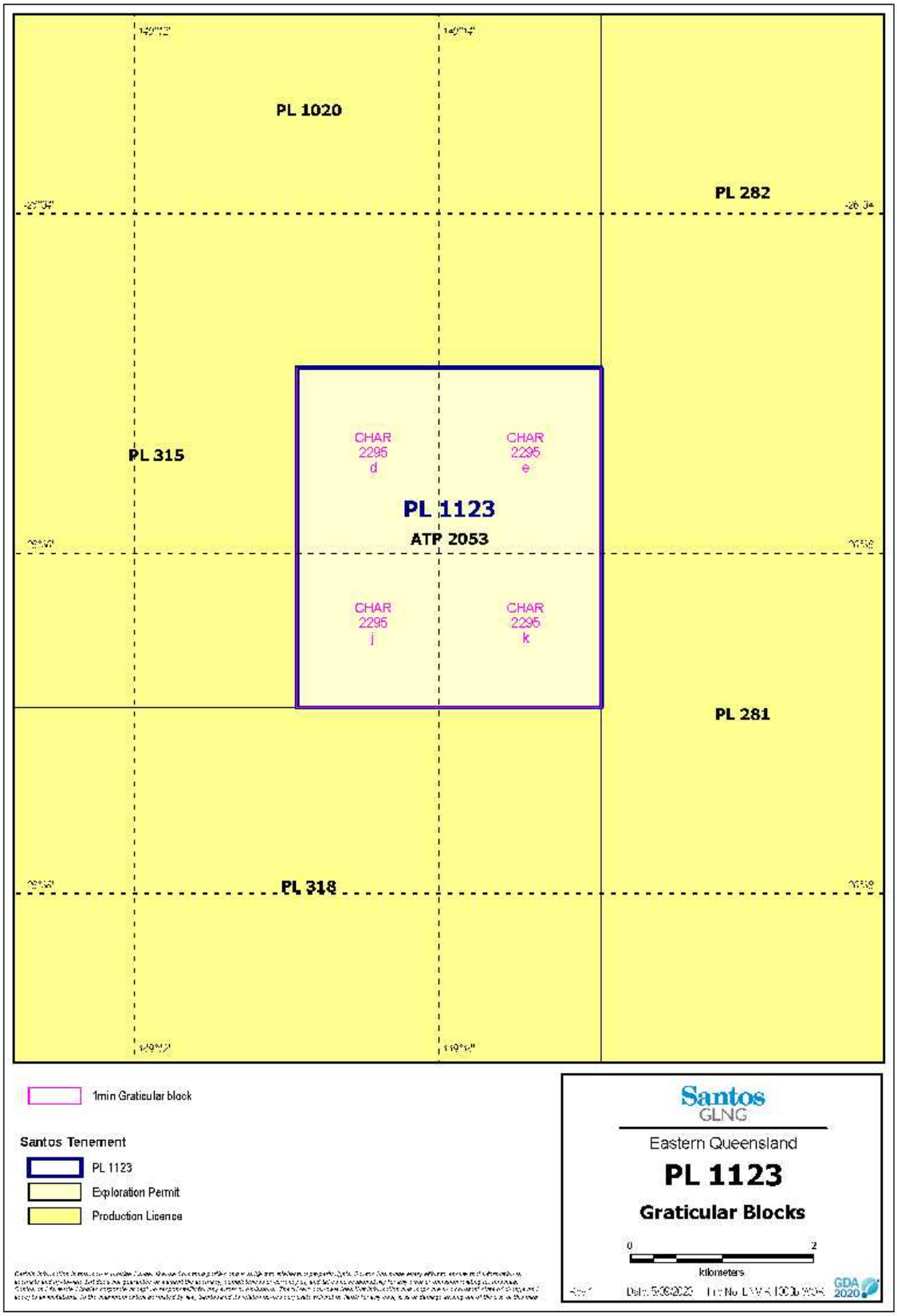


Figure 1: PL 1123 – Graticular Blocks

Land Use

Land within and surrounding the Project Area is predominantly used for agriculture (livestock grazing). The dominant land use is production from relatively natural environments specifically grazing native vegetation (94%). Grazing modified pastures and cropping is also undertaken in ~ 4% of the Project Area, with intensive land uses only constituting 0.8% (State of Queensland, 2025).

The land has been subject to intensive agricultural activities over an extended period of time, and this is reflected in the fragmented nature of remnant vegetation, and large areas of non-remnant vegetation present in the Project Area.

The proposed activities will not significantly impede land use for pastoral purposes (or future resource exploration purposes), and all landholders will be consulted prior to construction commencing.

Key industries within the wider region include agriculture, forestry, recreation and tourism, coal exploration and mining, and oil and gas exploration and production. The traditional industry base for the region has been agricultural, however in more recent times the oil and gas industry has become a more significant contributor to the region's economy.

The Project Area is intersected by the Warrego Highway and an associated stock route that follows the course of the highway (refer to Figure 1).

Further, the Project Area is wholly overlapped by 2 resource exploration permits – those being:

- EPG 2034 – Exploration Permit Geothermal with Within Energy Pty Ltd; and
- EPC 1763 – Exploration Permit Coal with Wanbei Coal Electricity International Mining (Australia) Pty Ltd.

Climate

Wallumbilla Post Office and Roma Airport (Bureau of Meteorology (BoM) site numbers 43038, 43091, respectively) are the closest active BoM weather stations (with rainfall and temperature data) to the Project Area. Monthly climate statistics from these weather stations indicate that Wallumbilla has a warm, sub-tropical environment receiving an average of 576 millimetres of rain per year, with the majority of this rainfall occurring during the summer period from October to March (BoM, 2025). Mean minimum and maximum temperatures range from 8.6–29.7 °C in July, and 20.7–45.8 °C in January.

Appendix D: EAR and MSES Report

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Ecological Assessment Report – MNES/MSES

Roma Phase 7-7B-SD20 Proposed Development

Compiled by BOOBOOK for Santos

Revision	Date	Description	Author	Verifier	Approved
A	3/11/2024	Draft issued to Client for review	C. Eddie, M. Cunningham, A. Warren	C. Eddie	C. Eddie
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2	25/2/2025	Updated report following Santos functional review	C. Eddie	-	C. Eddie
3	13/6/2025	Updated report including additional SRI assessments	C. Eddie, R. Aisthorpe, A. Warren	C. Eddie	C. Eddie

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Executive Summary

This report summarises ecological assessments of Authority to Prospect (ATP) 2053 ('the Project Area') undertaken for Santos between 2020 and 2024. The Project Area is proposed to be developed as part of the Roma Phase 7-7B-SD20 project and will involve the conversion of ATP 2053 to new Petroleum Lease (PL) 1123 to authorise commencement of Coal Seam Gas (CSG) production activities. Proposed activities within the Project Area would include CSG production, exploration and appraisal activities.

The Project Area is located approximately five km east of Wallumbilla, southern inland Queensland. The assessment includes surveys conducted by Boobook in March 2022, September 2023 and April 2024, covering parts of the Project Area south of the Warrego Highway, along with surveys by other contractors covering the remainder of ATP 2053.

Field surveys for this assessment included identification and mapping of remnant and regrowth regional ecosystems (RE) and Threatened Ecological Communities (TEC) across the Project Area. BioCondition assessments of vegetation condition were made at locations representing major vegetation types within the Project Area. Quaternary level vegetation structure assessments and faunal habitat assessments were made at representative locations across the Project Area.

Santos has developed a preliminary disturbance footprint (hereafter referred to as the Disturbance Footprint) for the project to locate infrastructure to avoid disturbance to Matters of National Environmental Significance (MNES), Matters of State Environmental Significance (MSES) and other environmental values. The Disturbance Footprint is defined as those parts of the Project Area that will be impacted by Project development activities. The Disturbance Footprint is displayed in Appendix A. Potential future changes to the Disturbance Footprint will be managed in accordance with the *Santos Roma Phase 7-7B-SD20 Development Environmental Protocol for Constraints Planning and Field Development Constraints Protocol* (Santos 2025).

Five RE types were recorded within the Project Area, these being:

- 11.3.2: *Eucalyptus populnea* woodland on alluvial plains (VM Act: Of Concern; Biodiversity status: Of Concern).
- 11.3.17: *Eucalyptus populnea* woodland with *Acacia harpophylla* and/or *Casuarina cristata* on alluvial plains (VM Act: Of Concern; Biodiversity status: Endangered).
- 11.3.25: *Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines (VM Act: Least Concern; Biodiversity status: Of Concern).
- 11.9.7: *Eucalyptus populnea*, *Eremophila mitchellii* shrubby woodland on fine-grained sedimentary rocks (VM Act: Of Concern; Biodiversity status: Of Concern).
- 11.9.10: *Eucalyptus populnea* open forest with a secondary tree layer of *Acacia harpophylla* and sometimes *Casuarina cristata* on fine-grained sedimentary rocks.

One RE occurs within the Disturbance Footprint:

- 11.3.2: *Eucalyptus populnea* woodland on alluvial plains (VM Act: Of Concern; Biodiversity status: Of Concern).

Two Threatened Ecological Communities (TEC) were present within the Project Area these being:

- Poplar Box grassy woodland on alluvial plains.
- Weeping Myall woodlands.

No TEC is present within the Disturbance Footprint.

No threatened flora species, listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) or the Queensland *Nature Conservation Act 1992* (NC Act) were considered likely to occur within the Project Area based on desktop assessments. Suitable habitat was present in the Project Area for one flora species listed under the EPBC Act and two flora species listed under the NC Act. Field survey of flora species was limited to incidental observations and active searches for threatened plants around vegetation structure points. No EPBC Act or NC Act threatened flora species were found.

No comprehensive fauna surveys were performed under this Scope of Works. Fauna surveys were limited to incidental observations and active searches at BioCondition and other vegetation and habitat quality assessment sites. No

threatened fauna species listed under the EPBC Act and/or the NC Act were detected during the field survey. Nine threatened fauna species, including seven species listed under the EPBC Act and nine species listed under the NC Act, were considered potentially present within the Project Area. Suitable habitat was present in the Project Area for one SLC fauna species listed under the NC Act. Potential habitat for these species was predicted and mapped based on known vegetation and habitat feature associations.

Multiple migratory and/or marine species listed under the EPBC Act were assessed as potentially present within the Project Area. These are all widespread and mobile species occurring in habitats that are common in this landscape. These species do not depend on specific resources within the Project Area.

Several mapped watercourses, varying from first to third order intermittently flowing drainage lines, occur within the Project Area. No referable wetlands, lakes or springs occur within the Project Area. Several wetlands of general ecological significance were ground-truthed as being present within the Project Area and Disturbance Footprint. These wetlands may provide temporary habitat for MNES/MSES fauna.

The following Category B ESA are present within the Project Area:

- areas of ground-truthed Endangered RE (biodiversity status): 11.3.17 and 11.9.10.

The following Category C ESA are present within the Project Area:

- areas of ground-truthed Of Concern RE (biodiversity status): 11.3.2, 11.3.25 and 11.9.7.
- an area validated from ground-truthing surveys as 'protected wildlife habitat' that is category A, B or C on the Remnant Vegetation Management Map, in accordance with section 20A of the *Vegetation Management Act 1999*, for a species of wildlife listed as critically endangered, endangered or vulnerable under the NC Act as follows:
    - ground-truthed protected wildlife habitat: Glossy Black-Cockatoo (*Calyptorhynchus lathami lathami*) - NC Act: Vulnerable: remnant and regrowth: RE 11.3.2, 11.3.25, 11.9.10.
    - ground-truthed protected wildlife habitat: White-throated Needletail (*Hirundapus caudacutus*) - NC Act: Vulnerable: remnant and regrowth: RE 11.3.2, 11.3.25, 11.9.10.
    - ground-truthed protected wildlife habitat: Koala (*Phascolarctos cinereus*) - NC Act: Endangered: remnant and regrowth REs 11.3.2, 11.3.25, 11.9.10.
    - ground-truthed protected wildlife habitat: Yakka Skink (*Egernia rugosa*) - NC Act: Vulnerable: remnant and regrowth: RE 11.3.2, 11.9.10.
    - ground-truthed protected wildlife habitat: Grey Snake (*Hemiaspis damelii*) - NC Act: Endangered: remnant and regrowth REs 11.3.2, 11.3.25.

The proposed CSG development would result in the following disturbance areas to remnant/regrowth RE and MNES/MSES fauna habitat:

- 11.3.2 remnant: 0.15 ha;
- 11.3.2 regrowth: 0.15 ha;
- MNES/MSES fauna wetland habitat: 0.6 ha.

No significant impact will occur as part of the proposed development for the following MNES:

- TEC;
- EPBC Act threatened flora populations/habitat;
- EPBC Act threatened and/or migratory fauna populations/habitat; and
- Wetlands of International or National Significance.

No significant residual impact will occur as part of the proposed development for the following MSES:

- Regulated vegetation;
- Connectivity areas;
- NC Act threatened flora populations/habitat;
- NC Act threatened and SLC fauna populations/habitat;
- Wetlands in a wetland protection area and wetlands of high ecological significance as shown on the Map of referrable wetlands under schedule 12, part 2 of the *Environmental Protection Regulation 2008*;
- Wetlands or watercourses in a high ecological value waters as identified under the *Environmental Protection (Water) Policy 2009*, schedule 2.Wetlands and watercourses;
- Designated precinct in a strategic environmental area;

- Protected wildlife habitat;
- Protected areas;
- Highly protected zones of State marine parks;
- Fish habitat areas;
- Waterway providing for fish passage because linear infrastructure construction activities located in waterways providing for fish passage would not:
    - reduce the extent, frequency, or duration of fish passage;
    - result in a substantial change to the hydrological regime of the watercourse; or
    - lead to significant changes in water quality parameters within the watercourse.
- Marine plants; and
- Legally secured offset areas.

List of Abbreviations

ALA	Atlas of Living Australia (database)
AoO	Area of Occupancy (the area of habitat used by a species)
ATP	Authority to Prospect
AU	Assessment Unit
Biosecurity Act	*Biosecurity Act 2014* (Queensland)
CE	Critically Endangered
CSG	Coal Seam Gas
DCCEEW	Department of Climate Change, Energy, the Environment and Water (Commonwealth)
DBH	Diameter at breast height
DESI	Department of Environment, Science and Innovation (Queensland) (formerly DES)
Disturbance Footprint	The Disturbance Footprint is defined as those parts of the Project Area that will be impacted by Project development activities.
DoR	Department of Resources (Queensland)
EoO	Extent of Occurrence (the geographic range of a species, including areas of unsuitable habitat)
EOR	*Environmental Offsets Regulation 2014* (Queensland)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
GIS	Geographic Information System
GLNG	Gladstone Liquefied Natural Gas
GPS	Global Positioning System
HVR	High Value Regrowth
km	kilometres
LC	Least Concern
MNES	Matters of National Environmental Significance
MSES	Matters of State Environmental Significance
NC Act	*Nature Conservation Act 1992* (Queensland)
NCAP	No Concern at Present
OC	Of Concern
PEM	Prescribed Environmental Matter
PL	Petroleum Lease
PMST	Protected Matters Search Tool
Project	The Project is defined as development activities associated with the Roma Phase 7-7B-SD20 Project
RE	Regional Ecosystem (s)
REDD	Regional Ecosystem Description Database
ROW	Right-of-Way
SEVT	Semi-evergreen vine thicket
SRI	Significant Residual Impact
TEC	Threatened Ecological Community (ies)
V	Vulnerable
VM Act	*Vegetation Management Act 1999* (Queensland)
WoNS	Weeds of National Significance

Conclusions drawn in this report are based on available information at the time of writing. Any additional information may alter such conclusions and the author reserves the right to do so if such information becomes available. This report has been made as at the date of the report and is not to be used after six (6) months and not if there are any material changes meanwhile. In either event it should be referred back for review. To the extent permitted by law BOOBOOK does not accept liability for any loss or damage which any person may suffer arising from any negligence or breach of contract on its part. This report was prepared for the benefit of the party to whom it is directed only and for the purpose identified within. BOOBOOK does not accept responsibility to any other person for the contents of the report.

1. Introduction

1.1. Purpose and Scope

Santos proposes to construct and operate infrastructure associated with coal seam gas (CSG) extraction including a total of 24 CSG wells and associated gas and water pipelines (flowlines), laydown areas and access tracks for the Roma Phase 7-7B-SD20 (the Project), located near Wallumbilla, southern inland Queensland. This report summarises an ecological assessment undertaken for Santos (the Client) within ATP 2053 (hereafter referred to as 'the Project Area') including the associated proposed Disturbance Footprint (Appendix A).

Santos (the Client) required the following services in relation to identifying ecological values and potential constraints within the Project Area:

- Ground-truthed Regional Ecosystem (RE) and high value regrowth (HVR) vegetation mapping;
- Verification and mapping of any Threatened Ecological Communities (TEC);
- Matters of National Significance (MNES)/ Matters of State Significance (MSES) flora assessment plus incidental threatened flora observations;
- MNES/MSES fauna habitat assessment as per agreed habitat descriptions plus incidental threatened fauna observations; and
- BioCondition surveys of vegetation within the Project Area.

The results of the ecological assessment are based on an initial desktop assessment followed by field surveys to confirm vegetation communities within the Project Area. Additional field surveys, including BioCondition assessments and records of notable flora/fauna species and habitat values within the Project Area were restricted to an area south of the Warrego Highway comprising parts of Washpool, Lyndale and Ruby Farm. The primary purpose of this report is to provide a summary of potential MNES/MSES ecological constraints and values within the Project Area.

1.2. Survey Team

An ecological field survey covering parts of the Project Area south of the Warrego Highway was conducted for this assessment by Michael Cunningham (Senior Ecologist, Boobook) and Courtney Andrew (Graduate Ecologist, Boobook) on the 2nd – 4th March 2022. A further survey of vegetation in the road and railway reserve south of the Warrego Highway was conducted by Michael Cunningham and Rosamund Aisthorpe (Senior Ecologist/Botanist, Boobook) on 16th September 2023. Additional surveys of areas within the proposed Disturbance Footprint were conducted by Michael Cunningham and Weston Campbell (Field Technician, Boobook) on 19th April 2024. Vegetation survey data covering other parts of the Project Area north of the Warrego Highway were provided by Santos (O2 Ecology 2016; spatial data provided via email from Alex Clarke 6th September 2023).

The project supervisor (Craig Eddie) was approved by the Department of Climate Change, Energy, the Environment and Water (DCCEEW), as the Commonwealth Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC), in writing on the 28th of January 2011 for the purpose of undertaking ecological assessment works for the Gladstone Liquefied Natural Gas (GLNG) project. All aspects of the project including field survey and reporting were conducted under the supervision of Craig Eddie.

1.3. Site Description

1.3.1. Location

The Project Area is located approximately 5 km east of Wallumbilla, south-central Queensland, within the Maranoa Regional Council area. It is accessed via the Warrego Highway, Seawrights Road and Scotts Road. The Project Area is shown within Appendix A.

1.3.2. Bioregion

The Project Area is entirely within Subregion 26 (Southern Downs) of the Brigalow Belt bioregion (Sattler and Williams 1999).

1.3.3. Vegetation

Much of the Project Area has been cleared of native vegetation to form non-remnant derived grassland dominated by introduced pasture grasses with occasional native trees and shrubs. Areas of remnant and regrowth native vegetation occur as irregular, discontinuous corridors along streamlines or as small, isolated fragments. River Red Gum (*Eucalyptus camaldulensis*) dominates riparian woodland along the banks of larger streams, while Poplar Box (*E. populnea*) dominates floodplain woodlands. Brigalow (*Acacia harpophylla*) and/or Belah (*Casuarina cristata*) are prominent in areas of heavy soil and patches of Weeping Myall (*A. pendula*) occur on floodplains. Some low-lying areas have groundcover dominated by characteristic wetland fringe plants including sedges, Nardoo (*Marsilea* spp.), forbs and grasses. These floodplain wetlands include areas of non-remnant vegetation and modified drainage structures such as channels and overflow areas around dams.

1.3.4. Geology, Topography & Soils

This is a landscape of low relief comprising a broad floodplain with meandering streamlines flanked by slightly elevated areas. Beyond the Project Area, to the east, an abrupt north-south trending plateau rises up to 50 m above the surrounds. There is no outcropping rock within the Project Area and the surface geology consists of Quaternary alluvial sediments (Qa) with an area of unconsolidated colluvial sediments derived from early Cretaceous mudstones of the Doncaster Member (Qs>Kud) in the east associated with the adjacent plateau (DoR 2024a). Soils vary from dark brown clay-loam and sandy clay-loams across much of the Project Area, to reddish clay-loam in the east.

1.3.5. Watercourses

The Project Area is drained by Washpool Creek and its minor tributaries which drain into Wallumbilla Creek, part of the Balonne River catchment, within the Murray-Darling Basin.

1.3.6. Current Land Use

The primary land use within the Project Area is livestock grazing.

1.3.7. Existing project related disturbances

Prior disturbances associated with gas exploration activities undertaken by Santos within ATP 2053 include the drilling of five CSG appraisal wells (RM23-21-1, RM23-43-1, RM23-42-1, RM23-41-1 and RM23-46-1) and construction of associated supporting infrastructure in 2022-2024.

2. Methodology

2.1. Desktop Assessment

A desktop assessment was performed prior to the field survey which included interrogation of the following datasets:

- EPBC Act Protected Matters Search Tool (PMST) (DCCEEW 2024a) (Appendix B);
- WildNet Queensland fauna and flora records (DESI 2024a,b);
- Atlas of Living Australia fauna and flora records (ALA 2024);
- Protected Plants Flora Survey Trigger Map (DESI 2024c);
- Referable Wetlands mapping (DESI 2024d);
- Environmentally Sensitive Area mapping (DESI 2024e);
- Matters of State Environmental Significance (DESI 2024f);
- State terrestrial biodiversity and aquatic conservation values (DESI 2024g);
- Regulated vegetation mapping as per the *Vegetation Management Act 1999* (VMA) (DoR 2024b);
- Remnant RE – biodiversity status (DESI 2024h);
- Mature Regrowth mapping (DESI 2024i);

- Essential Habitat mapping (DES 2022); and
- Ordered stream mapping (DoR 2024c).

The searches were conducted using online spatial layers and database searches, using land parcel (lot on plan) codes or central coordinates (26.60632°S, 149.23120°E, datum GDA94) as a geographic reference, and including a 10 km buffer. These datasets provided a baseline for subsequent field assessment.

2.2. Field Survey

In-field verification of desktop findings and additional findings of significance were undertaken in general accordance with the following:

- *Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland* (Neldner *et al.* 2022);
- *Methodology for Conducting Ecological Assessments* – GLNG Areas Rev 4.1 (Santos 2014); and
- *Functional Thresholds for Assessing Regional Ecosystem Functionality* (Santos 2015).

Formal survey sites were established in representative locations within each vegetation type, based on vegetation structure, floristics and condition. At each site quaternary vegetation structure and floristics, and fauna habitat assessments were conducted concurrently. Methodologies that were employed for each element of the field survey are further described in the following sections.

2.2.1. RE & TEC Assessment

RE and TEC assessment was informed by both desktop review and by ground-truthing during field assessment. Ground-truthing (and confidence level scoring) of the RE designation was undertaken using the quaternary level of data collection as described by Neldner *et al.* (2022).

Assessments were undertaken within 50 m x 20 m plots for the purpose of typifying the vegetation community under assessment. Plots were chosen within representative areas of each vegetation type encountered. Locations of quaternary assessment sites are shown in Appendix AC.

Vegetation community polygons were verified in accordance with Queensland RE description and biodiversity status as per the Regional Ecosystem Description Database (REDD) (Queensland Herbarium 2023a) and classified as remnant RE, vegetation consistent with RE (regrowth) or non-remnant vegetation (Santos 2014). For each area of potential TEC an assessment of vegetation survey data was made against TEC threshold criteria (e.g. TSSC 2013).

Vegetation community data was captured in the field and entered into Santos-specific data fields within spatial databases via GPS enabled Zebra tablet devices. Representative photographs were taken via a digital camera at each vegetation survey site and at other points as supporting evidence of the subject vegetation community. Capture and delineation of RE and TEC boundaries was undertaken using a combination of mobile GIS devices, GPS and/or delineation from imagery. A minimum mappable width of 25 m for linear vegetation corridors was applied. Patches were mapped to their full extent within the Project Area within practical limits (including land access constraints).

For any identified regrowth (i.e. vegetation floristically equivalent to a RE but not meeting structural thresholds of remnant RE) an ecosystem functionality assessment was conducted. This assessed selected vegetation characteristics against the parameters described in Santos (2015).

Plant names used within this document conform to those given in Bean (2024).

2.2.2. BioCondition Survey

BioCondition assessments were used to evaluate ecological functionality of vegetation in the Project Area. These assessments applied the methodologies described by Eyre *et al.* (2011, 2015). This involved the establishment of a 100 m x 50 m plot for measurements relating to canopy layer structure and diversity, a 100 m transect to measure canopy cover, a 50 m x 10 m subplot for measuring plant richness in shrub and ground layers, a 50 m x 20 m subplot for measuring coarse woody debris, and five 1 x 1 m quadrats to estimate ecological components of ground cover within the assessment area. These values were used as indicators of ecosystem function relative to minimally disturbed benchmark sites (Queensland Herbarium 2023b) within the same Assessment Unit (AU). Using the principle of streamlining (DES 2020), as requested by the client, two BioCondition assessments were considered sufficient

representation for each AU. BioCondition assessments were restricted to parts of the Project Area south of the Warrego Highway in Washpool, Lyndale and Ruby Farm.

For AU with very limited extent (< 10 ha) a single BioCondition assessment was considered sufficient representation. Where needed, additional quaternary vegetation assessments were made within each AU within the Project Area, as evidence of comparable vegetation condition.

The following information was recorded at each BioCondition site:

- Date;
- Observers;
- Description of location (bioregion, general description, co-ordinates for plot origin and centre, plot bearing and alignment);
- General habitat description and RE type;
- Median height for canopy, emergent and sub-canopy strata;
- Slope position/slope degree and slope aspect;
- Tree species richness (within 100 m x 50 m plot);
- Native plant species richness (within 50 m x 10 m plot);
- Non-native plant cover (within 50 m x 10 m plot);
- Total length of coarse woody debris (length >10 cm diameter and >0.5 m long within 50 m x 20 m plot);
- Number and average diameter at breast height (DBH) of large eucalypt and non-eucalypt trees (within 100 m x 50 m plot);
- Recruitment of canopy species (within the 100 m x 50 m plot);
- Tree and shrub canopy cover (within 100 m transect);
- Ground cover within 1 m x 1 m plots (native perennial grass and organic litter cover in the ground layer);
- Disturbances (severity, last event and observation type).

Large tree DBH thresholds for each RE were used where published benchmarks were available, otherwise the default ≥30 cm DBH for eucalypts and ≥20 cm DBH for non-eucalypts was applied.

Site photographs were taken using a digital camera in accordance with Eyre *et al.* (2015) (i.e. one photograph at plot origin and north, east, south and west photographs at the plot centre). Photograph numbers were recorded. Locations of BioCondition sites were determined using a handheld Global Positioning System (GPS) (Garmin GPSmap 78S) and BioCondition assessment data was captured by mobile GIS devices (Motion F5T tablet device).

This survey did not mark the origin and centre point of BioCondition plots with steel fence posts, as suggested in Eyre *et al.* (2015), due to current and proposed land use (grazing and coal seam gas development).

Scores for BioCondition sites were calculated in accordance with Eyre *et al.* (2015) which compares the values obtained at each survey site with values in the benchmark document for that particular RE (Queensland Herbarium 2023b). Subscores are awarded to each site are totalled and divided by the maximum possible score for that RE. This provides a numeric index along a continuum of biodiversity condition, where scores close to 0 indicate sites that are ecologically 'dysfunctional' and scores closer to 1 indicate increasing ecological integrity.

2.2.3. Fauna Habitat Assessment

An assessment of fauna habitat was completed at each quaternary vegetation assessment site and each BioCondition Site. Presence/absence, abundance or density of habitat features was recorded within a 50 m x 20 m plot at each survey site including:

- embedded and loose rocks and boulders (estimated % cover);
- logs (abundance);
- trees >18m height (abundance);

- logs with hollows (abundance);
- trees with hollows (abundance);
- trees and/or logs with loose bark (abundance);
- burrows, sinkholes and tunnel erosion (abundance);
- fallen bark (estimated % cover);
- shrub layer (estimated % cover);
- ground cover (estimated % cover);
- leaf litter (estimated % cover);
- termite mounds (abundance);
- mistletoe (abundance);
- rock structures (caves, overhangs and crevices);
- cliffs, escarpments and steep rocky slopes within 5km (presence);
- watercourses with permanent water, pools and riffles and abundant woody/rock cover (presence);
- cracking clays soils (presence);
- gilgai and ephemeral wetlands (presence); and
- canopy dominated by Myrtaceae species (presence).

In addition, representative fauna habitat features were recorded elsewhere, to indicate their type and occurrence throughout the Project Area, including non-remnant areas. Mapping of habitat features was not comprehensive. In general, fauna habitat features are expected to be most abundant in remnant and regrowth vegetation and these areas were addressed by assessment plots. The results of these assessments, combined with published information and suitably qualified ecologist knowledge of fauna distribution and habitat use in the region, were used to predict habitat suitability for nominated listed threatened fauna.

Results from fauna habitat assessments conducted within the Project Area and other records of fauna habitat features are included in spatial data provided to Santos. The location of mapped fauna habitat assessment sites is shown in Appendix C.

2.2.4. Threatened Flora Survey

Targeted surveys for threat-listed flora were informed by the desktop search results and local experience of Boobook ecologists. Searches for threat-listed flora under the EPBC and/or NC Act were carried out at vegetation assessment sites and in random meanders in targeted habitat types, including remnant and non-remnant vegetation. The results of these surveys and vegetation assessments, combined with published information and suitably qualified ecologist knowledge of flora distribution and habitat in the region, were used to predict habitat suitability for nominated listed threatened flora.

If detected, counts and extent of each population of threat-listed flora were made as well as structural characteristics and representative photographs taken. Data were recorded using the Santos-specific Notable Species - Flora Point or Region data capture layer.

2.2.5. Incidental Threatened Fauna Records

No comprehensive fauna surveys, using trapping, acoustic or other techniques, were undertaken under this Scope of Works. Incidental records of any threatened fauna obtained during field survey were fully documented including species name, location (with site co-ordinates or area of extent), habitat and number detected. Vegetation and habitat assessments were conducted at locations where threatened species were detected.

2.2.6. Survey Limitations

Individual mapped vegetation polygons have been assigned a confidence level (high, moderate, low) for both boundary accuracy and vegetation attributes within the polygon as per Neldner *et al.* (2022). All vegetation within the

Project Area was inspected in the field (ground-truthed) so that mapped polygons have a high confidence for boundary accuracy and vegetation attributes. Where Endangered or Of Concern RE types were encountered the full extent of the patch was mapped where this was physically practicable.

In some instances, vegetation communities may not be readily assigned to a RE, even when ground-truthed, as their floristics and structure reflect historical disturbance patterns such as clearing, thinning and fire history. In these cases, RE were allocated on the basis of 'best fit' with current RE descriptions.

Field surveys of Washpool, Lyndale and Ruby Farm were conducted in March 2022, during a warm, dry spell following a mild, wet late spring – early summer in late 2021. There was dense growth of grasses, which may have reduced detectability of some forb species. Conditions during the survey were suitable for identification of flowering forbs and grasses and identification of woody plant species based on vegetative features.

3. Results & Discussion

3.1. Matters of National Environmental Significance

3.1.1. Threatened Ecological Communities

PMST search results (DCCEEW 2024a) indicated the potential presence of five TEC within the Project Area these being:

- Brigalow (*Acacia harpophylla* dominant and co-dominant);
- Coolibah – Black Box woodlands of the Darling Riverine Plains and the Brigalow Belt South Bioregions;
- Poplar Box grassy woodland on alluvial plains;
- Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar Bioregions; and
- Weeping Myall woodlands.

Several areas of TEC were identified within the Project Area during field surveys including several small patches of Poplar Box Grassy Woodlands on Alluvial Plains TEC (Poplar Box TEC) and Weeping Myall Woodlands TEC (Weeping Myall TEC). All areas of TEC within the Project Area are disturbed by grazing and edge effects such as tree death and encroachment by introduced pasture grasses and other weeds. All Poplar Box TEC within the Project Area was assessed as Moderate Quality (Category C) with low native cover but retaining diverse native understorey plants and more than 10 mature trees per hectare (TSSC 2019). No TEC is present within the Disturbance Footprint. Mapped areas of TEC within the Project Area are shown in Appendix C. The extent of TEC within the Project Area is summarised in Table 1.

Table 1: Description and ground-truthed extent of TEC within the Project Area.

TEC Description	RE Code	Extent of TEC within the Project Area (ha)	Extent of TEC within the Disturbance Footprint (ha)
Poplar Box grassy woodland on alluvial plains	11.3.2	46.71	0.0
Weeping Myall Woodlands	11.3.2	7.61	0.0

3.1.2. Threatened Flora

3.1.2.1. Likelihood of Occurrence Assessment

PMST search results (DCCEEW 2024a, Appendix B) indicated the potential occurrence of four EPBC Act-listed threatened flora species within the Project Area, these being: Ooline (*Cadellia pentastylis*), a Bluegrass (*Dichanthium setosum*), Winged Pepper-cress (*Lepidium monoplocoides*) and Slender Tylophora (*Vincetoxicum forsteri*).

Desktop assessment (ALA 2024, DESI 2024a) did not produce any records of threatened flora species within 10 km of the Project Area.

A likelihood of occurrence assessment for EPBC Act-listed threatened flora potentially occurring within the Project Area is presented within Table 2.

Table 2: Assessment of likelihood of occurrence for EPBC Act-listed threatened flora within the Project Area.

Key to Status: E = Endangered; V = Vulnerable; NT = Near Threatened; C = Least Concern.

Class	Scientific & Common Name	EPBC Act Status	NC Act Status	Distribution and Known Habitat Use	Potentially Suitable RE within the Project Area	Likelihood of Occurrence
Apocynaceae	*Vincetoxicum forsteri* listed as *Tylophora linearis* Slender Tylophora	E	E	A cryptic twining vine, occurring in dry woodland along the western slopes of the Great Dividing Range, from Temora in southern NSW north to around Miles in southern Queensland (ALA 2024, DCCEEW 2024b, Boobook unpubl. data). The species is associated with shrubby woodland dominated by Ironbarks (*Eucalyptus crebra*, *E. fibrosa* or *E. sideroxylon*), Grey Box (*E. microcarpa*, *E. woollsiana*) or White Cypress Pine (*Callitris glaucophylla*) with a subcanopy of *Acacia* spp., *Melaleuca* spp., *Callitris* spp. and/or Bull Oak (*Allocasuarina luehmannii*) (Forster *et al.* 2004). These habitats occur on low fertility soils found on sandy plains, ironstone jump-ups and metamorphic substrates (land zones 5, 7 and 11). Aerial twines grow from a perennial rootstock after summer rains and wither in dry periods (Forster *et al.* 2004), during which the species may not be detectable.	None within the Project Area.	**Unlikely to be present.** There is no suitable habitat (i.e. dry shrubby woodland on land zones 5, 7 or 11) within the Project Area. This species does not occur in the vegetation types and landforms within the Project Area (i.e. grassy woodland on floodplains and low rises, land zones 3 and 9). The closest recorded occurrence is from Glenmorgan, 77 km south-southeast of the Project Area (ALA 2024).
Brassicaceae	*Lepidium monoplocoides* Winged Pepper-cress	V	C	A small forb occurring on semi-arid inland plains of the Murray-Darling Basin. It occurs in open, sparsely vegetated areas on heavy clay soils that are seasonally flooded (Mavromihalis 2010). This ephemeral species is found in floodplain woodlands dominated by Coolibah (*Eucalyptus coolabah*) and/or Black Box (*E. largiflorens*) as well as chenopod shrublands and halophytic wetlands. The species has a wide historic distribution through inland NSW and Victoria. The sole records from Queensland are from an area of natural saline scalds around Yelarbon, near the state border with NSW (ALA 2024). The Yelarbon population was recently described as a distinct species (Al-Shebaz 2023).	None within the Project Area.	**Unlikely to be present.** There are no suitable semi-arid, sparsely vegetated areas on heavy clay soils within the Project Area. There are no areas dominated by chenopods, halophytes or Coolibah/Black Box woodland in the Project Area. The Project Area is outside the known range of this species, being over 260 km from the closest records around Yelarbon (ALA 2024).
Poaceae	*Dichanthium setosum* A bluegrass	V	C	Occurs on basalt tablelands from southern NSW to Toowoomba in Queensland with disjunct populations in the central highlands, Einasleigh uplands and north-western highlands (ALA 2024; TSSC 2008). Found in eucalypt or Brigalow woodland on black clays and hard-setting red-brown loams (DESI 2024b; TSSC 2008). Occurs in some moderately disturbed areas such grassy roadside remnants and areas cleared for grazing (TSSC 2008).	None within the Project Area.	**Unlikely to be present.** There is no suitable habitat (i.e. basalt derived heavy clay soils – areas associated with landzone 8) within the Project Area or the vicinity. There are no records of the species within 200km of the Project Area (ALA 2024).

Class	Scientific & Common Name	EPBC Act Status	NC Act Status	Distribution and Known Habitat Use	Potentially Suitable RE within the Project Area	Likelihood of Occurrence
Surianaceae	*Cadellia pentastylis* Ooline	V	V	This tree species occurs in northern NSW and southern Queensland (DCCEEW 2024b). Within Queensland it occurs in patches throughout the southern Brigalow Belt, from the NSW border to Rockhampton and Blackall (ALA 2024). It grows to a large and conspicuous tree occurring on undulating plains, valley slopes, hillsides and scarps, often in association with Brigalow and SEVT communities (DCCEEW 2024b, Santos 2012).	None within the Project Area.	**Unlikely to be present.** The Project Area does not include suitable habitat areas of SEVT (RE 11.9.4) or Brigalow dominated woodland on rises, hills and scarps (RE 11.7.1, 11.9.5). The closest specimen records are from around 50 km north of the Project Area (ALA 2024).

3.1.2.2. Field Survey Results

No EPBC Act-listed threatened flora was detected during field surveys within the Project Area.

3.1.3. Weeds of National Significance

Weeds of National Significance (WoNS) detected within the Project Area are listed in Table 3. Representative locations of these species are shown within Appendix C.

Table 3: WoNS recorded within the Project Area.

Family	Scientific Name	Common Name	Comments
Cactaceae	*Opuntia stricta*	Common Pest Pear	Occurs throughout the Project Area at very low densities.
Cactaceae	*Opuntia sulphurea*	Sulphur Pear	Scattered occurrences across the Project Area.
Cactaceae	*Opuntia tomentosa*	Velvety Tree Pear	Occurs throughout the Project Area at low densities.
Solanaceae	*Lycium ferocissimum*	African Boxthorn	Scattered occurrences in riparian vegetation across the Project Area.

3.1.4. Threatened Fauna

3.1.4.1. Likelihood of Occurrence Assessment

PMST search results (DCCEEW 2024b, Appendix B) predicted twenty-four EPBC Act-listed threatened fauna species that might occur within the buffered desktop search area. Wildlife Online and ALA searches (DESI 2024a, ALA 2024) produced records of one EPBC Act-listed threatened fauna species within the buffered desktop search area this being Koala (*Phascolarctos cinereus*). A likelihood of occurrence assessment for EPBC-listed threatened fauna within the Project Area is presented in Table 4.

Table 4: Assessment of likelihood of occurrence for EPBC Act-listed threatened fauna within the Project Area.

Key to Status: CE/CR = Critically Endangered; E = Endangered; V = Vulnerable; C = Least concern (NC Act).

Class	Scientific & Common Name	EPBC Act Status	NC Act Status	Distribution and Known Habitat Use	Potentially Suitable RE within the Project Area	Likelihood of Occurrence within the Project Area
Birds	*Aphelocephala leucopsis* Southern Whiteface	V	V	A sedentary or locally nomadic species occurring in sparsely treed open woodlands and shrublands across southern inland Australia (TSSC 2023a). Often observed in semi-arid *Acacia* low open woodland, particularly Mulga (*Acacia aneura*), and chenopod shrublands (Higgins and Peter 2002). In Queensland the species is largely restricted to southern border areas in the Mulga Lands, Channel Country, Nandewar and Darling Riverine Plains Bioregions (ALA 2024). Sporadic reports from elsewhere in the southern Brigalow Belt probably reflect vagrancy at the edge of the species range (Higgins and Peter 2002). The specific habitat needs of this species and causes of population declines over recent decades are not understood (Ehmke *et al.* 2021).	Remnant and regrowth: RE 11.3.2, 11.3.17, 11.3.25, 11.9.7, 11.9.10 (i.e. all mapped vegetation within the Project Area)	**Unlikely to be present.** The Project Area is outside the range of this largely sedentary species. Vagrant individuals may occasionally reach this area but there are no established populations known from the Southern Brigalow Belt, beyond the border rivers area. The closest record to the Project Area is an unvalidated 2016 sighting from Judd's Lagoon, 15 km to the east (Birdlife Australia 2024). This may be a vagrant or a misidentification. There are no other sightings at that location despite over 64 subsequent surveys (eBird 2024). There are no other post-2000 records of the species within 100 km of the Project Area.
Birds	*Calidris acuminata* Sharp-tailed Sandpiper	V	V	A non-breeding migratory wader species occurring on coastal and inland wetlands (Clemens *et al.* 2021a). Population monitoring within Australia suggests that this species has declined by around 45% over the past two decades (Clemens *et al.* 2021a). Individuals and flocks are regularly recorded across inland Queensland, especially in October and April during migration (ALA 2024; Birdlife Australia 2024; eBird 2024). Breeds in northern Siberia (DCCEEW 2024c) between June and August (Higgins and Davies 1996).	Potential habitat comprises mapped wetland areas and artificial wetlands such as dams within the Project Area.	**Potentially present.** Passage migrants are periodically reported from the area. Generally recorded around larger wetlands. However, suitable habitat for short-term visitors exists around dams and floodplain soaks within the Project Area.

Class	Scientific & Common Name	EPBC Act Status	NC Act Status	Distribution and Known Habitat Use	Potentially Suitable RE within the Project Area	Likelihood of Occurrence within the Project Area
Birds	*Calidris ferruginea* Curlew Sandpiper	CE	CR	A non-breeding migratory wader species usually encountered on coastal and near-coastal saline and freshwater tidal and palustrine wetlands (Clemens *et al.* 2021b; DCCEEW 2024b). The Australian population has declined by 50-80% over the past two decades (Clemens *et al.* 2021b). Passage migrants are occasionally present on inland wetlands, and the species is sparsely recorded across inland Queensland (ALA 2024; Birdlife Australia 2024; eBird 2024).	None. Wetlands within the Project are not of sufficient size and quality to attract this species.	**Unlikely to be present.** Inland records are of sporadic passage migrants transiting during wet years but these are generally from larger wetlands.
Birds	*Calyptorhynchus lathami lathami* Glossy Black-Cockatoo (southeastern subspecies)	V	V	This subspecies occurs in subcoastal ranges from eastern Victoria north to central Queensland with sparse occurrences inland to the Carnarvon Range and along rivers of the Murray-Darling basin (ALA 2024; Cameron *et al.* 2021). The species occurs periodically around Roma, Surat, Glenmorgan, Jackson, Condamine and Chinchilla (BOOBOOK, unpubl.; ALA 2024). This is a specialised feeder dependent on the seeds of several species of *Allocasuarina* and *Casuarina*. It occurs in a variety of forest and woodland types where these food trees are present (Cameron *et al.* 2021; Menkhorst *et al.* 2020; Pizzey *et al.* 2012). It also uses isolated feed trees and small habitat patches within fragmented landscapes (Pavey *et al.* 2016; Holmes 2012). The species roves widely with some evidence of seasonal movements following maturation of She-oak fruits (Stock and Wild 2005; Hourigan 2012). Nesting habitat is in large, hollow-bearing live or dead trees usually in proximity to feed trees and water sources (Higgins 1999).	Primary feeding habitat - Remnant and regrowth: RE 11.3.17, 11.9.10 Sparse feed trees may occur in other remnant and regrowth vegetation and other non-remnant areas. Roosting and nesting habitat-remnant only: RE 11.3.2, 11.3.25, 11.9.7	**Potentially present.** Belah (*Casuarina cristata*) is moderately abundant within the Project Area. No other She-Oak tree species were observed. Potential nest trees (large trees with hollows near food and water sources) occur sparsely in remnant woodland within the Project Area. No evidence of Glossy Black-Cockatoo (chewed cones) was found within the Project Area but occasional visitors could occur.

Class	Scientific & Common Name	EPBC Act Status	NC Act Status	Distribution and Known Habitat Use	Potentially Suitable RE within the Project Area	Likelihood of Occurrence within the Project Area
Birds	*Climacteris picumnus victoriae* Brown Treecreeper (south-eastern)	V	V	This sedentary, cooperative breeding, insectivorous bird occurs broadly around the Great Dividing Range, from the Grampians of Victoria to the Bunya Mountains in Queensland (Ford *et al.* 2021; Menkhorst *et al.* 2020). Along the inland and northern side of this range is a broad intergradation zone with *C. p. picumnus*, which is not EPBC Act-listed (Ford *et al.* 2021; Menkhorst *et al.* 2020; TSSC 2023b). *C. p. victoriae* occurs in eucalypt dominated open forest and woodland, often in periodically inundated areas, where there are abundant tree hollows and hollow logs and high invertebrate biomass associated with woody debris and leaf litter (Ford *et al.* 2021). This species lives in pairs and small family groups, roosting and nesting in tree hollows and foraging on the ground and on trees (Bennett *et al.* 2012; TSSC 2023b). Older siblings contribute to predator vigilance and feeding young, resulting in breeding success increasing with group size (Doerr and Doerr 2007). The species has limited ability to disperse across pastoral lands, rarely crossing gaps larger than 100 m (Doerr *et al*. 2011), and dispersing individuals are vulnerable to predators (Bennet *et al.* 2012). The major threats to the species are habitat loss and fragmentation (Ford *et al.* 2021). It is also sensitive to habitat degradation from grazing pressure, weeds and insufficient or excessive fire, resulting in increased exposure to predation and harassment by Noisy Miners (*Manorina melanocephala*), particularly in small woodland fragments (Bennett *et al.* 2012; TSSC 2023b; Ford *et al.* 2021).	Remnant and regrowth: RE 11.3.2, 11.3.17, 11.3.25, 11.9.7, 11.9.10 (i.e. all mapped vegetation within the Project Area)	**Unlikely to be present.** Woodland within the Project Area consists of small, predominantly linear patches with sparse woody debris and very few log hollows or tree hollows. The landscape around the Project Area is overwhelmingly transformed with no larger areas of woodland within 5 km. Such small, isolated, disturbed patches within a largely cleared landscape are unlikely to support this fragmentation sensitive species. This vocal, group living species is readily detectable but it was not observed during field surveys of the Project Area. There are no records in the vicinity of the Project Area, despite moderate survey effort in the Wallumbilla area (Birdlife Australia 2024; eBird 2024). The closest records are from remnant riparian woodland at Beranga Lagoon around 50 km south of the Project Area (Birdlife Australia 2024; eBird 2024).

Class	Scientific & Common Name	EPBC Act Status	NC Act Status	Distribution and Known Habitat Use	Potentially Suitable RE within the Project Area	Likelihood of Occurrence within the Project Area
Birds	*Erythrotriorchis radiatus* Red Goshawk	E	E	A sparsely distributed raptorial bird that is now restricted to tropical Australia (MacColl *et al.* 2021). The species inhabits extensively wooded areas with permanent water sources and avoids extensively cleared landscapes (Czechura *et al.* 2010). This highly mobile bird has a large home range and is capable of long-distance dispersal (MacColl *et al.* 2021). It roosts and nests in tall forest along major drainage lines, especially around waterholes, where there is high avian prey diversity. Foraging birds could potentially disperse far from these areas (Marchant and Higgins 1993). Red Goshawk is sensitive to landscape level clearing and has declined to extinction in southern and central Queensland (DERM 2012; Seaton 2014). The Brigalow Belt Bioregion is now considered to be outside the species extent of occurrence (MacColl *et al*. 2021).	Remnant and regrowth: RE 11.3.2, 11.3.17, 11.3.25, 11.9.7, 11.9.10 (i.e. all mapped vegetation within the Project Area)	**Unlikely to be present.** The Project Area is in a transformed landscape of derived grassland with only small, linear patches of native vegetation remaining. This extensively cleared landscape offers insufficient foraging and shelter resources for this species. There are no known records of the species within 100 km of the Project Area. Furthermore, the species is now considered extinct throughout southern and central Queensland (MacColl *et al*. 2021).
Birds	*Falco hypoleucos* Grey Falcon	V	V	A rarely seen species, occurring at low densities throughout the arid and semi-arid interior of Australia (TSSC 2020; Schoenjahn *et al.* 2021). In Queensland the species is largely restricted to the southwestern Mulga Lands and Channel Country Bioregions. This is a pursuit predator that feeds almost exclusively on birds, which it hunts on open woodland plains and around water sources (Schoenjahn *et al* 2022). The species nests in large trees along streamlines (TSSC 2020). The species is partially nomadic and itinerant individuals are occasionally recorded in more mesic areas such as the Brigalow Belt (ALA 2024).	None	**Unlikely to be present.** The Project Area does not include the species preferred habitat *Acacia* shrubland plains traversed by tree-lined watercourses (TSSC 2020). The Project Area is outside the species breeding range, which is restricted to arid inland areas.
Birds	*Gallinago hardwickii* Latham's Snipe	V	V	A spring-summer migrant to Australia from breeding grounds on islands and mainland north-eastern Asia (Hansen *et al*. 2020). Declines of 30-50% in the Japanese breeding population, over the past decade, are attributed to drought and habitat change in Australia. The species follows a migration pathway through New Guinea to north-eastern Queensland, dispersing throughout eastern Australia as far as Tasmania (Hansen *et al*. 2020). This cryptic species favours wet pastures and boggy margins of vegetated wetlands (Pizzey *et al*. 2012) including artificial and ephemeral swamps, close to inundated areas (Hansen *et al*. 2020). Individuals and small groups are regularly reported from inland southern and central Queensland, particularly after rainy periods.	None. Potential habitat comprises mapped wetland areas and artificial wetlands such as dams within the Project Area.	**Potentially present.** Migrating individuals could potentially occur within the Project Area during wet periods. Suitable habitat for short-term visitors exists around dams and floodplain soaks within the Project Area.

Class	Scientific & Common Name	EPBC Act Status	NC Act Status	Distribution and Known Habitat Use	Potentially Suitable RE within the Project Area	Likelihood of Occurrence within the Project Area
Birds	*Geophaps scripta scripta* Squatter Pigeon (southern subspecies)	V	V	This is a ground-feeding, ground-nesting pigeon occurring in Queensland from Texas, on the NSW border, through to Cape York. The southern subspecies has undergone long-standing decline, becoming extinct in NSW and rare in southern Queensland (Ward *et al*. 2021). The species inhabits woodland with a low, open ground layer, usually within a few kilometres of a water source (Higgins and Davies 1996). It feeds on seeds of legumes, forbs and some grasses (Higgins and Davies 1996; Ward *et al*. 2021). The species is largely terrestrial, preferring to crouch and freeze when disturbed, although birds will fly to safety on closer approach and birds roost in trees at night (Higgins and Davies 1996). Ongoing declines, particularly in the south of the range, have been attributed to intensive grazing, land clearing, predation by foxes and cats, and encroachment of foraging habitat by introduced pasture grasses, especially Buffel Grass (*Cenchrus ciliaris*) (Ward *et al*. 2021). Squatter Pigeon occurs in small, sedentary flocks and is readily detected as it preferentially forages in sparsely vegetated areas, including disturbed sites along roads, dams and stockyards. The species is regularly encountered in the upper Dawson catchment but appears to be near extinct in the heavily cleared landscape between Roma and Miles (Boobook 2015). Occasional sight records from the past two decades suggest the possibility of a small remnant population in forested areas around the Balonne River (ALA 2024; Birdlife Australia 2024). However, sightings require validation as Common Bronzewing (*Phaps chalcoptera*), a pigeon of similar size and markings may be confused with Squatter Pigeon.	Remnant and regrowth: RE 11.3.2, 11.3.17, 11.3.25, 11.9.7, 11.9.10 (i.e. all mapped vegetation within the Project Area)	**Unlikely to be present.** There is potentially suitable grassy woodland habitat within the Project Area. However, the Project Area is in a heavily cleared and severely fragmented landscape where this species appears to be extinct (Boobook 2015). There are no records in the vicinity of the Project Area, despite moderate bird survey effort in the Wallumbilla area, e.g. 44 Birdata surveys and 18 eBird checklists within 10 km of the Project Area (Birdlife Australia 2024; eBird 2024). The closest recent record is a 2021 sighting of three individuals at Brucedale State Forest, 38 km to the southwest.

Class	Scientific & Common Name	EPBC Act Status	NC Act Status	Distribution and Known Habitat Use	Potentially Suitable RE within the Project Area	Likelihood of Occurrence within the Project Area
Birds	*Grantiella picta* Painted Honeyeater	V	V	An enigmatic, rarely encountered and dispersive species found in woodlands of inland eastern Australia, following fruiting of *Amyema* mistletoe food plants, on which it is dependent (Higgins *et al.* 2001; Watson 2012). Breeding in Box-Ironbark, Brigalow, Belah and Weeping Myall woodlands with abundant mistletoe, on the western slopes of the Great Dividing Range, from the Grampians in western Victoria north to around Chinchilla in Queensland (Watson *et al.* 2021). Dispersed records from further northwest in Queensland and the Northern Territory represent seasonal and nomadic movements across the winter range (Watson *et al.* 2021; ALA 2024). Historical declines occurred in heavily cleared areas in the south of the breeding range (Higgins *et al.* 2001). However, recent analyses suggest that the species population is larger than previously thought with no significant decline in the past decade (Watson *et al*. 2021).	Remnant and regrowth: RE 11.3.2, 11.3.17, 11.9.10	**Unlikely to be present.** The species is observed periodically in the region and nesting has been recorded from the Roma area. The species was recorded in 2023 from Brigalow woodland around Roma (eBird 2024). However, this species is closely associated with *Amyema* mistletoes, which are rare within the Project Area.
Birds	*Hirundapus caudacutus* White-throated Needletail	V	V	An aerial insectivore present in eastern Australia as a spring/summer non-breeding migrant from Asia (Tarburton 2021). Occurs over all habitat types, including disturbed areas, but with most sightings over wooded areas (Tarburton and Garnett 2021). Individuals roost on trunks and upper branches of tall trees at forest edges or trees on ridgelines, arriving and leaving roosts in the dark (Tarburton 2021). During cold conditions, birds may roost in tree hollows for a period of days, in a torpid state (Tarburton 2021). Migrating birds fly at high altitude and at night (Tarburton 2021). The species has few predators in Australia but predation of roosting birds by owls and, rarely, capture of birds in flight by Peregrine Falcon, have been recorded (Tarburton 2021). Ongoing declines appear largely due to loss of breeding sites (large trees with hollows) in northeast Asia (Tarburton and Garnett 2021). However, deaths from collision with wind turbines, in Australia and elsewhere, at night and in daylight, is an increasing threat for this bird (Tarburton 2021).	Remnant and regrowth: RE 11.3.2, 11.3.17, 11.3.25, 11.9.7, 11.9.10 (i.e. all mapped vegetation within the Project Area).	**Likely to be present.** The species occurs in the region and is likely to overfly the Project Area occasionally between September and April, following storm fronts. There are no hills within the Project Area and few large trees and therefore the species is unlikely to roost here. There are no specific habitat features that would attract the species to this Site.

Class	Scientific & Common Name	EPBC Act Status	NC Act Status	Distribution and Known Habitat Use	Potentially Suitable RE within the Project Area	Likelihood of Occurrence within the Project Area
Birds	*Rostratula australis* Australian Painted Snipe	E	E	A secretive nomadic wader that forages and breeds in variably inundated wetlands with features such as complex shorelines, areas of shallow water, dense low vegetation and exposed wet mud (DEE 2019; Rogers *et al*. 2021). Uses both artificial and natural ephemeral and permanent wetlands (Marchant and Higgins 1993). Forages at shallow edges and adjacent vegetated margins of wetlands (DCCEEW 2024b) for seeds and invertebrates (Rogers *et al*. 2021). Recorded over much of Australia other than the driest interior, but most frequently recorded within the Murray-Darling Basin (ALA 2024). Partially migratory, with birds in south-eastern Australia moving in autumn-winter to coastal areas of central and northern Queensland, where it occurs year-round (Rogers *et al*. 2021). The species is unpredictable in occurrence and difficult to detect. Total numbers are estimated at below 2500 individuals (DEE 2019).	None. Potential habitat comprises mapped wetland areas and artificial wetlands such as dams within the Project Area.	**Potentially present.** Migrating individuals could potentially occur within the Project Area during wet periods. Suitable habitat for short-term visitors exists around dams and floodplain soaks within the Project Area.
Birds	*Stagonopleura guttata* Diamond Firetail	V	V	An inobtrusive small ground-feeding finch that occurs in grassy woodlands and forests on tablelands and inland slopes of the Great Dividing Range across south-eastern Australia (Menkhorst *et al*. 2020). In Queensland the species range formerly extended throughout upland areas of the Brigalow Belt but is now largely confined to the New England Tableland Bioregion (ALA 2024; Hodder *et al*. 2021). Declines are attributed to woodland clearing and fragmentation with replacement of perennial indigenous grasses by introduced annual grasses (Hodder *et al*. 2021). Occasional recent records from the Expedition Range and Gurulmundi-Barakula areas may represent dispersing vagrants or small extant populations in rugged, forested uplands which are rarely surveyed (ALA 2024).	Remnant and regrowth: RE 11.3.2, 11.3.17, 11.3.25, 11.9.7, 11.9.10 (i.e. all mapped vegetation within the Project Area)	**Unlikely to be present.** Woodland in and around the Project Area consists of small, disturbed fragments encroached by pasture grasses. The species is intolerant of fragmentation and dependent on abundant native grass seeds for food in winter. Very occasional records from the Southern Brigalow Belt Bioregion over the past two decades are confined to extensively forested areas (ALA 2024; Birdlife Australia 2024; eBird 2024). The closest recent record is from Gurulmundi State Forest on the Great Dividing Range, around 80 km to the northeast of the Project Area.

Class	Scientific & Common Name	EPBC Act Status	NC Act Status	Distribution and Known Habitat Use	Potentially Suitable RE within the Project Area	Likelihood of Occurrence within the Project Area
Fish	*Maccullochella peelii* Murray Cod	V	-	A long-lived species, capable of surviving in impoundments and smaller intermittently connected waterholes. This species prefers slow flowing river channels with abundant instream wood and overhanging vegetation over steep banks (Koehn 2012). In Queensland naturally occurring populations of this species are confined to permanent water in riverine environments in the Condamine, Maranoa-Balonne, Weir, Moonie and Macintyre River catchments (Lintermans 2007).	None	**Unlikely to be present.** No suitable riverine habitat with permanent waterholes exists within the Project Area.
Mammals	*Chalinolobus dwyeri* Large-eared Pied Bat	E	E	This communally roosting insectivorous bat species extends across coastal ranges and inland around the Great Dividing Range, from Ulladulla in southern NSW to Shoalwater Bay in Queensland (ALA 2024; TSSC 2023c). The species inhabits forested rocky uplands within several kilometres of roost sites comprising caves, fissures and sheltered overhangs in cliffs and rocky outcrops (TSSC 2023c; Williams and Thompson 2018). Foraging habitat comprises the outer foliage of canopy trees including along forest edges and streamlines (Williams and Thompson 2018). In southern Queensland the species occurs in the Main Range east of Warwick, in forested areas around Stanthorpe and Western Creek, and in the Expedition and Carnarvon Ranges (ALA 2024).	None	**Unlikely to be present.** There is no suitable forest habitat within the Project Area. There is no suitable shelter habitat (rocky cliffs with deep crevices and caves) within 5 km of the Project Area. The closest records of the species are over 130 km to the north, in the rugged and extensively forested Expedition Range.
Mammals	*Dasyurus hallucatus* Northern Quoll	E	C	The historical distribution of this species in eastern Australia comprised extensively forested subcoastal ranges north from around Toowoomba through to Cape York, extending inland through the Fitzroy Basin (ALA 2024). However, the species has declined markedly and is now confined to rugged and remote areas throughout its distribution (Burnett 2012). Rugged forested uplands with abundant rock outcrops and boulder piles are required to support the species (Oakwood 2008). Post-2000 records in the Southern Brigalow Belt are from the Carnarvon Range and Kroombit Tops, near Biloela (ALA 2024).	None	**Unlikely to be present.** There are no extensively wooded areas within the Project Area. The landscape around the Project Area is largely cleared. There is no suitable shelter and denning habitat (rocky outcrops and boulder piles with crevices and caves) in the vicinity of the Project Area. There are no recent records of the species within 200 km of the Project Area.

Class	Scientific & Common Name	EPBC Act Status	NC Act Status	Distribution and Known Habitat Use	Potentially Suitable RE within the Project Area	Likelihood of Occurrence within the Project Area
Mammals	*Nyctophilus corbeni* South-eastern Long-eared Bat	V	V	This poorly known species has a patchy occurrence across the inland Murray-Darling basin and southern FitzRoy basin (Churchill 2008; Reardon 2012; ALA 2024). The species inhabits a variety of dry shrubby woodland and open forest types, particularly Box/Ironbark/Cypress Pine vegetation with a dense cluttered understory (Reardon 2012; TSSC 2015). Foraging individuals use temporary daytime roosts in tree hollows and crevices or under loose bark (Reardon 2012; TSSC 2015). Maternity colonies of up to 20 individuals roost in tree hollows, often in stags (TSSC 2015). Validated records of the species are known from sites in Expedition National Park, in the Carnarvon Ranges, Barakula State Forest and the Dawson River near Precipice National Park (ALA 2024).	Remnant and regrowth: RE 11.3.2, 11.3.17, 11.3.25, 11.9.7, 11.9.10 (i.e. all mapped vegetation within the Project Area)	**Unlikely to be present.** The species is generally restricted to the vicinity of extensively wooded areas. The landscape around the Project Area is largely cleared. Woodland within the Project Area is disturbed and open without a complex understorey.
Mammals	*Petauroides volans volans* Southern Greater Glider	E	E	The listed form occurs in south and central Queensland, extending inland beyond the western slopes of the Great Dividing Range (ALA 2024; TSSC 2022). This exclusively arboreal species is sensitive to fragmentation, being restricted to large habitat patches and highly connected corridors of riparian woodland with abundant hollow-bearing roost trees (TSSC 2022). Populations in this region are considered a distinct species, Central Greater Glider, *Petauroides armillatus*, by some authors (McGregor *et al*. 2020).	Remnant only: RE 11.3.2, 11.3.17, 11.3.25, 11.9.7, 11.9.10.	**Unlikely to be present.** Woodland in the Project Area consists of small, disconnected fragments that are distant from larger areas of remnant vegetation. There are no continuous riparian corridors within the Project Area and few large trees with hollows (none or 1-5 tree hollows recorded in 50 x 20 m plots in each vegetation type). The closest known occurrences are from the well-developed riparian corridor along Tchanning Creek, over 30 km to the east (Boobook, unpubl. data).

Class	Scientific & Common Name	EPBC Act Status	NC Act Status	Distribution and Known Habitat Use	Potentially Suitable RE within the Project Area	Likelihood of Occurrence within the Project Area
Mammals	*Phascolarctos cinereus* Koala	E	E	Found in coastal and inland areas throughout eastern Australia. Inland areas, such as the southern Brigalow Belt, support a sparse and mobile population (Davies *et al.* 2013). Koalas require woodland and forest habitat with suitable food trees (mainly *Eucalyptus spp.*) (DAWE 2022). Eucalypts in riparian/alluvial areas are particularly favoured, including *E. tereticornis*, *E. camaldulensis* and in some areas *E. populnea* (Wu *et al.* 2012; Smith *et al.* 2013; Melzer *et al.* 2014). Other common food trees in the southern Brigalow Belt include Coolibah (*E. coolabah*), Ironbarks (*E. crebra, E. fibrosa*, *E. melanophloia*), Grey gums (*E. major*), Grey Box (*E. moluccana*, *E. microcarpa*) and Spotted Gum (*Corymbia citriodora*) (Youngentob *et al.* 2021). Koalas outside riparian habitat in inland Queensland also require access to water sources within 1 km, especially during dry periods (Davies *et al.* 2013). The species is sensitive to habitat fragmentation (McAlpine *et al.* 2015; DAWE 2022). Koalas are capable of traversing gaps between habitat patches and may feed in scattered paddock trees, but dispersing individuals in open habitats are at greater risk of predation and vehicle collision (Youngentob *et al.* 2021; DAWE 2022). The species generally occurs at lower density in fragmented landscapes and depends on larger areas of primary habitat as source populations and as refuges in drought (Smith *et al.* 2013; McAlpine *et al.* 2015).	Remnant and regrowth: RE 11.3.2, 11.3.17, 11.3.25, 11.9.7, 11.9.10 (i.e. all mapped vegetation within the Project Area)	**Potentially present.** Riparian remnant and regrowth woodland dominated by *E. camaldulensis* and *E. populnea* provides suitable habitat for transient individuals to move through the Project Area. The landscape is heavily fragmented, however Koala are capable of dispersing over land using scattered paddock trees and corridors along streams. Koala are sparsely distributed in this area but there is a record from similar habitat within 10 km of the Project Area (ALA 2024). No scratches or other evidence of Koala were observed during field surveys.
Reptiles	*Anomalopus mackayi* Long-legged Worm-skink	V	E	A reduced limb burrowing skink found in grassland and grassy woodland on heavy black soil cracking-clay plains (Wilson 2022). Occurs on the Darling Downs of southern Queensland and the Darling River floodplains of northern inland NSW (ALA 2024; Wilson 2022). Australian government modelling of the species distribution predicts that the species may occur between Warwick and Condamine and between Goondiwindi, Narrabri and Walgett, NSW (DCCEEW 2023).	None	**Unlikely to be present.** There is no suitable habitat (heavy black cracking clay soils) for this species within the Project Area. The Project Area is outside the modelled potential distribution of the species (DCCEEW 2023). The closest records of the species are from Jimbour on the Darling Downs, around 190 km away.

Class	Scientific & Common Name	EPBC Act Status	NC Act Status	Distribution and Known Habitat Use	Potentially Suitable RE within the Project Area	Likelihood of Occurrence within the Project Area
Reptiles	*Delma torquata* Collared Delma	V	V	This flapfooted lizard ranges from around Ipswich in South-east Queensland through the Southern Brigalow Belt, although occupancy appears extremely localised and patchy (DCCEEW 2023; ALA 2024). Lives under surface rock or large woody debris in eucalypt woodlands and open forests (Peck 2012, Wilson 2022). The species has been recorded from some roadside corridor areas but is not known from small, isolated patches (ALA 2024). The species is rarely encountered, difficult to detect and search effort in this region is low.	Remnant and regrowth: RE 11.3.2, 11.3.17, 11.3.25, 11.9.7, 11.9.10 (i.e. all mapped vegetation within the Project Area)	**Unlikely to be present.** It is unlikely that this species could persist in such small, isolated and disturbed vegetation patches. The closest publicly accessible records are from the Hodgson area around 65 km to the west (ALA 2024).
Reptiles	*Egernia rugosa* Yakka Skink	V	V	The range of this large, communal-living skink extends throughout the Brigalow Belt and adjacent areas (ALA 2024). It inhabits woodland and open forests dominated by *Eucalyptus*, *Acacia* and *Callitris* spp. and may also occur in grassland areas with regrowth trees (DCCEEW 2023). The species requires loamy soils for burrows or shelters in sinkholes, abandoned rabbit warrens or piles of woody debris (Wilson 2022; Ferguson and Mathieson 2014; Eddie 2012). The species is rarely encountered, difficult to detect and search effort in this region is low.	Remnant and regrowth: RE 11.3.2, 11.3.17, 11.9.7, 11.9.10	**Potentially present.** Possible shelter habitat features within the Project Area, such as logs, were present but not abundant. The species is known to occur in some areas of disturbed habitat where suitable shelter sites are present. The species has been recorded from similarly fragmented vegetation around 21 km north of the Project Area.
Reptiles	*Furina dunmalli* Dunmall's Snake	V	V	A rarely encountered snake occurring in scattered patches of woodland and open forest throughout the Southern Brigalow Belt and adjacent parts of South-east Queensland (ALA 2024, DCCEEW 2023). This species requires abundant leaf litter and woody debris for shelter and prey (Hobson 2012a). Feeds nocturnally on small lizards such as skinks and geckos (Shine 1981). Occurs on heavy soils (Wilson 2022), often with soil cracks and/or gilgais. Most known sites are in large woodland patches and the species is not known to occur in heavily fragmented landscapes. The species is rarely encountered, difficult to detect and search effort in this region is low.	Remnant and regrowth: RE 11.3.2, 11.3.17, 11.3.25, 11.9.7, 11.9.10 (i.e. all mapped vegetation within the Project Area)	**Unlikely to be present.** It is unlikely that this species could persist in such small, isolated and disturbed vegetation patches. The species has been recorded from Yuleba State Forest, around 28 km east-northeast of the Project Area (ALA 2024).

Class	Scientific & Common Name	EPBC Act Status	NC Act Status	Distribution and Known Habitat Use	Potentially Suitable RE within the Project Area	Likelihood of Occurrence within the Project Area
Reptiles	*Hemiaspis damelii*	E	E	A small to medium sized snake generally found on flood-prone soils including floodplains and gilgai-forming clay plains (Wilson 2022). Shelters in soil cracks and under debris, forages mainly nocturnally, feeding on frogs. Associated with ephemeral waterbodies in woodlands and open forests on heavy cracking clays, where it shelters in soil cracks (Hobson 2012b). It is also known to use cleared areas with suitable shelter and foraging habitat, such as gilgais with sedges and rushes.	Remnant and regrowth: RE 11.3.2, 11.3.17, 11.3.25 and mapped wetland areas within the Project Area.	**Potentially present** The Project Area is peripheral to the species distribution, with the closest records from the Glenmorgan area, 85 km southeast (ALA 2024). However, the species is difficult to detect and the Project Area includes some floodplain wetland habitat with cracking clay soils.

3.1.4.2. Field Survey Results

No threatened fauna were recorded during field surveys of the Project Area; however, no intensive fauna surveys were undertaken.

3.1.4.3. Predictive Habitat Mapping

Microhabitat assessments and other field-based habitat observations were conducted within the Project Area as described in Section 2.2.3. The results of these assessments were then combined with ecologist knowledge to develop RE-based predictive habitat mapping for EPBC and NC Act-listed threatened fauna species confirmed, likely or potentially present within the Project Area.

Identified habitat RE were classified as Primary or General Habitat as follows:

Primary habitat - is an area containing resources that are considered essential for the maintenance of populations of the species (e.g. potential habitat for breeding, roosting, foraging, shelter, for either migratory or non-migratory species). 'Primary Habitat' is defined from known records and/or expert advice (including the findings of preclearance surveys).

General habitat - consists of areas or locations that are used by transient individuals or where species have been recorded but there is insufficient information to assess the area as 'Primary Habitat'. 'General Habitat' may be defined from known records or habitat that is considered to potential support a species according to expert knowledge of habitat relationships, despite the absence of specimen backed records. 'General Habitat' may include areas of suboptimal habitat for species.

Habitat mapping rules and the estimated total of General and Primary Habitat for each species within the Project Area and Disturbance Footprint are summarised in Table 5. Predictive habitat maps for threatened fauna are shown in Appendix D.

Table 5: Potentially suitable REs and estimated extent of Primary and General Habitat for EPBC Act-listed threatened fauna species assessed as likely to occur or potentially present within the Project Area and Disturbance Footprint.

Class	Species Name	Potentially Suitable REs within the Project Area	Mapped Extent of Habitat (ha) within the Project Area	Mapped Extent of Habitat (ha) within the Disturbance Footprint	Habitat Mapping Rules/Notes
Birds	*Calidris acuminata* Sharp-tailed Sandpiper	N/A. No ground-truthed RE are wetland REs.	General: 7.31	General: 0.60	No ground-truthed RE are wetland REs. Mapped General Habitat includes any ground-truthed wetlands and dams.
Birds	*Calyptorhynchus lathami lathami* Glossy Black-Cockatoo	Primary: 11.3.17, 11.9.10 General: 11.3.2, 11.3.25, 11.9.7 Remnant and regrowth of all REs.	Primary: 10.71 General: 68.81	Primary: 0.0 General: 0.30	This species requires suitable *Casuarina* or *Allocasuarina* feed trees and large hollow-bearing eucalypts for nesting and roost sites. Primary Habitat includes remnant and regrowth RE with moderate to high abundance of food trees being *Casuarina* and/or *Allocasuarina* spp. Mapped General Habitat includes remnant and regrowth RE that may contain suitable nesting features and/or a lower abundance of food trees and/or presence lesser utilised food trees.

Class	Species Name	Potentially Suitable REs within the Project Area	Mapped Extent of Habitat (ha) within the Project Area	Mapped Extent of Habitat (ha) within the Disturbance Footprint	Habitat Mapping Rules/Notes
Birds	*Gallinago hardwickii* Latham's Snipe	N/A. No ground-truthed RE are wetland REs.	General: 7.31	General: 0.60	No ground-truthed RE are wetland REs. Mapped General Habitat includes any ground-truthed wetlands and dams.
Birds	*Hirundapus caudacutus* White-throated Needletail	Primary: N/A General: 11.3.2, 11.3.17, 11.3.25, 11.9.7, 11.9.10 Remnant and regrowth of all REs.	Primary: 0.00 ha General: 79.52	Primary: 0.0 General: 0.30	This species feeds aerially over all habitat types. Mapped General Habitat includes all remnant and regrowth RE.
Birds	*Rostratula australis* Australian Painted Snipe	N/A. No ground-truthed RE are wetland REs.	General: 7.31	General: 0.60	No ground-truthed RE are wetland REs. Mapped General Habitat includes any ground-truthed wetlands and dams.
Mammals	*Phascolarctos cinereus* Koala	Primary: 11.3.2, 11.3.25, 11.9.7 General: 11.3.17, 11.9.10 Remnant and regrowth of all REs.	Primary: 68.81 General: 10.71	Primary: 0.30 General: 0.0	Mapped Primary Habitat includes all remnant and regrowth of RE dominated by Myrtaceae species containing known food trees e.g. *Eucalyptus populnea*, *E. camaldulensis*. General Habitat comprises other RE that may contain a lower abundance of food trees or less preferred food species within the family Myrtaceae.
Reptiles	*Egernia rugosa* Yakka Skink	Primary: 11.3.2 General: 11.3.17, 11.9.10 Remnant and regrowth of all REs.	Primary: 67.51 General: 10.71	Primary: 0.30 General: 0.00	Mapped Primary Habitat is based on known records within the nominated RE and includes all remnant and regrowth of the nominated RE. Mapped General Habitat includes all remnant vegetation and regrowth of the nominated RE. This may include sub-optimal habitat.
Reptiles	*Hemiaspis damelii* Grey Snake	Primary: N/A General: 11.3.2, 11.3.17, 11.3.25 Remnant and regrowth of all REs.	Primary: 0.00 General: 67.51	Primary: 0.0 General: 0.30	Mapped General Habitat includes all remnant and regrowth of the nominated RE.

The suitability of areas of vegetation as fauna habitat is determined by the presence and abundance of microhabitat features relevant to the needs of individual species or groups of species (e.g. terrestrial reptiles). In general, mature vegetation (remnant or regrowth) is more likely to support appropriate levels of these microhabitat features, while their presence in younger regrowth and clearings is less likely.

This is particularly the case where clearing for agriculture or other purposes has involved the destruction of fallen timber and coarse woody debris, such that where young regrowth is present it lacks necessary microhabitat for ground-dwelling fauna. It is acknowledged that some areas of young regrowth may contain suitable habitat for some species (e.g. log piles used by reptiles). However, such areas were rare within the Project Area which has a largely intact native vegetation cover. For the purposes of this report, Primary and/or General Habitat is assumed to be present only in remnant and regrowth vegetation.

3.1.5. Migratory and Marine Fauna

PMST search results (DCCEEW 2024a) indicated nine EPBC Act-listed migratory and 14 EPBC Act-listed marine fauna species that may occur within the buffered desktop search area. All EPBC Act-listed migratory and marine fauna species that may possibly occur within the Project Area are birds. A likelihood of occurrence assessment for EPBC Act-listed migratory and marine fauna is presented in Table 6.

Table 6: Assessment of likelihood of occurrence for EPBC Act-listed migratory and marine fauna within the Project Area.

Key to Status: CE/CR = Critically Endangered; E = Endangered; V = Vulnerable; NT = Near Threatened; SL = Special Least Concern; C = Least Concern; M = Migratory; Ma = Marine.

Scientific Name	Common Name	EPBC Act Status	Distribution and Known Habitat Use	Potentially Suitable RE/habitat within the Project Area	Likelihood of Occurrence within the Project Area
Actitis hypoleucos	Common Sandpiper	M, Ma	Spring-summer migrant to Australia usually found in coastal environments (muddy, sandy or rocky stream banks, mangrove margins) but occasionally recorded from inland freshwater or saline wetlands during passage, including artificial habitats (Pizzey *et al.* 2012). There are no recent records from the Maranoa region (ALA 2024).	Potential habitat comprises mapped wetland areas and artificial wetlands such as dams within the Project Area	**Potentially present.** Passage migrants are periodically reported from the area. Generally recorded around larger wetlands. However, suitable habitat for short-term visitors exists around dams and floodplain soaks within the Project Area.
Apus pacificus	Fork-tailed Swift	M, Ma	Seasonal migrant to Australia present October – April. An aerial species, commonly travelling in large flocks ahead of low-pressure cells in pursuit of insects which it takes on the wing (Menkhorst *et al.* 2020; Pizzey *et al.* 2012). Present over most habitat types including disturbed areas (ALA 2024; DoE 2015; DCCEEW 2024b). Most common in drier areas with large flocks roving over inland plains (DoE 2015; Tarburton 2015). In contrast to White-throated Needletail, populations of this species appear to be relatively stable (Tarburton 2015).	All vegetated and non-remnant areas.	**Likely to be present.** The species is periodically recorded in the region. Likely to overfly and feed above the Project Area in Spring and Summer.
Bubulcus ibis (as *Ardea ibis*)	Cattle Egret	Ma	Widely distributed in northern and eastern Australia, also south-west Australia. Inhabits a wide range of dryland and wetland habitats including pastoral areas and notably associates with livestock (Menkhorst *et al.* 2020, Pizzey *et al.* 2012). Nests colonially in flooded or swamp forests. An uncommon visitor to southern inland Queensland (ALA 2024).	All non-remnant areas.	**Potentially present.** The species could occasionally occur as a casual visitor within any cleared part of the Project Area.
Calidris acuminata	Sharp-tailed Sandpiper	V, M, Ma	A widespread spring-summer migrant to Australia, utilizing both inland and coastal wetlands such as tidal mudflats, saltmarshes and saline and freshwater inland swamps (Pizzey *et al.* 2012). There are numerous records in inland southern Queensland (ALA 2024).	Potential habitat comprises mapped wetland areas and artificial wetlands such as dams within the Project Area.	**Potentially present.** Passage migrants are periodically reported from the area. Generally recorded around larger wetlands. However, suitable habitat for short-term visitors exists around dams and floodplain soaks within the Project Area.

Scientific Name	Common Name	EPBC Act Status	Distribution and Known Habitat Use	Potentially Suitable RE/habitat within the Project Area	Likelihood of Occurrence within the Project Area
Calidris ferruginea	Curlew Sandpiper	CE, M, Ma	A migratory species usually encountered on coastal and near-coastal saline and freshwater tidal and palustrine wetlands (DCCEEW 2024b). Passage migrants are occasionally present on inland wetlands, and the species is sparsely recorded across inland Queensland (ALA 2024).	No suitable wetland habitat is present for this species within the Disturbance Footprint.	**Unlikely to be present.** Inland records are of sporadic passage migrants transiting during wet years but these are generally from larger wetlands.
Calidris melanotos	Pectoral Sandpiper	M, Ma	Spring-summer migrant preferring freshwater wetlands, both inland and sub-coastally (Menkhorst *et al.* 2020, Pizzey *et al.* 2012). Much less common than the related Sharp-tailed Sandpiper in Australia, there are few records in inland southern Queensland (ALA 2024).	Potential habitat comprises mapped wetland areas and artificial wetlands such as dams within the Project Area	**Potentially present.** Passage migrants are very rarely reported from the area. Generally recorded around larger wetlands. However, suitable habitat for short-term visitors exists around dams and floodplain soaks within the Project Area.
Chalcites osculans (as *Chrysococcyx osculans*)	Black-eared Cuckoo	Ma	Breeding migrant to inland Australia, inhabiting dry woodlands and shrublands (Menkhorst *et al.* 2020, Pizzey *et al.* 2012). The species is common in southern inland Queensland (ALA 2024).	Remnant and regrowth: RE 11.3.2, 11.3.17, 11.3.25, 11.9.7, 11.9.10 (i.e. all mapped vegetation within the Project Area). Also uses non-remnant areas for foraging, shelter and breeding.	**Likely to be present.** Suitable habitat is present within remnant and non-remnant woodland and paddock trees. The species has been recorded from the broader region.
Cuculus optatus (including *C. saturatus*)	Oriental Cuckoo	M, Ma	Migrant to coastal and near-inland northern and eastern Australia, inhabiting denser forest types but may occur in other habitats on passage (Pizzey *et al.* 2012). There are scattered inland southern Queensland records (ALA 2024), however most are from woodland on or closer to the Great Dividing Range and/or in large forest blocks.	11.3.25	**Unlikely to be present.** The highly fragmented and disturbed vegetation present within the Project Area is unlikely to be utilised by this forest-dwelling species.
Gallinago hardwickii	Latham's Snipe	V, M, Ma	Spring-summer migrant, preferring wet pastures, boggy margins of vegetated wetlands and similar habitat at a range of elevations (Pizzey *et al.* 2012). Occasional records from the region.	Potential habitat comprises mapped wetland areas and artificial wetlands such as dams within the Project Area.	**Potentially present.** Migrating individuals could potentially occur within the Project Area during wet periods. Suitable habitat for short-term visitors exists around dams and floodplain soaks within the Project Area.
Haliaeetus leucogaster	White-bellied Sea-Eagle	Ma	Occurs around the entire Australian coast but also penetrates far inland on larger rivers (Menkhorst *et al.* 2020, Pizzey *et al.* 2012). Feeds on a variety of vertebrates and will take carrion.	11.3.25	**Unlikely to be present.** Transient individuals may overfly the Project Area, however there is no suitable lacustrine or riverine habitat within the Project Area.

Scientific Name	Common Name	EPBC Act Status	Distribution and Known Habitat Use	Potentially Suitable RE/habitat within the Project Area	Likelihood of Occurrence within the Project Area
Hirundapus caudacutus	White-throated Needletail	V, M, Ma	Summer visitor in small to very large flocks that travel with weather fronts, occurring mainly in eastern Australia (Pizzey *et al.* 2012, ALA 2024). It feeds aerially over all natural and artificial environments.	Remnant and regrowth: RE 11.3.2, 11.3.17, 11.3.25, 11.9.7, 11.9.10 (i.e. all mapped vegetation within the Project Area).	**Likely to be present.** The Project Area is within the known range of the species and it may forage aerially over all habitat types.
Merops ornatus	Rainbow Bee-eater	Ma	A widespread and abundant species that is a breeding migrant in this region. It arrives from the north in September, returning in April (Menkhorst *et al.* 2020, Pizzey *et al.* 2012). It feeds on bees and other invertebrates, aerially, sallying from a perch, or on the ground. It is a summer breeder in the region but requires open areas of loamy soil for nesting tunnels.	Remnant and regrowth: RE 11.3.2, 11.3.17, 11.3.25, 11.9.7, 11.9.10 (i.e. all mapped vegetation within the Project Area). Also uses non-remnant areas for foraging, shelter and breeding.	**Likely to be present.** This species is regularly observed throughout the region in Spring – Summer.
Motacilla tschutschensis (as *Motacilla flava*)	Eastern Yellow Wagtail	M, Ma	Summer migrant in small numbers to coastal northern Australia with vagrants to southern Australia. It prefers open grassed areas such as wetland margins, short pasture and parks (Pizzey *et al.* 2012). There are no records for southern inland Queensland (ALA 2024).	None	**Unlikely to be present.** There are no existing records of this species from southern inland Queensland (ALA 2024).
Myiagra cyanoleuca	Satin Flycatcher	M, Ma	A passage migrant in southern Queensland, with birds recorded in a variety of woodland types as well as parks and gardens, but breeding in south-east Australia in more closed forest types (Pizzey *et al.* 2012). There are no records from the region (ALA 2024).	None	**Unlikely to be present.** The Project Area is on the inland periphery of the known range of this species (ALA 2024). Occasional passage migrants occur within the region, however the disturbed and highly fragmented woodland patches are unlikely to be utilised by this species.
Rostratula australis (as *Rostratula benghalensis*)	Australian Painted Snipe	E, Ma	Recorded over much of Australia other than the driest interior, but most frequently recorded within the Murray-Darling Basin (ALA 2024). Forages at shallow edges and adjacent vegetated margins of freshwater wetlands (DCCEEW 2024b) and is able to use both artificial and natural ephemeral and permanent wetlands (Marchant and Higgins 1993). Occasional records from the region (ALA 2024).	Potential habitat comprises mapped wetland areas and artificial wetlands such as dams within the Project Area.	**Potentially present.** Migrating individuals could potentially occur within the Project Area during wet periods. Suitable habitat for short-term visitors exists around dams and floodplain soaks within the Project Area.

3.1.6. Internationally & Nationally Important Wetlands

No internationally or nationally significant wetlands are present within or in close proximity to the Project Area. All Wetlands of International Significance identified within the PMST search are greater than 300-400 km downstream from the Project Area.

3.2. Matters of State Environmental Significance

3.2.1. Regional Ecosystems

State government mapped remnant RE (biodiversity status), regulated vegetation as per VMA and mature regrowth (DESI 2024h, DESI 2024i, DoR 2024b) is shown in Appendix A. No remnant (Category B) vegetation is mapped within the Project Area. Three areas within the Project Area are mapped as Category C regrowth containing Of Concern vegetation equivalent to the mixed RE 11.3.2/11.3.17/11.3.25 (70/20/10).

Ground-truthing identified five RE types within the Project Area, including those that are regrowth shown in government mapping (Appendix A). Vegetation in the southern part of the Project Area is on land zone 3 (Quaternary alluvium) associated with streamlines and alluvial plains. Vegetation in the northern part of the Project Area includes areas on land zone 9 (fine-grained sediments). Remnant vegetation occurs as disturbed, irregular and discontinuous corridors along streams, road easements and fence line corridors. Regrowth vegetation comprises Poplar Box (*Eucalyptus populnea*) woodland in riparian corridors, on narrow floodplains and on gently undulating terrain. Summary data for remnant and regrowth RE within the Project Area is presented within Table 7. Mapping of ground-truthed RE from field surveys is presented in Appendix C.

Table 7: Summary of extent of individual mapped REs from ground-truthing and imagery analysis within the Project Area and Disturbance Footprint.

RE Code	VM Act Class	Biodiversity Status	Short Description	Extent in the Project Area – remnant (ha)	Extent in the Project Area – regrowth (ha)	Extent in the Disturbance Footprint – remnant (ha)	Extent in the Disturbance Footprint – regrowth (ha)
11.3.2	OC	OC	*Eucalyptus populnea* woodland on alluvial plains	19.41	65.38	0.15	0.15
11.3.17	OC	E	*Eucalyptus populnea* woodland with *Acacia harpophylla* and/or *Casuarina cristata* on alluvial plains	10.81	0.00	0.00	0.00
11.3.25	LC	OC	*Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines	20.94	0.00	0.00	0.00
11.9.7	OC	OC	*Eucalyptus populnea*, *Eremophila mitchellii* shrubby woodland on fine-grained sedimentary rocks	0.61	1.30	0.00	0.00
11.9.10	OC	E	*Eucalyptus populne*a open forest with a secondary tree layer of *Acacia harpophylla* and sometimes *Casuarina cristata* on fine-grained sedimentary rocks	23.96	2.34	0.00	0.00

E = Endangered; OC = Of Concern; LC = Least Concern; NCAP = No Concern at Present

3.2.2. BioCondition Assessment

Vegetation condition was assessed using the BioCondition methodology of Eyre *et al.* (2015). Assessments were completed at 7 locations in the Project Area (Appendix AC), these being representative samples of four AU (i.e. remnant and regrowth RE) described in Table 7. Raw data for BioCondition assessment sheets have been provided separately to this report. BioCondition site characteristics and scores are summarised in Table 8.

Table 8: Summary of BioCondition assessment sites and results within the Project Area.

AU	RE	Structural condition	Assessment sites	Averaged BioCondition score
1	11.3.2	remnant	863-B03, 863-B05	0.60
2	11.3.2	regrowth	863-B01, 863-B02	0.53
3	11.3.17	remnant	863-B04, 863-B07	0.47
4	11.3.25	remnant	863-B06	0.47

All AU received moderate BioCondition scores (0.47 – 0.60) which indicate significant disturbance and consequent loss of ecosystem integrity relative to intact areas of each RE. These scores also reflect landscape level fragmentation of native vegetation, which is in small patch size, low connectivity among AU and a low proportion of remnant and regrowth vegetation in the surrounding landscape.

3.2.3. Threatened Flora & Essential Habitat

Desktop assessment (ALA 2024, DESI 2024a) did not produce any records of threatened flora species within 10 km of the Project Area. A likelihood assessment for NC Act-listed threatened flora that are also EPBC Act-listed species is included within Table 2 within section 3.1.2 of this report. A likelihood of occurrence assessment for NC Act-listed threatened flora which are not EPBC Act-listed species is included in Table 9.

Table 9: Assessment of likelihood of occurrence for NC Act-listed threatened flora within the Project Area.

Key to Status: E = Endangered; V = Vulnerable; NT = Near Threatened; C = Least Concern.

Class	Scientific & Common Name	EPBC Act Status	NC Act Status	Distribution and Known Habitat Use	Likelihood of Occurrence
Asteraceae	*Picris barbarorum* Plains Picris	-	V	An erect annual daisy occurring in grassy woodlands on floodplains, riverbanks and grasslands on heavy cracking clay soils (DESI 2024b). A record (ALA 2024) exists in roadside vegetation near Roma (ALA 2024).	**Unlikely to be present.** Habitat at the known sites is native grassland associated with heavy cracking clay soils. This habitat type is absent from the Project Area.

No NC Act-listed threatened flora was detected during field surveys of the Project Area.

The Project Area is not located within a High-Risk Area as shown on a Protected Plants Flora Survey Trigger Map (DESI 2024c). There is no state government mapped Essential Habitat for NC Act-listed threatened flora (DES 2022).

3.2.4. Special Least Concern Flora

No Special Least Concern (SLC) flora was detected within the Project Area.

3.2.5. Biosecurity Act Weeds & Other Weeds of Management Concern

Records of African Boxthorn (*Lycium ferocissimum*) and Sulphur Cactus (*Opuntia sulphurea*) were returned by desktop searches within 5 km of the Project Area centre point (DESI 2024a, ALA 2024). Four species of weeds (invasive plants) prescribed under the Queensland *Biosecurity Act 2014* were detected within the Project Area. These are Sulphur Cactus which is listed as a prohibited invasive plant, along with Velvety Tree Pear (*Opuntia tomentosa*), Common Pest Pear (*O. stricta*) and African Boxthorn which are listed as Category 3 restricted matter. These four species are also WoNS as described at Section 3.1.3.

3.2.6. Threatened Fauna

3.2.6.1. Likelihood of Occurrence Assessment

Desktop searches of public databases (DESI 2024a, ALA 2024) contained records of Koala (NC Act: Endangered), Woma (*Aspidites ramsayi*) (NC Act: Near Threatened) and Common Death Adder (*Acanthophis antarcticus*) (NC Act: Vulnerable) within 10 km of the Project Area.

A likelihood of occurrence assessment for NC Act-listed threatened fauna that are also EPBC Act-listed species is included within Table 4 (refer to section 3.1.4 of this report). A likelihood of occurrence assessment for NC Act-listed threatened fauna which are not also EPBC Act-listed is shown in Table 10.

Table 10: Likelihood of occurrence assessment for NC Act-listed threatened fauna (additional to EPBC Act-listed species) within the Project Area.

Class	Scientific & Common Name	NC Act Status	Distribution and Known Habitat Use	Potentially Suitable RE within the Project Area	Likelihood of Occurrence within the Project Area
Insects	*Jalmenus eubulus* Pale Imperial Hairstreak (butterfly)	V	This butterfly is essentially limited to the Brigalow Belt: its range extends from inland of Eungella, central Qld southward to the Carnarvon Range and Darling Downs, extending into far northern NSW (ALA 2024). Usually associated with mature Brigalow (*Acacia harpophylla*) open forests and woodlands (Eastwood *et al.* 2008; Valentine and Johnson 2012). The species has a naturally fragmented habitat and is capable of dispersal over moderate distances, with vagrant individuals found far from patches of Brigalow habitat (Eastwood *et al.* 2008).	Remnant: 11.3.17, 11.9.10	**Unlikely to be present.** There is no Brigalow dominated woodland or other suitable habitat within the Project Area. Brigalow trees associated with RE 11.3.17 and 11.9.10 within the Project Area are in very low density and therefore unlikely to attract this species.
Reptiles	*Acanthophis antarcticus* Common Death Adder	V	A widespread but patchily distributed snake species with several historical records from the region (ALA 2024, DESI 2024b). Lives in woodlands, open forests and heathlands; requires abundant shelter/ambush predation cover e.g. low shrubs, rocks, logs and dense leaf litter (Wilson 2022).	Remnant: 11.9.10	**Unlikely to be present.** There are historical records of this species from around Wallumbilla. However, woodland within the Project Area is disturbed and open, containing few of the required microhabitat features for this species (i.e. there is a low density/abundance of low shrubs, rocks, dense leaf litter and/or rocks).
Reptiles	*Aspidites ramsayi* Woma	NT	A snake recorded from a variety of woodland and shrubland habitats in sub-humid to arid Australia (Wilson 2022). Shelters in hollow logs and abandoned animal burrows (e.g. rabbit warrens). It preys on reptiles and small mammals.	Remnant and regrowth: RE 11.3.2, 11.3.17, 11.3.25, 11.9.7, 11.9.10 (i.e. all mapped vegetation within the Project Area)	**Potentially present.** There are several records of this species from the vicinity of the Project Area. The species can persist in disturbed and fragmented habitats providing prey and shelter sites are present.

Class	Scientific & Common Name	NC Act Status	Distribution and Known Habitat Use	Potentially Suitable RE within the Project Area	Likelihood of Occurrence within the Project Area
Reptiles	*Strophurus taenicauda* Golden-tailed Gecko	NT	This gecko is endemic to inland southern and central Queensland, where it inhabits a variety of dry woodland and open forest habitats in the Brigalow Belt (DESI 2024b). Within these habitats it lives in tree hollows and splits, and under loose bark on live and dead trees (DESI 2024b, Wilson 2022).	Remnant and regrowth: RE 11.3.2, 11.3.17, 11.3.25, 11.9.7, 11.9.10 (i.e. all mapped vegetation within the Project Area)	**Unlikely to be present.** The species has been recorded from nearby areas within large forest tracts. Potentially suitable habitat (dry woodland and open forest) occurs within the Project Area, however woodland within the Project Area is fragmented, disturbed and open, containing few of the required microhabitat features for this species (i.e. there is a low density/abundance of loose bark) and likely high levels of competition between Dubious Dtella (*Gehyra dubia*).

3.2.6.1. Field Survey Results

No NC Act-listed threatened species were found during the field survey; however, no intensive fauna surveys were undertaken.

3.2.6.2. Essential Habitat

There is no State government mapped Essential Habitat (DES 2022) for NC Act-listed threatened fauna within the Project Area.

3.2.6.3. Predictive Habitat Mapping

Predictive habitat mapping was developed for EPBC and NC Act-listed threatened fauna species confirmed, likely or potentially present within the Project Area as described in Section 3.1.4.3. These results were informed by likelihood of occurrence assessments listed within Table 4 and Table 10 for EPBC and/or NC Act-listed threatened fauna that may potentially occur within the Project Area. Predictive habitat mapping for NC Act-listed fauna potentially occurring within the Disturbance Footprint is shown in Appendix D. Species listed as Near Threatened under the NC Act that could potentially occur within the Project Area (e.g. Woma) do not constitute a MSES and are excluded from predictive habitat mapping.

3.2.7. Special Least Concern Fauna

3.2.7.1. Likelihood of Occurrence Assessment

Wildlife Online and ALA searches (DESI 2024a, ALA 2024) produced records of one SLC fauna species within the buffered desktop search area this being Short-beaked Echidna (*Tachyglossus aculeatus*). A likelihood of occurrence assessment for SLC fauna within the Project Area is presented in Table 11.

Table 11: Assessment of likelihood of occurrence for SLC fauna within the Project Area.

Key to Status: SLC = Special Least Concern

Class	Scientific and Common Name	EPBC Act Status	NC Act Status	General Habitat Requirements	Potentially Suitable RE within the Project Area	Likelihood of Occurrence
Mammals	Short-beaked Echidna *Tachyglossus aculeatus*	-	SLC	A ubiquitous inhabitant of a wide variety of landforms and climatic regimes across Australia (Augee 2008) where it digs in soil and litter for ants, termites and their larvae and eggs. It is commonly found in a variety of woodland types as well as cleared pastoral and farming lands with suitable microhabitat and food sources.	11.3.2, 11.3.17, 11.3.25, 11.9.7, 11.9.10	**Potentially present.** Recorded within the desktop search area (ALA 2024, DESI 2024a). The species is likely to have a patchy occurrence in the Project Area. Suitable habitat features such as logs and woody debris were scarce within the Project Area.
Mammals	Platypus *Ornithorhynchus anatinus*	-	SLC	Widespread species in eastern Australia but confined to permanent freshwater rivers and streams. It is patchily distributed in inland Queensland and is regularly reported from the Dawson River and its major tributaries (ALA 2024).	11.3.25	**Unlikely to be present.** The nearest records of this species are located over 100 km to the east and north of the Project Area. The areas of RE 11.3.25 within the Project Area do not include permanent aquatic habitat.

Migratory fauna that are SLC are addressed within section 3.1.5 of this report.

3.2.7.2. Field Survey Results

No SLC fauna species were recorded within the Project Area during the field survey, however no intensive fauna surveys were undertaken.

3.2.7.1. Predictive Habitat Mapping

Mapping rules and the estimated extent of potentially suitable habitat for SLC fauna species likely to occur within the Project Area are given in Table 12. Refer to Table 11 (Section 3.2.7.1) for a summary of habitat requirements for SLC species.

Table 12: Potentially suitable REs and estimated extent of habitat for SLC fauna species within the Project Area and Disturbance Footprint.

Class	Scientific and Common Name	Potentially Suitable REs within the Project Area	Mapped Extent of Habitat within the Project Area	Mapped Extent of Habitat (ha) within the Disturbance Footprint (ha)	Habitat Mapping Rules/Notes
Mammals	Short-beaked Echidna *Tachyglossus aculeatus*	Primary: N/A General: 11.3.2, 11.3.17, 11.3.25, 11.9.7, 11.9.10	Primary: 0.0 General: 153.08	Primary: 0.0 General: 0.30	Mapped General Habitat includes remnant and regrowth areas of the nominated RE.

3.2.8. Fauna Habitat Features & Potential Breeding Places

The results of fauna habitat assessments conducted within the Project Area are included within associated spatial data. Fauna habitat features present within the Project Area included hollow-bearing trees (dead and alive), hollow-bearing logs and piles of pushed timber. Location of fauna habitat assessment sites are shown in Appendix C.

3.2.9. Wetlands, Lakes & Springs

No springs or lakes were mapped as present within the Project Area. No wetlands of High Ecological Significance or wetlands of General Ecological Significance, as shown on a Map of Referable Wetlands (DESI 2024d), were mapped as present within the Project Area. No mapped wetlands in high ecological value waters, as identified under the *Environmental Protection (Water) Policy 2009,* occur within the Project Area.

No springs or lakes were detected during the field survey. Several areas of habitat which meet the criteria for wetlands (DERM 2011) were detected within the Project Area. These are wetlands of general ecological significance and their location and extent is shown within Appendix C. Representative images are shown in Figure 4a-b in Section 8.

3.2.10. Watercourses & Drainage Features

Several mapped streams occur within the Project Area including Washpool Creek. No stream assessments were undertaken within this scope of works. No mapped watercourses in high ecological value waters, as identified under the *Environmental Protection (Water) Policy 2009,* occur within the Project Area.

3.2.10.1. Waterways Providing for Fish Passage

The Queensland waterways for waterway barrier works mapping helps identify waterways as defined by the *Fisheries Act 1994* and the fisheries interest in waterways providing fish passage (a MSES under the *Environmental Offsets Act 2014*). In total, three waterways with a fish passage attribute 1 (green); one waterway with a fish passage attribute 2 (amber); and two waterways with a fish passage attribute 3 (red) occur within the Project Area. Each of these waterways, except one green and one amber, are intersected by the proposed Disturbance Footprint.

3.2.11. Environmentally Sensitive Areas

The following Category B ESA are present within the Project Area:

- areas of ground-truthed Endangered RE (biodiversity status): 11.3.17 and 11.9.10.

The following Category C ESA are present within the Project Area:

- areas of ground-truthed Of Concern RE (biodiversity status): 11.3.2, 11.3.25 and 11.9.7.
- an area validated from ground-truthing surveys as 'protected wildlife habitat' that is category A, B or C on the Remnant Vegetation Management Map, in accordance with section 20A of the *VMA*, for a species of wildlife listed as critically endangered, endangered or vulnerable under the NC Act as follows:
    - ground-truthed protected wildlife habitat: Glossy Black-Cockatoo (*Calyptorhynchus lathami lathami*) - NC Act: Vulnerable: remnant and regrowth: RE 11.3.2, 11.3.25, 11.9.10.
    - ground-truthed protected wildlife habitat: White-throated Needletail (*Hirundapus caudacutus*) - NC Act: Vulnerable: remnant and regrowth: RE 11.3.2, 11.3.25, 11.9.10.
    - ground-truthed protected wildlife habitat: Koala (*Phascolarctos cinereus*) - NC Act: Endangered: remnant and regrowth REs 11.3.2, 11.3.25, 11.9.10.
    - ground-truthed protected wildlife habitat: Yakka Skink (*Egernia rugosa*) - NC Act: Vulnerable: remnant and regrowth: RE 11.3.2, 11.9.10.
    - ground-truthed protected wildlife habitat: Grey Snake (*Hemiaspis damelii*) - NC Act: Endangered: remnant and regrowth REs 11.3.2, 11.3.25.

Ground-truthed regional ecosystems comprising Category B and C ESA are shown in Appendix E1. Category C ESA comprising protected wildlife habitat as per the VMA regulated vegetation map (Appendix A2) are shown in Appendix E2.

3.2.12. Connectivity Areas

Connectivity areas are areas of remnant vegetation outside urban areas containing prescribed RE that are required for ecosystem functioning. As both test results were negative, the overall result is the impact will not be significant. Results of the connectivity tool are summarised in Table 13.

Table 13: Connectivity areas that are a RE (not in urban area) within the Project Area.

Connectivity Test	Regional scale[i] extent of core remnant RE pre-impact	Change threshold for local scale[ii] core remnant RE	Change in core local scale remnant RE post-impact	Number of core areas ≥1 ha pre-impact	Number of core areas ≥1 ha post-impact	Test Result
Change in core remnant RE extent at the local scale	4.4%	2%	0%			Not Significant
Loss/ fragmentation of core remnant RE at the site (Disturbance Footprint) scale				0	0	Not Significant

[i] Regional scale is an area within a 20 km buffer of the Disturbance Footprint
[ii] Local scale is an area within a 5 km buffer of the Disturbance Footprint

4. Potential Impacts

4.1. Predicted Impacts within the Project Area

The following assessment of potential impacts is based on the proposed Disturbance Footprint provided by Santos.

4.1.1. Matters of National Environmental Significance

4.1.1.1. Threatened Ecological Communities

No TEC occurs within the Disturbance Footprint within the Project Area therefore there will be no impact on TEC.

4.1.1.2. Threatened Flora

EPBC Act-listed threatened plant species that may potentially occur within the Project Area are given in Table 2 (section 3.1.2). No threatened plant species were detected during field surveys of the proposed disturbance area. No threatened flora species are expected to occur within the Project Area. The Project is therefore unlikely to impact on any threatened flora species and no impact assessment is required.

4.1.1.3. Threatened Fauna

EPBC Act-listed threatened fauna species that are likely to occur or may potentially occur within the Project Area are listed within Table 4 (section 3.1.4.1). Predicted mapping of threatened species habitat is shown in Appendix D. Potential impacts on species identified as likely to occur or potentially present within the Project Area are assessed below in Table 11, following the EPBC Act guidelines for Significant Impacts on Matters of National Environmental Significance (DoE 2013).

Potential impacts on EPBC Act-listed endangered fauna assessed as likely to occur or potentially occurring within the Project Area are summarised below in Table 11, following the EPBC Act *Guidelines for Significant Impacts on Matters of National Environmental Significance* (DoE 2013).

Table 14: Assessment of potential significant impacts (as per Significant Impact criteria within DoE 2013) upon EPBC Act-listed endangered fauna species within the Project Area.

Class	Species	Significant Impact Criteria (DoE 2013)									Significant Impact
		Lead to a long-term decrease in the size of a population	**Reduce the Area of Occupancy (AoO) of the species**	**Fragment an existing population into two or more populations**	**Adversely affect habitat critical to the survival of a species**	**Disrupt the breeding cycle of a population**	**Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**	**Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the critically endangered or endangered threatened species' habitat.**	**Introduce disease that may cause the population to decline.**	**Interfere with the recovery of the species.**	
Birds	*Rostratula australis* Australian Painted Snipe	No: The species is a rare visitor in very low numbers to the region. There are no known important populations of the species in or near the Project Area.	No: The available wetland habitat within the Project Area (0.60 ha) is likely to support only a few individuals during favourable conditions in spring-summer only.	No: The species is mobile and wide-ranging and occurs only sporadically in the region. The proposed development is unlikely to restrict dispersal in this species.	No: Wetlands within the Project Area are very small and highly ephemeral. Although these wetlands may occasionally be used by transitory individuals, they do not represent habitat critical to the surveyal of the species.	Unlikely: Breeding has been recorded in all months of the year in response to wetland conditions. The small and highly ephemeral nature of wetlands within the Project Area are unlikely to be attractive for breeding by this species.	No: Wetlands within the Project Area are very small and highly ephemeral. Disturbance will only occur to 0.60 ha of 7.31 ha available wetland habitat within the Project Area. Disturbance to this small area will not cause this species to decline.	None known.	None known.	No: The Project is unlikely to cause harm to any individuals and is therefore unlikely to interfere with recovery of the species.	No: There will be no substantial decrease in available foraging habitat within the Project Area i.e. there will be disturbance to only 0.60 ha of mapped wetland habitat. Total available mapped wetland habitat available within the Project Area is 7.31 ha. There will be no loss if individuals as a result of Project activities.

Class	Species	Significant Impact Criteria (DoE 2013)									Significant Impact
		Lead to a long-term decrease in the size of a population	**Reduce the Area of Occupancy (AoO) of the species**	**Fragment an existing population into two or more populations**	**Adversely affect habitat critical to the survival of a species**	**Disrupt the breeding cycle of a population**	**Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**	**Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the critically endangered or endangered threatened species' habitat.**	**Introduce disease that may cause the population to decline.**	**Interfere with the recovery of the species.**	
Mammals	*Phascolarctos cinereus* Koala	Unlikely: Loss of 0.30 ha of eucalypt woodland will not lead to a decrease in size of the local population.	Unlikely: No sign of Koala was detected within the Project Area. It is likely that this area would be used by occasional transient individuals. The loss of 0.30 ha of potential habitat in the Disturbance Footprint is unlikely to affect the occurrence of Koala within the Project Area.	No: Koala are capable of crossing gaps between habitat patches and may use isolated paddock trees. The loss of several small areas of potential habitat, summing to 0.30 ha, will not disrupt habitat corridors through this area and will have negligible effect on Koala dispersal through the Project Area.	Unlikely: The loss of several small areas of potential habitat, summing to 0.30 ha, is unlikely to have measurable impacts on occasional Koala usage of the Project Area.	No: No evidence of Koala was found within the Project Area and it is likely that Koala occurrence within the Project Area is occasional and transient. The breeding cycle is unlikely to be disrupted.	No: This small area is unlikely to reduce Koala numbers or to disrupt Koala movement through the Project Area. It is likely that the 0.30 ha of potential habitat proposed to be cleared involves the removal of <15 mature trees from the Disturbance Footprint.	None known	None known: chlamydia is present in the Koala population of southern inland Queensland but this bacterial disease is unlikely to be exacerbated by the proposed development.	Unlikely: The loss of several small areas of potential habitat, totalling 0.30 ha will have minimal effect on the recovery of Koala in this area.	No: The proposed development will result in the loss of up to 0.30 ha of potential habitat (RE 11.3.2) spread across several fragments. This small area is unlikely to reduce Koala numbers or to disrupt Koala movement through the area. No evidence of Koala was found within the Project Area and it is likely that Koala occurrence within the Project Area is occasional and transient.

Class	Species	Significant Impact Criteria (DoE 2013)									Significant Impact
		Lead to a long-term decrease in the size of a population	**Reduce the Area of Occupancy (AoO) of the species**	**Fragment an existing population into two or more populations**	**Adversely affect habitat critical to the survival of a species**	**Disrupt the breeding cycle of a population**	**Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**	**Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the critically endangered or endangered threatened species' habitat.**	**Introduce disease that may cause the population to decline.**	**Interfere with the recovery of the species.**	
Reptiles	*Hemiaspis damelii* Grey Snake	Unlikely: 0.30 ha of potential habitat occurs within the Disturbance Footprint. Mapped habitat comprises fragmented patches of riparian or floodplain woodland.	Unlikely: The 0.30 ha of mapped habitat includes already fragmented habitat patches.	No: The proposed development will not exacerbate existing fragmentation.	Unlikely: The 0.30 ha of mapped shelter, foraging, breeding and dispersal habitat comprises disturbed alluvial woodland fragments. Similar features occur in the vicinity and this habitat is unlikely to be limiting.	No: Only 0.30 ha of mapped habitat within the Disturbance Footprint with similar habitat abundant in the vicinity.	Unlikely: The 0.30 ha of mapped shelter, foraging, breeding and dispersal habitat comprises disturbed alluvial woodland fragments. Similar features occur in the vicinity and this habitat is unlikely to be limiting. Loss of 0.30 ha of habitat is unlikely to contribute to a decline in the species.	None known.	None known.	No: Only 0.30 ha of mapped habitat within the Disturbance Footprint with similar habitat abundant in the vicinity.	No: Presence of this species within the Project Area was not confirmed during the field survey. The Project Area is peripheral to the species distribution and there are no records in the vicinity. Potentially suitable floodplain woodland and ephemeral wetland habitat (RE 11.3.2) is widespread beyond the Disturbance Footprint.

Potential impacts on EPBC Act-listed vulnerable fauna assessed as likely to occur or potentially occurring within the Project Area are summarised below in Table 12, following the EPBC Act *Guidelines for Significant Impacts on Matters of National Environmental Significance* (DoE 2013).

Table 15: Assessment of potential significant impacts (as per Significant Impact criteria within DoE 2013) upon EPBC Act-listed vulnerable fauna species within the Project Area.

Class	Species	Significant Impact Criteria (DoE 2013)									Significant Impact
		Lead to a long-term decrease in the size of an important population of a species	**Reduce the Area of Occupancy (AoO) of an important population**	**Fragment an existing population into two or more populations**	**Adversely affect habitat critical to the survival of a species**	**Disrupt the breeding cycle of an important population**	**Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**	**Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat.**	**Introduce disease that may cause the species to decline.**	**Interfere substantially with the recovery of the species.**	
Birds	*Calidris acuminata* Sharp-tailed Sandpiper	No: The species is an occasional visitor in low numbers to the region. There are no important populations of the species in or near the Project Area.	No: The available wetland habitat within the Project Area (0.60 ha) is likely to support only a few individuals during favourable conditions in spring-summer only.	No: The species is mobile and wide-ranging and occurs only sporadically in the region. The proposed development is unlikely to restrict dispersal of this species.	No: Wetlands within the Project Area are very small and highly ephemeral. Although these wetlands may occasionally be used by transitory individuals, they do not represent habitat critical to the surveyal of the species.	No: The species does not breed within Australia. Breeding occurs between June and August in northern Siberia (DCCEEW 2024c).	No: Wetlands within the Project Area are very small and highly ephemeral. Disturbance will only occur to 0.60 ha of 7.31 ha available wetland habitat within the Project Area. Disturbance to this small area will not cause this species to decline.	None known.	None known.	No: The Project is unlikely to cause harm to any individuals and is therefore unlikely to interfere with recovery of the species.	No: There will be no substantial decrease in available foraging habitat within the Project Area i.e. there will be disturbance to only 0.60 ha of mapped wetland habitat. Total available mapped wetland habitat available within the Project Area is 7.31 ha. There will be no loss if individuals as a result of Project activities.

Class	Species	Significant Impact Criteria (DoE 2013)									Significant Impact
		Lead to a long-term decrease in the size of an important population of a species	**Reduce the Area of Occupancy (AoO) of an important population**	**Fragment an existing population into two or more populations**	**Adversely affect habitat critical to the survival of a species**	**Disrupt the breeding cycle of an important population**	**Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**	**Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat.**	**Introduce disease that may cause the species to decline.**	**Interfere substantially with the recovery of the species.**	
Birds	*Calyptorhynchus lathami lathami* Glossy Black-Cockatoo	Unlikely: Loss of 0.30 ha of potential shelter and breeding habitat. Feed trees occur nearby but are not present in the Disturbance Footprint. This small area supports few potential nest/roost trees. The species has not been recorded in the Project Area and is likely to occur as an occasional visitor, rather than being a resident.	Unlikely: Loss of 0.30 ha of potential shelter and breeding habitat. No nest or roost trees were identified during surveys. This mobile and wide-ranging species is capable of traversing non-remnant areas between nest/roost trees and feed trees.	No: The disturbance will not affect dispersal of this species, which travels long distances between suitable foraging trees.	Unlikely: Loss of 0.30 ha of potential habitat is unlikely to affect habitat critical to the survival of the species.	Unlikely: Loss of 0.30 ha of potential habitat with no known nesting trees is unlikely to disrupt the breeding cycle of this species. However, the species has not been recorded in the Project Area and is likely to occur as an occasional visitor, rather than being a breeding resident.	Unlikely: Loss of 0.30ha of potential habitat is unlikely to cause the species to decline. Feed trees occur nearby but are not present in the Disturbance Footprint.	None known	None known	Unlikely: Loss of 0.30 ha of potential habitat will not substantially interfere with the recovery of the species.	No: There will be no significant loss of habitat for this species within the Disturbance Footprint.

Class	Species	Significant Impact Criteria (DoE 2013)									Significant Impact
		Lead to a long-term decrease in the size of an important population of a species	**Reduce the Area of Occupancy (AoO) of an important population**	**Fragment an existing population into two or more populations**	**Adversely affect habitat critical to the survival of a species**	**Disrupt the breeding cycle of an important population**	**Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**	**Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat.**	**Introduce disease that may cause the species to decline.**	**Interfere substantially with the recovery of the species.**	
Birds	*Gallinago hardwickii* Latham's Snipe	No: The species is an occasional visitor in low numbers to the region. There are no important populations of the species in or near the Project Area.	No; The available wetland habitat within the Project Area (0.60 ha) is likely to support only a few individuals during favourable conditions in spring-summer only.	No: The species is mobile and wide-ranging and occurs only sporadically in the region. The proposed development is unlikely to restrict dispersal of this species.	No: Wetlands within the Project Area are very small and highly ephemeral. Although these wetlands may occasionally be used by transitory individuals they do not represent habitat critical to the surveyal of the species.	No: The species does not breed within Australia. Breeding occurs between May and July in north-eastern Asia (Hansen *et al*. 2020).	No: Wetlands within the Project Area are very small and highly ephemeral. Disturbance will only occur to 0.60 ha of 7.31 ha available wetland habitat within the Project Area. Disturbance to this small area will not cause this species to decline.	None known.	None known.	No: The Project is unlikely to cause harm to any individuals and is therefore unlikely to interfere with recovery of the species.	No: There will be no substantial decrease in available foraging habitat within the Project Area i.e. there will be disturbance to only 0.60 ha of mapped wetland habitat. Total available mapped wetland habitat available within the Project Area is 7.31 ha. There will be no loss if individuals as a result of Project activities.

Class	Species	Significant Impact Criteria (DoE 2013)									Significant Impact
		Lead to a long-term decrease in the size of an important population of a species	**Reduce the Area of Occupancy (AoO) of an important population**	**Fragment an existing population into two or more populations**	**Adversely affect habitat critical to the survival of a species**	**Disrupt the breeding cycle of an important population**	**Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**	**Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat.**	**Introduce disease that may cause the species to decline.**	**Interfere substantially with the recovery of the species.**	
Birds	*Hirundapus caudacutus* White-throated Needletail	No: The species is an aerial feeding insectivore that forages over a wide range of intact and modified landscapes, with a general preference for wooded areas.	No: The proposed disturbance is not materially relevant to the species.	No: The proposed disturbance is not materially relevant to the species.	No: No impact on foraging resources is anticipated, no other critical locations are relevant to the species in Australia. The species roosts overnight in tall trees along scarps and is unlikely to roost in the Project Area.	No: the species does not breed in Australia during its summer presence.	No: The proposed disturbance is not materially relevant to the species.	None known	None known	No: The proposed disturbance will not reduce the extent of remnant woodland. The species does not breed in Australia.	No: The proposed disturbance is not materially relevant to the species.

Class	Species	Significant Impact Criteria (DoE 2013)									Significant Impact
		Lead to a long-term decrease in the size of an important population of a species	**Reduce the Area of Occupancy (AoO) of an important population**	**Fragment an existing population into two or more populations**	**Adversely affect habitat critical to the survival of a species**	**Disrupt the breeding cycle of an important population**	**Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**	**Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat.**	**Introduce disease that may cause the species to decline.**	**Interfere substantially with the recovery of the species.**	
Reptiles	*Egernia rugosa* Yakka Skink	Unlikely: Removal of logs and accumulations of woody debris in 0.30 ha of potential habitat within the Disturbance Footprint could reduce some shelter and breeding habitat for this species. However, these features are scarce within the Project Area and Disturbance Footprint (BioCondition scores for woody debris averaged 20% of benchmark values) and low numbers of logs/log piles were recorded in microhabitat assessments.	Unlikely: Loss of 0.30 ha of potential habitat could potentially impact any resident individuals. However, few individuals would occupy this small area. The species was not detected within the Project Area and shelter habitat features were scarce. The disturbance will not affect the broader distribution of the species.	No: The species is mobile and the proposed disturbance does not pose a barrier to dispersal of this species.	Unlikely: Removal of logs and large woody debris may reduce shelter and breeding habitat. However, these habitat features are scarce in the Project Area and within the Disturbance Footprint.	Unlikely: The species has a patchy occurrence in the region and potentially suitable habitat features such as logs and woody debris were scarce within the Project Area.	Unlikely: The species has a patchy occurrence in the region and potentially suitable habitat features such as logs and woody debris were scarce within the Project Area.	None known.	None known.	Unlikely: Loss of 0.30 ha, across several habitat patches could potentially impact on any resident individuals but the disturbance is unlikely to affect overall abundance and occurrence within the region.	No: The presence of this species was not confirmed within the Project Area. Loss of up to 0.30 ha of potential habitat (RE 11.3.2) could impact on any resident individuals. However, this small area would hold few, if any, individuals and these impacts may be mitigated by preclearing of the route by a fauna spotter.

4.1.1.4. Migratory Fauna

DoE (2013) identifies criteria for identifying significant impacts on EPBC-listed migratory species. An action is likely to have a significant impact on a listed migratory species if it results in:

- Isolation, modification or destruction of important habitat for this species.
- Establishment of a harmful invasive species in an area of important habitat.
- Disruption to breeding, feeding, migration, resting behaviour or life-expectancy of an ecologically significant proportion of the population of a listed species.

Government guidelines for assessing the significance of impacts refer to the linked concepts of 'important habitat' and an 'ecologically significant proportion' of a listed species' population (DoE 2013). The definition of these terms vary across species ecology, range, population size and circumstances (DoE 2013; DoE 2015). DoEE (2017) defines important habitat for migratory shorebirds that aggregate in flocks as an area:

- that has been identified as internationally important for shorebirds; or
- that supports at least 0.1 per cent of the East Asian-Australasian flyway population; or,
- that supports at least 2000 migratory shorebirds; or
- that supports at least 15 migratory shorebird species.

For Latham's Snipe, which has a more dispersed occurrence, important habitat is defined as an area that supports at least 18 individuals of this species (DoEE 2017). Guidelines for other listed migratory species suggest upper and lower thresholds of 1% and 0.1% of species populations as ecologically significant proportions at an international and national level, respectively (DoE 2015). Estimates of the lower threshold vary from 10 individuals of White-throated Needletail and 100 Fork-tailed Swift.

Wetland migratory species potentially occurring within the Project Area include Australian Painted Snipe, Latham's Snipe, Common Sandpiper, Sharp-tailed Sandpiper and Pectoral Sandpiper. None of these species will be significantly impacted by the proposed project as there will be minor disturbance to wetland habitat (0.60 ha out of 7.31 ha of available habitat in the Project Area).

For the other migratory species, these being White-throated Needletail and Fork-tailed Swift, these are both aerial species which will not be impacted upon by the Project as this development is not materially relevant to them.

The Project Area is unlikely to harbour an ecologically significant proportion of any listed migratory species' population. The proposed action is unlikely to reduce the geographic range of any of these species and the Project Area does not otherwise contain or constitute important habitat for these species. Therefore, the proposed action is unlikely to result in significant impacts on any listed migratory species.

4.1.1.5. Internationally and Nationally Important Wetlands

No internationally or nationally important wetlands occur at or near the Project Area. The Project will therefore not impact upon any internationally or nationally important wetlands.

4.1.2. Matters of State Environmental Significance

A summary of MSES prescribed environmental matters (PEM) potentially within the Project Area is below in Table 16.

Table 16: Summary of Significant Residual Impacts assessed within the Project Area.

Prescribed environmental matter (PEM) as per EOR	Presence in the Project Area	
Regulated vegetation: Endangered and Of Concern REs	☒	The Project Area does not contain areas of regulated vegetation that is a 'prescribed RE'. DEHP (2014) defines regulated vegetation to be a prescribed RE as per the *Environmental Offsets Regulation 2014* (EOR) which does not include regrowth (Category C) vegetation. No remnant or Category B areas are present within the Project Area on the '*Regulated Vegetation Management Map'*. As discussed in Section 3.2.1, regulated vegetation mapped within the Project Area on the *Regulated Vegetation Management Map* consists entirely of three areas of Category C (RE 11.3.2/11.3.17/11.3.25, high value regrowth) vegetation. Therefore, the Project Area contains no prescribed RE or MSES PEM for the purposes of SRI assessment under the EOR and *Significant Residual Impact Guideline* (DEHP 2014). In conclusion, the proposed activities will not result in an SRI to *Regulated Vegetation* (Endangered and Of Concern RE).
Regulated vegetation: Prescribed RE within the defined distance of a watercourse	☒	The Project Area does not contain areas of regulated vegetation that is a 'prescribed RE' within the defined distance of a watercourse. DEHP (2014) defines regulated vegetation to be a prescribed RE as per the *Environmental Offsets Regulation 2014* (EOR) which does not include regrowth (Category C) vegetation. No remnant or Category B areas are present within the Project Area on the '*Regulated Vegetation Management Map'*. As discussed in Section 3.2.1, regulated vegetation mapped within the Project Area on the *Regulated Vegetation Management Map* consists entirely of three areas of Category C (RE 11.3.2/11.3.17/11.3.25, high value regrowth) vegetation. Portions of two Category C areas occur within the defined distance from the defining banks of a watercourse identified on the vegetation management watercourse map. As these areas are mapped as regrowth, they are not prescribed RE. Therefore, the Project Area contains no prescribed RE or MSES PEM for the purposes of SRI assessment under the EOR and *Significant Residual Impact Guideline* (DEHP 2014). In conclusion, the proposed activities will not result in an SRI to *Regulated Vegetation* (within the defined distance of a watercourse).
Connectivity areas	☑	The Landscape Fragmentation and Connectivity Tool was utilised to assess the proposed disturbances for potential impacts to Connectivity Areas. The Tool determined no SRI was triggered by the proposed activities. Refer to Section 3.2.12 for further information.
Wetlands and watercourses	☒	The following wetlands or watercourses are not present within the Project Area: • Wetlands in a wetland protection area as shown on the Map of referrable wetlands under schedule 12, part 2 of the *Environmental Protection Regulation 2008*; • Wetlands of high ecological significance as shown on the Map of referrable wetlands under schedule 12, part 2 of the *Environmental Protection Regulation 2008*; or • Wetlands or watercourses in a high ecological value waters as identified under the *Environmental Protection (Water) Policy 2009*, schedule 2.
Designated precinct in a strategic environmental area	☒	The Project Area is not located in a designated precinct in a strategic environmental area.
Protected wildlife habitat	☑	• Based on fauna habitat / RE associations, wildlife habitat for NC Act listed species relevant to SRI assessment may be present within the Project Area (refer Sections 3.2.11 and 4.1.2.5 for further information). • No high-risk areas on the flora survey trigger map exist within the Project Area.
Protected areas	☒	There are no protected areas within the Project Area.
Highly protected zones of State marine parks	☒	The Project Area does not contain highly protected zones of a State marine park.
Fish habitat areas	☒	Areas declared under the *Fisheries Act 1994* to be a fish habitat area are not present within the Project Area.
Waterway providing for fish passage	☑	The Project Area contains watercourses providing potential fish passage, as detailed in Section 3.2.10.1. The proposed development would not have an SRI on this PEM because linear infrastructure construction activities located in waterways providing for fish passage would not: • reduce the extent, frequency, or duration of fish passage; • result in a substantial change to the hydrological regime of the watercourse; or • lead to significant changes in water quality parameters within the watercourse.
Marine plants	☒	Areas containing marine plants are not present in the Project Area.
Legally secured offset areas	☒	No legally secured offset areas are present within the Project Area.

4.1.2.1. Regional Ecosystems

The proposed development will not impact on any Endangered RE.

A total of .18 ha of OC RE (11.3.2) occurs within the Disturbance Footprint (refer to Table 7: section 3.2.1). The Project Area is in a largely cleared landscape. These disturbance areas are a small fraction of each vegetation assessment unit within the Project Area and are largely on the margins of vegetation fragments. The proposed development will have minimal effect on the extent and connectivity of these ecosystems within the Project Area.

The proposed development will not impact on any No Concern at Present RE.

4.1.2.2. Threatened flora

NC Act-listed threatened plant species that may potentially occur within the Project Area are given in Table 9 (Section 3.2.3). No NC Act-listed threatened plant species were detected during field surveys and none are expected to occur within the Project Area. Therefore, the Project is unlikely to impact on any NC Act-listed threatened flora species.

4.1.2.3. Threatened fauna

NC Act-listed threatened fauna that may potentially occur within the Project Area are listed within Table 4 and Table 10. Predictive habitat mapping for NC Act-listed fauna potentially occurring within the Disturbance Footprint is shown in Appendix D. Potential impacts on endangered and vulnerable fauna species that are NC Act-listed are assessed in Table 13. Other NC Act-listed species that could potentially occur within the Project Area (e.g. Woma) are excluded from impact assessment as Near Threatened species do not constitute MSES. This assessment is consistent with the Significant Residual Impact criteria from Section 5 of the *Significant Residual Impact Guideline* (DEHP 2014). This assessment is also consistent with the MNES significant impact assessment as per section 4.1.1.3 (Tables 11 and 12). In summary, no significant impact is expected on any NC Act-listed MSES fauna.

Table 17: Assessment of potential significant residual impacts (as per SRI criteria within DEHP (2014) upon NC Act-listed endangered and vulnerable fauna species potentially present within the Project Area.

Class	Species	Significant Residual Impact Criteria (DEHP 2014)							Significant Residual Impact
		Lead to a long-term decrease in the size of a population.	**Reduce the Extent of Occurrence (EoO) of the species.**	**Fragment an existing population / result in genetically distinct populations forming as a result of habitat isolation.**	**Cause disruption to ecologically significant locations (breeding, feeding, nesting, migration or resting sites) of a species.**	**Result in invasive species that are harmful to an endangered or vulnerable species becoming established in the endangered or vulnerable species' habitat.**	**Introduce disease that may cause the population to decline.**	**Interfere with the recovery of the species.**	
Birds	*Calidris acuminata* Sharp-tailed Sandpiper NC Act: Vulnerable	No: The species is an occasional visitor in low numbers to the region. There are no important populations of the species in or near the Project Area.	No: The available wetland habitat within the Project Area (0.60 ha) is likely to support only a few individuals during favourable conditions in spring-summer only. This is a trans-continental species therefore there will be no reduction in EoO as a result of Project activities.	No: The species is mobile and wide-ranging and occurs only seasonally in the region. The proposed development is unlikely to restrict dispersal in this species, nor result in the formation of genetically distinct populations.	No: The Project Area is not an ecologically significant location for the species. Similar areas used for foraging, migration and/or resting are abundant in the surrounding landscape. The species does not breed within Australia.	None known	None known	No: The Project is unlikely to cause harm to any individuals and is therefore unlikely to interfere with recovery of the species.	No: There will be no substantial decrease in available foraging habitat within the Project Area i.e. there will be disturbance to only 0.60 ha of mapped wetland habitat. Total available mapped wetland habitat available within the Project Area is 7.31 ha. There will be no loss if individuals as a result of Project activities.
Birds	*Calyptorhynchus lathami* Glossy Black-Cockatoo NC Act: Vulnerable	Unlikely: Loss of 0.30 ha of potential shelter and breeding habitat. This small area supports few potential nest/roost trees. The species has not been recorded in the Project Area and is likely to occur as an occasional visitor, rather than being a resident.	Unlikely: Loss of 0.30 ha of potential shelter and breeding habitat. No nest or roost trees were identified during surveys. This mobile and wide-ranging species is capable of traversing non-remnant areas between nest/roost trees and feed trees.	No: The disturbance will not affect dispersal of this species, which travels long distances between suitable foraging trees.	Unlikely: Loss of 0.30 ha of potential habitat is unlikely to cause disruption to any ecological significant locations for breeding, feeding or nesting. The species has not been recorded in the Project Area and is likely to occur as an occasional visitor, rather than being a resident.	None known	None known	Unlikely: Loss of 0.30 ha of potential habitat will not substantially interfere with recovery of the species.	No: there will be no significant loss of habitat for this species within the Disturbance Footprint.

Class	Species	Significant Residual Impact Criteria (DEHP 2014)							Significant Residual Impact
		Lead to a long-term decrease in the size of a population.	**Reduce the Extent of Occurrence (EoO) of the species.**	**Fragment an existing population / result in genetically distinct populations forming as a result of habitat isolation.**	**Cause disruption to ecologically significant locations (breeding, feeding, nesting, migration or resting sites) of a species.**	**Result in invasive species that are harmful to an endangered or vulnerable species becoming established in the endangered or vulnerable species' habitat.**	**Introduce disease that may cause the population to decline.**	**Interfere with the recovery of the species.**	
Birds	*Gallinago hardwickii* Latham's Snipe NC Act: Vulnerable	No: The species is an occasional visitor in low numbers to the region. There are no important populations of the species in or near the Project Area.	No. The available wetland habitat within the Project Area (0.60 ha) is likely to support only a few individuals during favourable conditions in spring-summer only. This is a trans-continental species therefore there will be no reduction in EoO as a result of Project activities.	No: The species is mobile and wide-ranging and occurs only seasonally in the region. The proposed development is unlikely to restrict dispersal in this species, nor result in the formation of genetically distinct populations.	No: The Project Area is not an ecologically significant location for the species. Similar areas used for foraging, migration and/or resting are abundant in the surrounding landscape. The species does not breed within Australia.	None known	None known	No: The Project is unlikely to cause harm to any individuals and is therefore unlikely to interfere with recovery of the species.	No: There will be no substantial decrease in available foraging habitat within the Project Area i.e. there will be disturbance to only 0.60 ha of mapped wetland habitat. Total available mapped wetland habitat available within the Project Area is 7.31 ha. There will be no loss if individuals as a result of Project activities.
Birds	*Hirundapus caudacutus* White-throated Needletail NC Act: Vulnerable	No: The species is an aerial feeding insectivore that forages over a wide range of intact and modified landscapes, with a general preference for wooded areas. It does not breed in Australia during its summer presence.	No: The proposed disturbance is not materially relevant to the species.	No: The proposed disturbance is not materially relevant to the species.	No: No impact on foraging resources is anticipated, no other critical locations are relevant to the species in Australia. The species roosts overnight in tall trees along scarps and is unlikely to roost in the Project Area.	None known	None known	No: The proposed disturbance will not reduce the extent of remnant woodland. The species does not breed in Australia.	No: The proposed disturbance is not materially relevant to the species.

Class	Species	Significant Residual Impact Criteria (DEHP 2014)							Significant Residual Impact
		Lead to a long-term decrease in the size of a population.	**Reduce the Extent of Occurrence (EoO) of the species.**	**Fragment an existing population / result in genetically distinct populations forming as a result of habitat isolation.**	**Cause disruption to ecologically significant locations (breeding, feeding, nesting, migration or resting sites) of a species.**	**Result in invasive species that are harmful to an endangered or vulnerable species becoming established in the endangered or vulnerable species' habitat.**	**Introduce disease that may cause the population to decline.**	**Interfere with the recovery of the species.**	
Birds	*Rostratula australis* Australian Painted Snipe NC Act: Endangered	No: The species is a rare visitor in very low numbers to the region. There are no known important populations of the species in or near the Project Area.	No: The available wetland habitat within the Project Area (0.60 ha) is likely to support only a few individuals during favourable conditions in spring-summer only. The disturbance will not affect the broader distribution of the species which is extensive across Australia.	No: The species is mobile and wide-ranging and occurs only sporadically in the region. The proposed development is unlikely to restrict dispersal in this species, nor result in the formation of genetically distinct populations.	No: The Project Area is not an ecologically significant location for the species. Similar areas used for foraging, migration and/or resting are abundant in the surrounding landscape. Breeding has been recorded in all months of the year in response to wetland conditions. The small and highly ephemeral nature of wetlands within the Project Area are unlikely to be attractive for breeding by this species.	None known.	None known.	No: The Project is unlikely to cause harm to any individuals and is therefore unlikely to interfere with recovery of the species.	No: There will be no substantial decrease in available foraging habitat within the Project Area i.e. there will be disturbance to only 0.60 ha of mapped wetland habitat. Total available mapped wetland habitat available within the Project Area is 7.31 ha. There will be no loss if individuals as a result of Project activities.

Class	Species	Significant Residual Impact Criteria (DEHP 2014)							Significant Residual Impact
		Lead to a long-term decrease in the size of a population.	**Reduce the Extent of Occurrence (EoO) of the species.**	**Fragment an existing population / result in genetically distinct populations forming as a result of habitat isolation.**	**Cause disruption to ecologically significant locations (breeding, feeding, nesting, migration or resting sites) of a species.**	**Result in invasive species that are harmful to an endangered or vulnerable species becoming established in the endangered or vulnerable species' habitat.**	**Introduce disease that may cause the population to decline.**	**Interfere with the recovery of the species.**	
Mammals	*Phascolarctos cinereus* Koala NC Act: Endangered	Unlikely: Potential loss of 0.30 ha of potential habitat will not lead to a decrease in size of the local population.	Unlikely: No sign of Koala was detected within the Project Area. It is likely that the Project Area would be used by occasional transient individuals. The loss of 0.30 ha of potential habitat in the Disturbance Footprint is unlikely to affect the occurrence of Koala within the Project Area.	No: Koala are capable of crossing gaps between habitat patches and may use isolated paddock trees. The loss of several small areas of potential habitat, summing to 0.30 ha, will not disrupt habitat corridors through this area and will have negligible effect on Koala dispersal through the Project Area.	Unlikely: The loss of several small areas of potential habitat, summing to 0.30 ha, is unlikely to have measurable impacts on occasional Koala usage of the Project Area. All habitat within the Project Area is already fragmented and disturbed by thinning, grazing, weeds and edge effects. The Disturbance Footprint is a small proportion of this habitat and would require the potential removal of <15 mature trees.	None known	None known: chlamydia is present in the Koala population of southern inland Queensland but this bacterial disease is unlikely to be exacerbated by the proposed development.	Unlikely: The loss of several small areas of potential habitat, totalling 0.30 ha will have minimal effect on the recovery of Koala in this area.	No: The proposed development will result in the loss of up to 0.30 ha of potential habitat (RE 11.3.2) spread across several fragments. This small area is unlikely to reduce Koala numbers or to disrupt Koala movement through the area. No evidence of Koala was found within the Project Area and it is likely that Koala occurrence within the Project Area is occasional and transient.

Class	Species	Significant Residual Impact Criteria (DEHP 2014)							Significant Residual Impact
		Lead to a long-term decrease in the size of a population.	**Reduce the Extent of Occurrence (EoO) of the species.**	**Fragment an existing population / result in genetically distinct populations forming as a result of habitat isolation.**	**Cause disruption to ecologically significant locations (breeding, feeding, nesting, migration or resting sites) of a species.**	**Result in invasive species that are harmful to an endangered or vulnerable species becoming established in the endangered or vulnerable species' habitat.**	**Introduce disease that may cause the population to decline.**	**Interfere with the recovery of the species.**	
Reptiles	*Egernia rugosa* Yakka Skink NC Act: Vulnerable	Unlikely: Removal of logs and accumulations of woody debris in 0.30 ha of potential habitat within the Disturbance Footprint could reduce some shelter and breeding habitat for this species. However, these features are scarce within the Project Area (BioCondition scores for woody debris averaged 20% of benchmark values) and low numbers of logs/log piles were recorded in microhabitat assessments.	Unlikely: Loss of 0.30 ha of potential habitat could potentially impact any resident individuals. However, few individuals would occupy this small area. The species was not detected within the Project Area and shelter habitat features were scarce. The disturbance will not affect the broader distribution of the species.	No: The species is mobile and the proposed disturbance does not pose a barrier to dispersal of this species.	Unlikely: Removal of logs and large woody debris may reduce shelter and breeding habitat. However, these habitat features are scarce in the Project Area and within the Disturbance Footprint.	None known.	None known.	Unlikely: Loss of 0.30 ha, across several habitat patches could potentially impact on any resident individuals but the disturbance is unlikely to affect overall abundance and occurrence within the region.	No: The presence of this species was not confirmed within the Project Area. Loss of up to 0.30 ha of potential habitat (RE 11.3.2) could impact on any resident individuals. However, this small area would hold few, if any, individuals and these impacts may be mitigated by preclearing of the route by a fauna spotter.
Reptiles	*Hemiaspis damelii* Grey Snake NC Act: Endangered	Unlikely: 0.30 ha of potential habitat occurs within the Disturbance Footprint. Mapped habitat comprises fragmented patches of riparian or floodplain woodland.	Unlikely: The Project Area is peripheral to the species distribution. If the species occurs in this area, it is unlikely to be restricted to the mapped habitat.	No: The proposed development will not exacerbate existing fragmentation.	Unlikely: The 0.30 ha of mapped shelter, foraging, breeding and dispersal habitat comprises disturbed alluvial woodland fragments. Similar features occur in the vicinity and this habitat is unlikely to be limiting. Loss if 0.30 ha of potential habitat is unlikely to contribute to a decline in the species.	None known.	None known.	No: Only 0.30 ha of mapped habitat is within the Disturbance Footprint with similar habitat abundant in the vicinity.	No: Presence of this species within the Project Area was not confirmed during the field survey. The Project Area is peripheral to the species distribution and there are no records in the vicinity. Potentially suitable floodplain woodland and ephemeral wetland habitat (RE 11.3.2) occurs beyond the Disturbance Footprint.

4.1.2.4. SLC fauna

SLC fauna (other than those that are also migratory species) that may potentially occur within the Project Area are discussed in section 3.2.7. Predictive habitat for SLC fauna potentially occurring within the Disturbance Footprint is shown in Appendix D. Potential impacts on SLC species are assessed in Table 14.

Table 18: Assessment of potential significant residual impacts (as per SRI criteria within DEHP (2014) upon NC Act-listed SLC (non-migratory) fauna species potentially present within the Project Area.

Class	Species	Significant Residual Impact (DEHP 2014)					
		Lead to a long-term decrease in the size of a local population.	**Reduce the Extent of Occurrence (EoO) of the species.**	**Fragmentation of an existing population.**	**Result in genetically distinct populations forming as a result of habitat isolation.**	**Disruption to ecologically significant locations (breeding, feeding or nesting sites) of a species.**	**Significant Residual Impact**
Mammals	*Tachyglossus aculeatus* Short-beaked Echidna	Unlikely: Loss of up to 0.30 ha of potential habitat comprising regrowth and remnant. Removal of logs and accumulations of woody debris could reduce shelter and breeding habitat for this species. However, these features are scarce within the Project Area and Disturbance Footprint (BioCondition scores for woody debris averaged 20% of benchmark values. 1-5 logs with hollows in each 0.5 ha assessment site).	Unlikely: Loss of up to 0.30 ha of potential habitat could potentially impact upon foraging or sheltering resident individuals. However, few individuals would occur in these small peripheral areas. The species was not detected within the Project Area and critical habitat features (e.g. log piles, large logs, rock crevices) were scarce or absent. The disturbance will not affect the broader distribution of the species.	No: The disturbance does not pose a barrier to dispersal of this mobile species.	No: The disturbance does not pose a barrier to dispersal of this species.	Unlikely: Removal of some logs and large woody debris may reduce shelter and breeding habitat. However, these habitat features are scarce in the Project Area and Disturbance Footprint. Available habitat in the Project Area is 153.08 ha	No: The species was not confirmed present within the Project Area. Loss of up to 0.30 ha of potential habitat (RE 11.3.2) could impact on any resident individuals. However, this small area would hold few, if any, individuals and these impacts may be mitigated by preclearing of the route by a fauna spotter. The species is likely to have a patchy occurrence in the Project Area and suitable habitat features such as logs and woody debris were scarce within the Project Area.

4.1.2.5. Environmentally Sensitive Areas

The Disturbance Footprint includes a total of 0.30 ha of ESA category C, comprising one Of Concern regional ecosystem (RE 11.3.2). Impacts on these areas are addressed in section 4.1.2.1 (Regional Ecosystems).

The following Category C ESA is present within the Disturbance Footprint:

- ground-truthed protected wildlife habitat: Glossy Black-Cockatoo (*Calyptorhynchus lathami lathami*) - NC Act: Vulnerable: remnant and regrowth RE 11.3.2 (0.30 ha).
- ground-truthed protected wildlife habitat: White-throated Needletail (*Hirundapus caudacutus*) - NC Act: Vulnerable: remnant and regrowth RE 11.3.2 (0.30 ha).
- ground-truthed protected wildlife habitat: Koala (*Phascolarctos cinereus*) - NC Act: Endangered: remnant and regrowth RE 11.3.2 (0.30 ha).
- ground-truthed protected wildlife habitat: Yakka Skink (*Egernia rugosa*) - NC Act: Vulnerable: remnant and regrowth RE 11.3.2 (0.30 ha).
- ground-truthed protected wildlife habitat: Grey Snake (*Hemiaspis damelii*) - NC Act: Endangered: remnant and regrowth RE 11.3.2 (0.30 ha).

4.1.2.6. Watercourses, Wetlands & Springs

The Project Area includes crossing points on mapped streams, comprising first to third order intermittent streams. No assessment of stream impacts was conducted within this scope of works. There are no state government mapped wetlands or springs within the Project Area. The Project will potentially impact on 0.6 ha of ground-truthed wetland which may provide temporary habitat for MNES/MSES wetland fauna species.

5. Conclusions

An ecological assessment within the Project Area identified the following ecological values/potential constraints:

Matters of National Environmental Significance:

- Two TEC were detected within the Project Area:
  - Poplar Box grassy woodland on alluvial plains; and
  - Weeping Myall woodlands.
- No EPBC Act-listed threatened flora species were detected within the Project Area and no suitable habitat is present for species identified within desktop searches.
- Four species of WoNS were detected within the Project Area, namely:
  - Common Pest Pear (*Opuntia stricta*);
  - Sulphur Cactus (*O. sulphurea*);
  - Velvety Tree Pear (*O. tomentosa*); and
  - African Boxthorn (*Lycium ferocissimum*).
- No EPBC Act-listed threatened fauna species were detected within the Project Area:
- Potential habitat for the following EPBC Act-listed threatened fauna species was present within the Project Area:
  - Sharp-tailed Sandpiper (*Calidris acuminata*) – Vulnerable;
  - Glossy Black-Cockatoo (*Calyptorhynchus lathami lathami*) – Vulnerable;
  - Latham's Snipe (*Gallinago hardwickii*) – Vulnerable;
  - White-throated Needletail (*Hirundapus caudacutus*) – Vulnerable;
  - Australian Painted Snipe (*Rostratula australis*) – Endangered;
  - Koala (*Phascolarctos cinereus*) – Endangered;
  - Yakka Skink (*Egernia rugosa*) – Vulnerable; and

- Grey Snake (*Hemiaspis damelii*) – Endangered.

- Potential habitat for the following EPBC Act-listed threatened fauna species is present within the Disturbance Footprint:
  - Sharp-tailed Sandpiper – 0.60 ha;
  - Glossy Black-Cockatoo – 0.30 ha;
  - Latham's Snipe – 0.60 ha;
  - White-throated Needletail – 0.30 ha;
  - Australian Painted Snipe – 0.60 ha;
  - Koala – 0.30 ha;
  - Yakka Skink – 0.30 ha; and
  - Grey Snake – 0.30 ha.
- Potential habitat for multiple EPBC Act-listed migratory fauna species is present within the Project Area.
- No Wetlands of International or National Significance occur within the Project Area.

Significant Impacts

- No TEC is present within the Disturbance Footprint and therefore no significant impact to TEC will occur as part of the proposed development.
- No significant impact to MNES flora will occur as part of the proposed development.
- No significant impact to MNES wetlands will occur as part of the proposed development.
- No significant impact to MNES threatened and/or migratory fauna populations/habitat is expected as a result of the proposed development. This is due to existing severe fragmentation of vegetation/habitat, generally poor habitat quality, the very small and localised disturbance area relative to surrounding habitat patches and citing of infrastructure to largely avoid disturbance to vegetation.

Matters of State Environmental Significance and/or potential constraints:

- Two Endangered RE are present within the Project Area these being:
  - 11.3.17: *Eucalyptus populnea* woodland with *Acacia harpophylla* and/or *Casuarina cristata* on alluvial plains; and
  - 11.9.10: *Eucalyptus populne*a open forest with a secondary tree layer of *Acacia harpophylla* and sometimes *Casuarina cristata* on fine-grained sedimentary rocks.
- Three Of Concern RE are present within the Project Area these being:
  - 11.3.2: *Eucalyptus populnea* woodland on alluvial plains;
  - 11.3.25: *Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines; and
  - 11.9.7: *Eucalyptus populnea*, *Eremophila mitchellii* shrubby woodland on fine-grained sedimentary rocks.
- One Of Concern RE is present within the Disturbance Footprint:
  - 11.3.2: *Eucalyptus populnea* woodland on alluvial plains.
- BioCondition scores for regrowth and remnant vegetation within the Project Area varied from 0.47 to 0.60 indicating significant disturbance and loss of ecological integrity relative to benchmark sites.
- No NC Act-listed threatened flora species were detected within the Project Area and no suitable habitat is present for these species.
- Four Biosecurity Act Category 3 Restricted Matter invasive plants were present within the Project Area, these being the three WoNS species (above): Velvety Tree Pear (*Opuntia tomentosa*), Sulphur Cactus (*O. sulphurea*), Common Pest Pear (*O. stricta*) and African Boxthorn (*Lycium ferocissimum*).

- No NC Act-listed threatened fauna species were detected within the Project Area.
- Potentially suitable habitat is present for multiple NC Act-listed threatened fauna species, including the EPBC Act-listed species (above), and additionally:
    - Woma (*Aspidites ramsayi*) (NC Act - Near Threatened).
- Potentially suitable habitat is present for one NC Act-listed SLC fauna species, this being:
    - Short-beaked Echidna (*Tachyglossus aculeatus*).
- The Project Area includes scarce potential fauna breeding and/or shelter places (e.g. fallen timber and wood piles, logs, decorticating trees, hollow-bearing live or dead trees and small ephemeral wetlands).
- No mapped referable wetlands occur within the Project Area. Several wetlands were ground-truthed as being present within the Project Area and Disturbance Footprint.
- No lakes or springs occur within the Project Area.
- Several mapped streams occur within the Project Area varying from Order 1 to 3 intermittent drainage lines.
- The following Category B ESA are present within the Project Area:
    - areas of ground-truthed Endangered RE (biodiversity status): 11.3.17 and 11.9.10.
- The following Category C ESA are present within the Project Area:
    - areas of ground-truthed Of Concern RE (biodiversity status): 11.3.2, 11.3.25 and 11.9.7.
    - an area validated from ground-truthing surveys as 'protected wildlife habitat' that is category A, B or C on the Remnant Vegetation Management Map, in accordance with section 20A of the VMA, for a species of wildlife listed as critically endangered, endangered or vulnerable under the NC Act as follows:
        - ground-truthed protected wildlife habitat: Glossy Black-Cockatoo (*Calyptorhynchus lathami lathami*) - NC Act: Vulnerable: remnant and regrowth: RE 11.3.2, 11.3.25, 11.9.10.
        - ground-truthed protected wildlife habitat: White-throated Needletail (*Hirundapus caudacutus*) - NC Act: Vulnerable: remnant and regrowth: RE 11.3.2, 11.3.25, 11.9.10.
        - ground-truthed protected wildlife habitat: Koala (*Phascolarctos cinereus*) - NC Act: Endangered: remnant and regrowth REs 11.3.2, 11.3.25, 11.9.10.
        - ground-truthed protected wildlife habitat: Yakka Skink (*Egernia rugosa*) - NC Act: Vulnerable: remnant and regrowth: RE 11.3.2, 11.9.10.
        - ground-truthed protected wildlife habitat: Grey Snake (*Hemiaspis damelii*) - NC Act: Endangered: remnant and regrowth REs 11.3.2, 11.3.25.

Significant Residual Impacts

- No significant residual impact to MSES flora will occur as part of the proposed development.
- No areas mapped as Category B (remnant) occur within the regulated vegetation management map and therefore no significant residual impact to MSES regulated vegetation will occur as part of the proposed development.
- No significant residual impact to MSES connectivity areas will occur as part of the proposed development.
- No significant residual impact to MSES threatened and SLC fauna populations/habitat is expected as a result of the proposed development. This is due to existing severe fragmentation of vegetation/habitat, generally poor habitat quality, the very small and localised disturbance area relative to surrounding habitat patches and citing of infrastructure to largely avoid disturbance to vegetation.
- No MSES wetlands occur within the Project Area and therefore no significant residual impact will occur as part of the proposed development.
- No MSES watercourses occur within the Project Area and therefore no significant residual impact will occur as part of the proposed development.

6. Recommendations

It is recommended that the findings in this report are considered during detailed project planning such that disturbance to the ecological values within the Project Area may be avoided wherever practical.

Where disturbance is unavoidable, the following impact mitigation measures should be implemented in accordance with the approved site environmental management plan and regulatory approval conditions:

- Briefing of Project personnel on habitat values, species, possible impacts and procedural responses.
- As the Project Area is already fragmented and flora/fauna habitat is limited, disturbance to remaining regrowth and remnant vegetation should be avoided wherever possible and practical.
- Utilise existing roads where possible for access tracks including any existing crossings of watercourses and through vegetation strips.
- Fauna spotter to be present on-site to move fauna and habitat features prior to and during any clearing within identified regrowth and/or remnant vegetation and in identified wetland areas.
- Implement weed hygiene measures for vehicles and machinery entering the Project Area;
- Implement weed control measures for Sulphur Cactus (*Opuntia sulphurea*), a Prohibited weed under the Biosecurity Act, within the Project Area prior to any disturbance.

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8. Figures




Figure 1a-b. View north from survey site 863-S02 in non-remnant pastoral grassland with scattered regrowth of shrubs and small trees (left); view west from BioCondition site 863-B03 in disturbed remnant Poplar Box (*Eucalyptus populnea*) woodland (RE 11.3.2, Poplar Box TEC) (right).




Figure 2a-b. View north from BioCondition site 863-B02 in regrowth Poplar Box woodland (regrowth RE 11.3.2, Poplar Box TEC), note the scarcity of woody debris and decorticating trees (left); view east from survey site 863-S05 in Weeping Myall TEC (also regrowth RE 11.3.2) with scattered Weeping Myall (*Acacia pendula*) in growth stages from recruits to senescent trees.



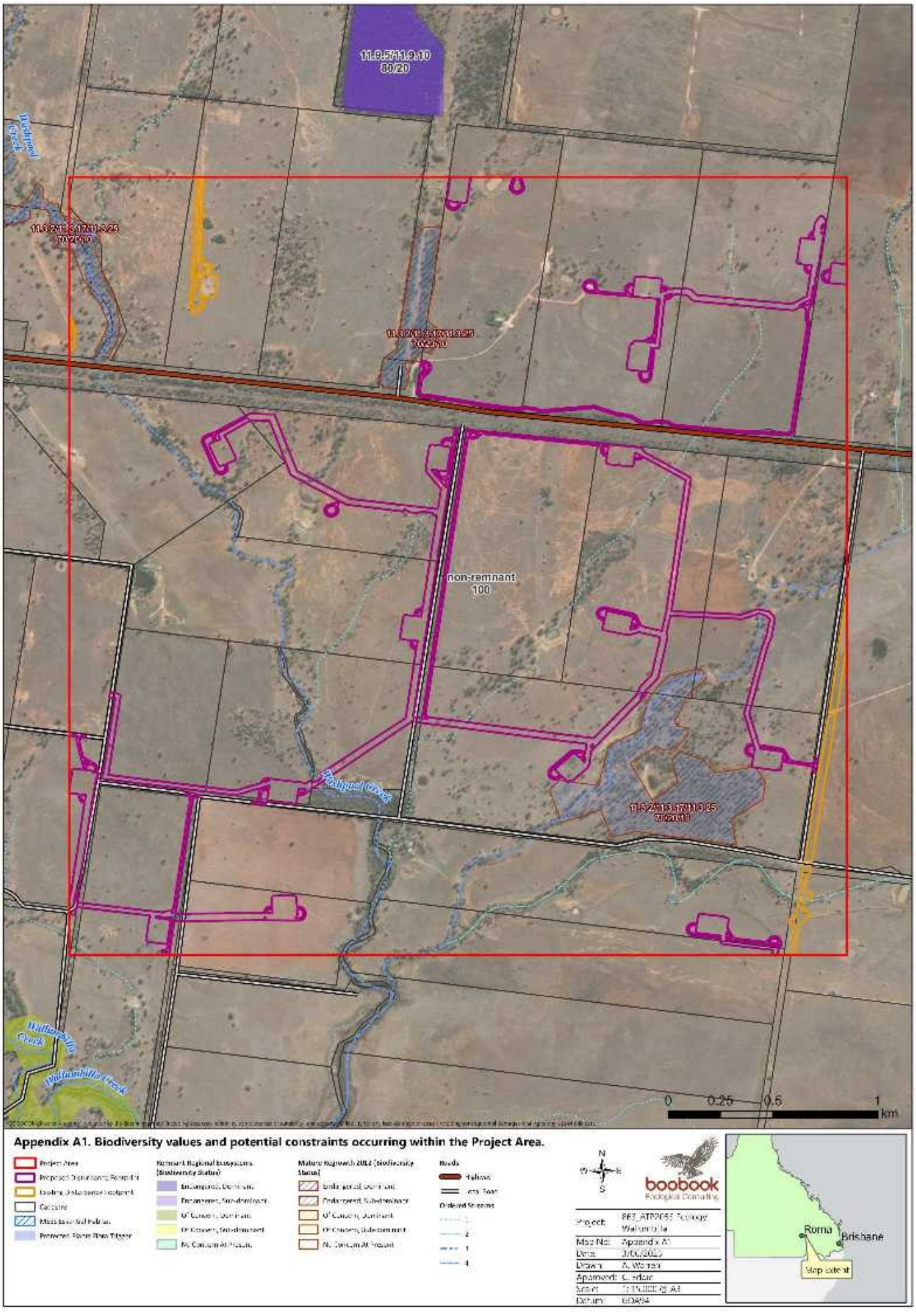

Figure 3a-b. View west from BioCondition site 863-B04 in disturbed remnant Poplar Box and Belah (*Casuarina cristata*) woodland (RE 11.3.17) (left); view east at the origin of BioCondition site 863-B06 in River Red Gum (*Eucalyptus camaldulensis*) riparian woodland along Washpool Creek (RE 11.3.25) (right).

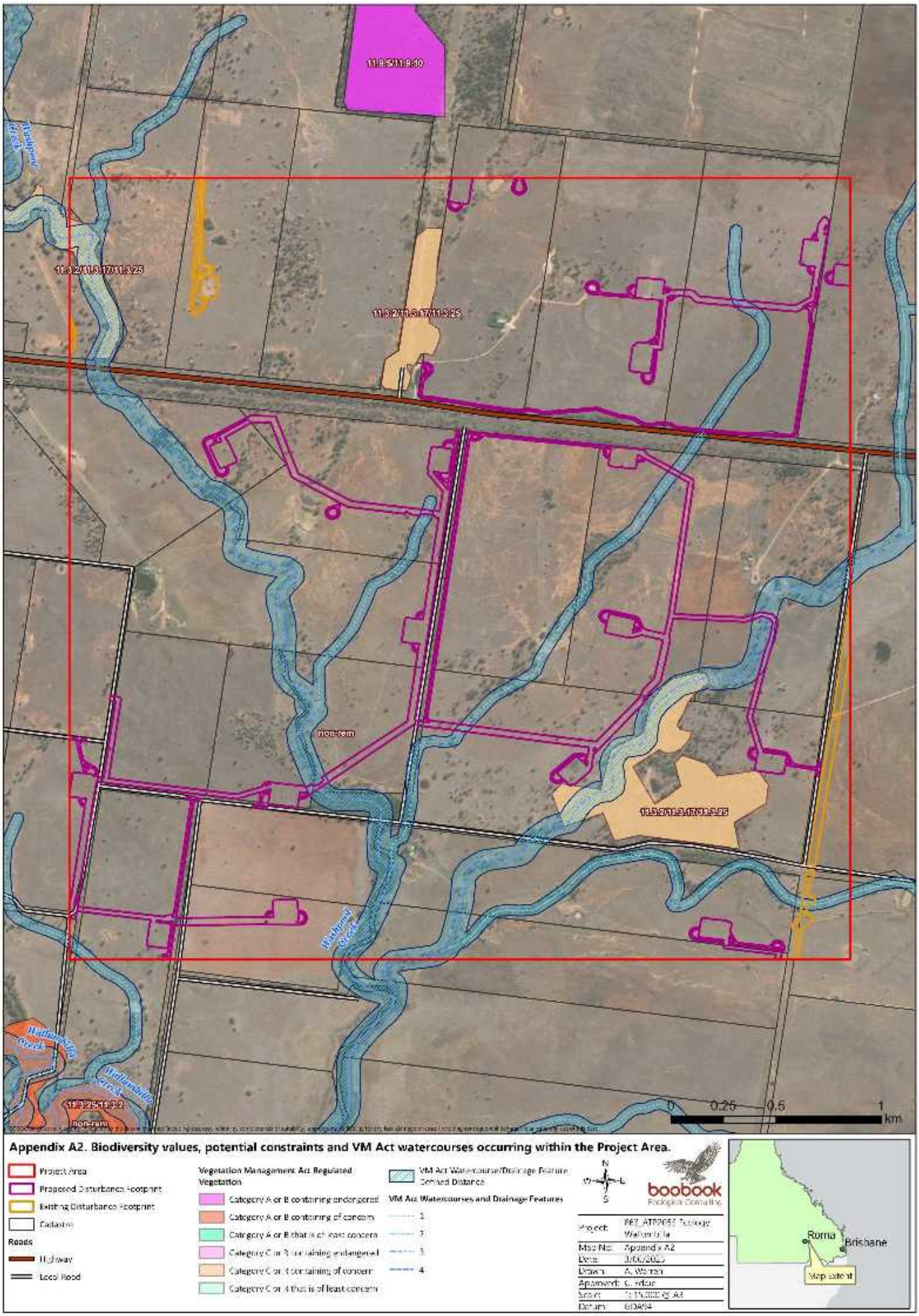


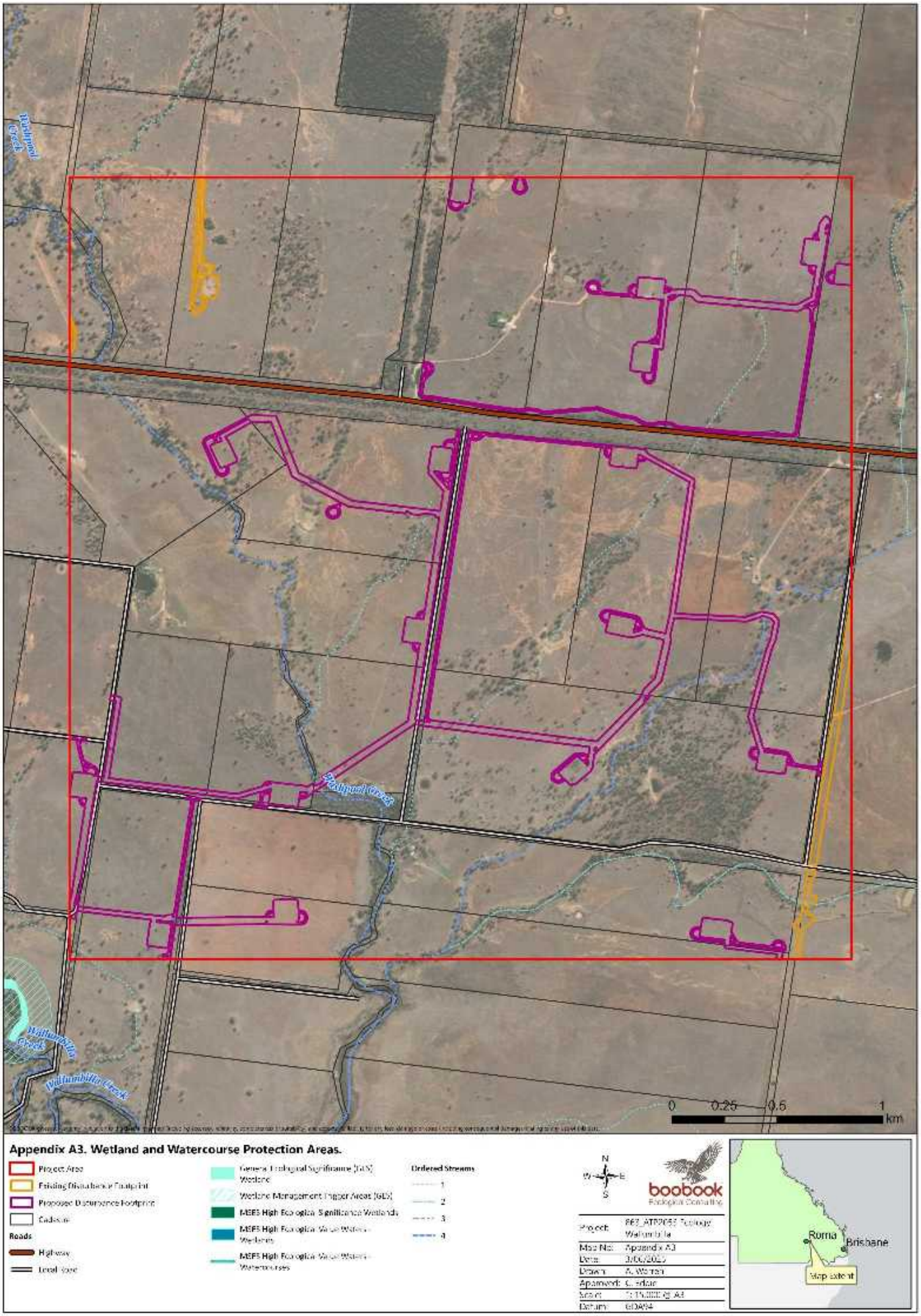


Figure 4a-b. View west from Survey-site 863-S03 in a floodplain sedge and grass soak (left); a well vegetated overflow wetland upstream of a farm dam (right). Similar small, ephemeral wetland areas are common across this landscape and are potential temporary habitat for wetland species such as Australian Painted Snipe (*Rostratula australis*) and Latham's Snipe (*Gallinago hardwickii*).

Appendix A. Desktop biodiversity values and potential constraints occurring within the Project Area.


11.9.5/11.9.10
80/20
non-remnant
100
0
0.25
0.5
1
km
Appendix A1. Biodiversity values and potential constraints occurring within the Project Area.
boobook
Ecological Consulting
Roma
Brisbane
Map extent


11.3.2/11.3.17/11.3.25
11.3.2/11.3.17/11.3.25
non-rem
11.3.2/11.3.17/11.3.25
Walloomba Creek
Walloomba Creek
11.3.25/11.3.2
non-rem
0 0.25 0.5 1 km
Appendix A2. Biodiversity values, potential constraints and VM Act watercourses occurring within the Project Area.
Project Area
Proposed Disturbance Footprint
Existing Disturbance Footprint
Cadastre
Roads
Highway
Local Road
Vegetation Management Act Regulated Vegetation
Category A or B containing endangered
Category A or B containing of concern
Category A or B that is of least concern
Category C or R containing endangered
Category C or R containing of concern
Category C or R that is of least concern
VM Act Watercourse/Drainage Feature Defined Distance
VM Act Watercourses and Drainage Features
1
3
3
4
N
W
E
S
boobook
Ecological Consulting
Project: 862_ATP2053 Toolooy Walloomba
Map No: Appendix A2
Date: 3/06/2025
Drawn: A. Warren
Approved: C. Erdos
Scale: 1:15,000 @ A3
Datum: GDA94
Roma
Brisbane
Map extent


Appendix A3. Wetland and Watercourse Protection Areas.
Project Area
Existing Disturbance Footprint
Proposed Disturbance Footprint
Cadastre
Roads
Highway
Local road
Ordered Streams
1
2
3
4
boobook
Ecological Consulting
Project
Map No.
Date
Drawn
Approved
Scale
Datum
GDA94
Roma
Brisbane
Map extent
0
0.25
0.5
1
km

Appendix B. PMST Results



Australian Government

Department of Climate Change, Energy, the Environment and Water

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 23-Oct-2024

Summary

Details

- Matters of NES
- Other Matters Protected by the EPBC Act
- Extra Information

Caveat

Acknowledgements

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance (Ramsar	4
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	5
Listed Threatened Species:	28
Listed Migratory Species:	9

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	14
Whales and Other Cetaceans:	None
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None
Habitat Critical to the Survival of Marine Turtles:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	None
Regional Forest Agreements:	None
Nationally Important Wetlands:	None
EPBC Act Referrals:	10
Key Ecological Features (Marine):	None
Biologically Important Areas:	None
Bioregional Assessments:	1
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

Wetlands of International Importance (Ramsar Wetlands) [Resource Information]

Ramsar Site Name	Proximity	Buffer Status
Banrock station wetland complex	1100 - 1200km upstream from Ramsar site	In feature area
Narran lake nature reserve	300 - 400km upstream from Ramsar site	In feature area
Riverland	1100 - 1200km upstream from Ramsar site	In feature area
The coorong, and lakes alexandrina and albert wetland	1300 - 1400km upstream from Ramsar site	In feature area

Listed Threatened Ecological Communities [Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.
Status of Vulnerable, Disallowed and Ineligible are not MNES under the EPBC Act.

Community Name	Threatened Category	Presence Text	Buffer Status
Brigalow (Acacia harpophylla dominant and co-dominant)	Endangered	Community known to occur within area	In buffer area only
Coolibah - Black Box Woodlands of the Darling Riverine Plains and the Brigalow Belt South Bioregions	Endangered	Community may occur within area	In feature area
Poplar Box Grassy Woodland on Alluvial Plains	Endangered	Community likely to occur within area	In feature area
Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar Bioregions	Endangered	Community likely to occur within area	In buffer area only
Weeping Myall Woodlands	Endangered	Community likely to occur within area	In feature area

Listed Threatened Species [Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text	Buffer Status

Scientific Name	Threatened Category	Presence Text	Buffer Status
BIRD			
Aphelocephala leucopsis Southern Whiteface [529]	Vulnerable	Species or species habitat may occur within area	In feature area
Calidris acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat may occur within area	In feature area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area	In feature area
Calyptorhynchus lathami lathami South-eastern Glossy Black-Cockatoo [67036]	Vulnerable	Species or species habitat may occur within area	In feature area
Climacteris picumnus victoriae Brown Treecreeper (south-eastern) [67062]	Vulnerable	Species or species habitat may occur within area	In buffer area only
Erythrotriorchis radiatus Red Goshawk [942]	Endangered	Species or species habitat may occur within area	In feature area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]	Vulnerable	Species or species habitat may occur within area	In feature area
Geophaps scripta scripta Squatter Pigeon (southern) [64440]	Vulnerable	Species or species habitat may occur within area	In feature area
Grantiella picta Painted Honeyeater [470]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Hirundapus caudacutus White-throated Needletail [682]	Vulnerable	Species or species habitat may occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Rostratula australis			
Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area	In feature area
Stagonopleura guttata			
Diamond Firetail [59398]	Vulnerable	Species or species habitat may occur within area	In feature area
FISH			
Maccullochella peelii			
Murray Cod [66633]	Vulnerable	Species or species habitat may occur within area	In buffer area only
MAMMAL			
Chalinolobus dwyeri			
Large-eared Pied Bat, Large Pied Bat [183]	Endangered	Species or species habitat may occur within area	In buffer area only
Dasyurus hallucatus			
Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat may occur within area	In feature area
Nyctophilus corbeni			
Corben's Long-eared Bat, South-eastern Long-eared Bat [83395]	Vulnerable	Species or species habitat may occur within area	In feature area
Petauroides volans			
Greater Glider (southern and central) [254]	Endangered	Species or species habitat likely to occur within area	In feature area
Phascolarctos cinereus (combined populations of Qld, NSW and the ACT)			
Koala (combined populations of Queensland, New South Wales and the Australian Capital Territory) [85104]	Endangered	Species or species habitat likely to occur within area	In feature area
PLANT			
Cadellia pentastylis			
Ooline [9828]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Dichanthium setosum			
bluegrass [14159]	Vulnerable	Species or species habitat likely to occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Lepidium monoplocoides			
Winged Pepper-cress [9190]	Endangered	Species or species habitat may occur within area	In feature area
Vincetoxicum forsteri listed as Tylophora linearis			
[92384]	Endangered	Species or species habitat may occur within area	In buffer area only
REPTILE			
Anomalopus mackayi			
Five-clawed Worm-skink, Long-legged Worm-skink [25934]	Vulnerable	Species or species habitat may occur within area	In feature area
Delma torquata			
Adorned Delma, Collared Delma [1656]	Vulnerable	Species or species habitat may occur within area	In feature area
Egernia rugosa			
Yakka Skink [1420]	Vulnerable	Species or species habitat may occur within area	In feature area
Furina dunmalli			
Dunmall's Snake [59254]	Vulnerable	Species or species habitat may occur within area	In feature area
Hemiaspis damelii			
Grey Snake [1179]	Endangered	Species or species habitat likely to occur within area	In feature area

Listed Migratory Species		[Resource Information]	
Scientific Name	Threatened Category	Presence Text	Buffer Status
Migratory Marine Birds			
Apus pacificus			
Fork-tailed Swift [678]		Species or species habitat likely to occur within area	In feature area
Migratory Terrestrial Species			
Cuculus optatus			
Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat may occur within area	In feature area
Hirundapus caudacutus			
White-throated Needletail [682]	Vulnerable	Species or species habitat may occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area	In feature area
Migratory Wetlands Species			
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area	In feature area
Calidris acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat may occur within area	In feature area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area	In feature area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area	In feature area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]	Vulnerable	Species or species habitat may occur within area	In feature area

Other Matters Protected by the EPBC Act

Listed Marine Species		[Resource Information]	
Scientific Name	Threatened Category	Presence Text	Buffer Status
Bird			
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area	In feature area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area	In feature area
Bubulcus ibis as Ardea ibis Cattle Egret [66521]		Species or species habitat may occur within area overfly marine area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Calidris acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat may occur within area	In feature area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area overfly marine area	In feature area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area overfly marine area	In feature area
Chalcites osculans as Chrysococcyx osculans Black-eared Cuckoo [83425]		Species or species habitat likely to occur within area overfly marine area	In feature area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]	Vulnerable	Species or species habitat may occur within area overfly marine area	In feature area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat may occur within area	In feature area
Hirundapus caudacutus White-throated Needletail [682]	Vulnerable	Species or species habitat may occur within area overfly marine area	In feature area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area overfly marine area	In feature area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area overfly marine area	In feature area
Myiagra cyanoleuca Satin Flycatcher [612]		Species or species habitat may occur within area overfly marine area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Rostratula australis as Rostratula benghalensis (sensu lato)			
Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area overfly marine area	In feature area

Extra Information

EPBC Act Referrals				[Resource Information]
Title of referral	Reference	Referral Outcome	Assessment Status	Buffer Status
Coal Seam Gas Field Development for Natural Gas Liquefaction Park, Curtis Island	2008/4059		Post-Approval	In buffer area only
Controlled action				
Expansion of Coal Seam Gas Fields	2009/4974	Controlled Action	Post-Approval	In feature area
Queensland Hunter Gas Pipeline, approximately 825 km in length	2008/4483	Controlled Action	Completed	In buffer area only
Santos GLNG Gas Field Development Project, QLD	2012/6615	Controlled Action	Post-Approval	In feature area
Not controlled action				
Comet Ridge to Wallumbilla natural gas pipeline	2006/2604	Not Controlled Action	Completed	In buffer area only
Construct and operate 112km long underground gas transmission pipeline	2008/4358	Not Controlled Action	Completed	In buffer area only
Improving rabbit biocontrol: releasing another strain of RHDV, sthrn two thirds of Australia	2015/7522	Not Controlled Action	Completed	In feature area
QSN3 Project, expand 935km gas pipeline and supporting infrastructure	2009/5072	Not Controlled Action	Completed	In buffer area only
Queensland Hunter Gas Pipeline, approximately 833 km in length	2008/4620	Not Controlled Action	Completed	In buffer area only
Reedy Creek to Wallumbilla gas transmission pipeline, sthrn Qld	2017/7888	Not Controlled Action	Completed	In buffer area only

Bioregional Assessments			[Resource Information]
SubRegion	BioRegion	Website	Buffer Status
Maranoa-Balonne-Condamine	Northern Inland Catchments	BA website	In feature area

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

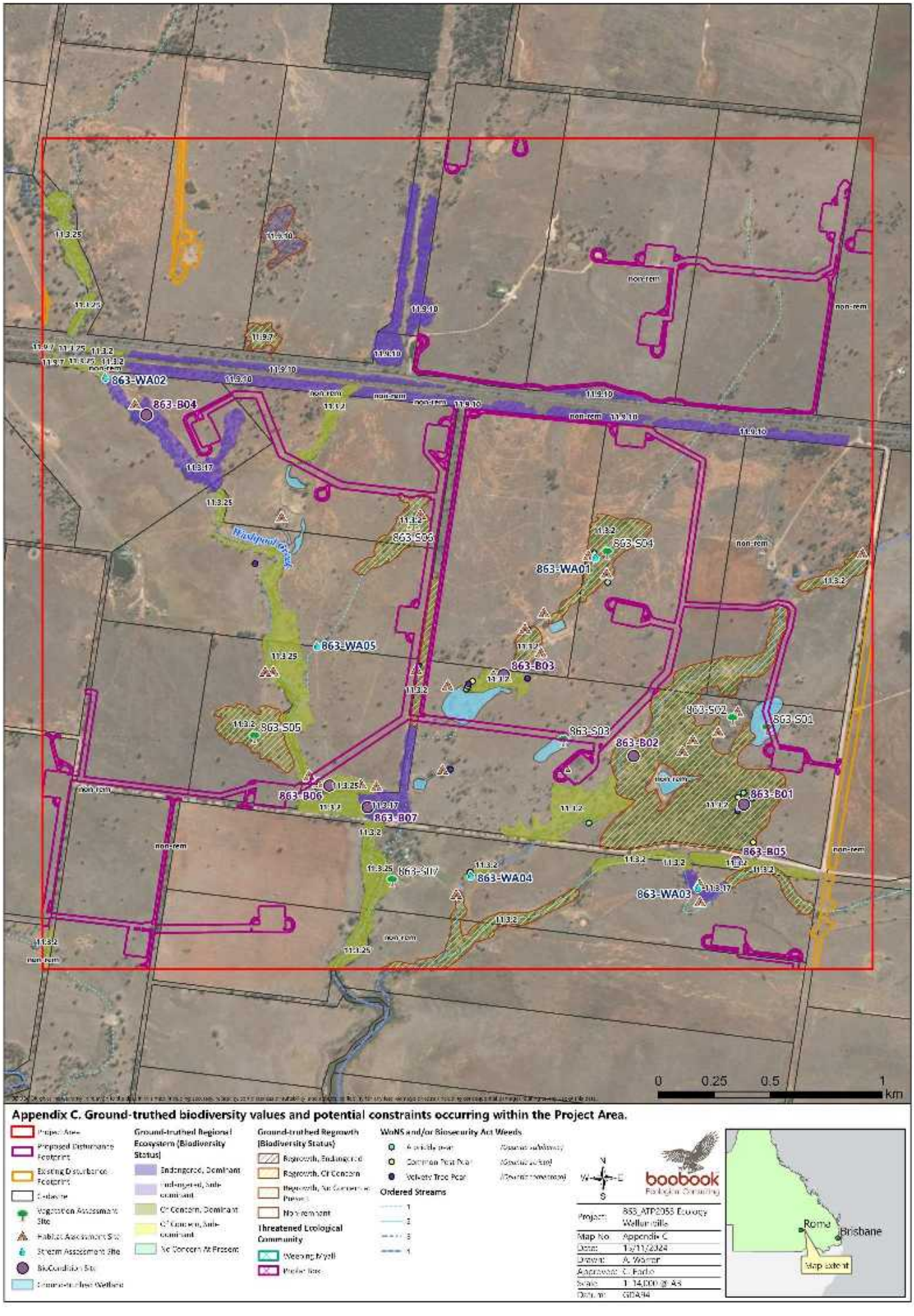
-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact us page.

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Canberra ACT 2601 Australia
+61 2 6274 1111

Appendix C. Ground-truthed biodiversity values and potential constraints occurring within the Project Area.



Appendix C. Ground-truthed biodiversity values and potential constraints occurring within the Project Area.

Project Area
Proposed Disturbance Footprint
Existing Disturbance Footprint
Exclusion
Vegetation Assessment Site
Habitat Assessment Site
Stream Assessment Site
BioCondition Site
Conservation Estate Wetland

Ground-truthed Regional Ecosystem (Biodiversity Status)
Endangered, Dominant
Endangered, Sub-dominant
Of Concern, Dominant
Of Concern, Sub-dominant
No Concern At Present

Ground-truthed Regrowth (Biodiversity Status)
Regrowth, Endangered
Regrowth, Of Concern
Regrowth, No Concern at Present
Non-remnant

Threatened Ecological Community
Weeping Myall
Prickly Box

WoNS and/or Biosecurity Act Weeds
Parkinsonia
Common Pear Tree
Velvety Tree Pear

Ordered Streams
1
2
3
4

N
W
E
S

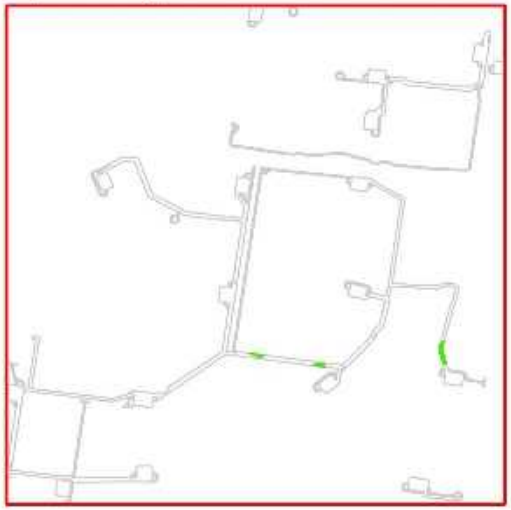
boobook Ecological Consulting

Project:	863_ATP2053 Economy Wellington
Map No:	Appendix C
Date:	13/11/2024
Drawn:	A. Warner
Approved:	C. Bardo
Scale:	1: 14,000 @ A3
Datum:	GDA94

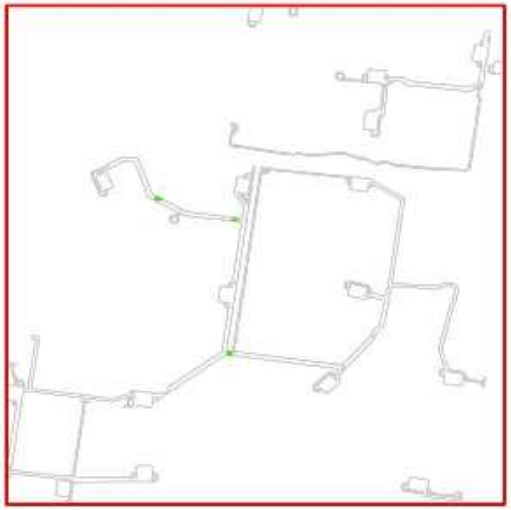
Roma
Brisbane
Map extent

Appendix D. Predictive threatened and SLC fauna habitat mapping within the Project Area.

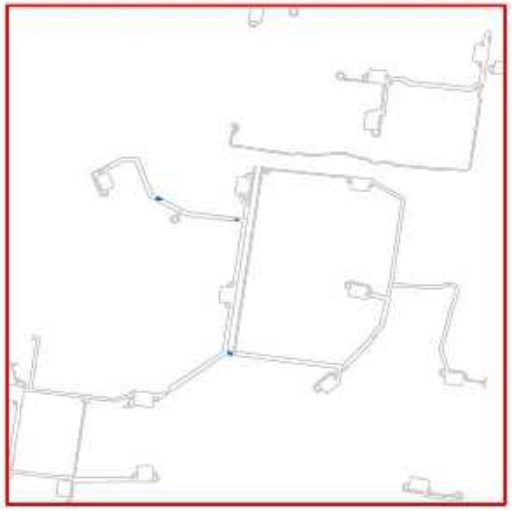
Australian Painted Snipe,
Latham's Snipe,
Sharp-tailed Sandpiper



Glossy Black-Cockatoo



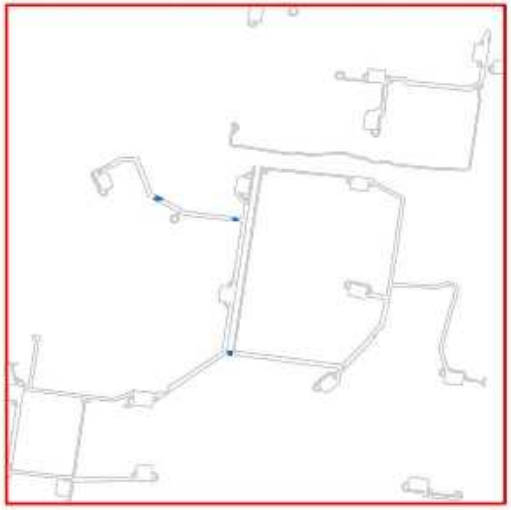
Koala



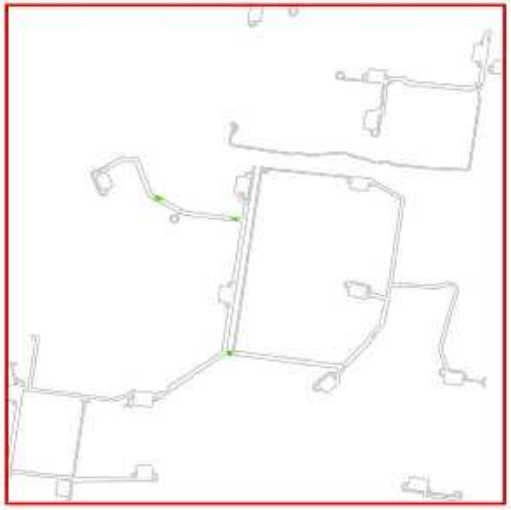
Appendix D. Predictive threatened and SLC fauna habitat within the Disturbance Footprint.

- Project Area
- Disturbance Footprint
- Primary Habitat
- General Habitat

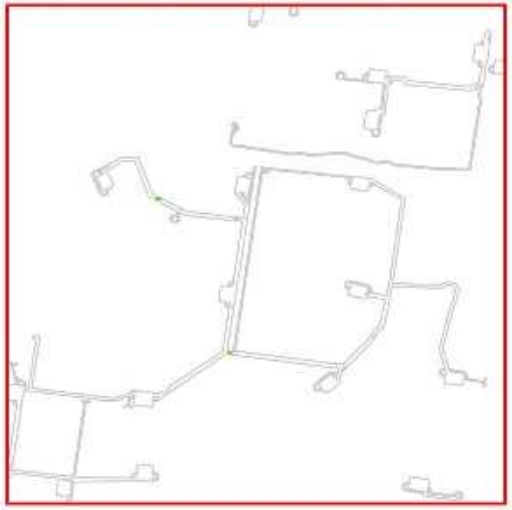
Yakka Skink



Grey Snake



White-throated Needletail,
Short-beaked Echidna



N
W E
S

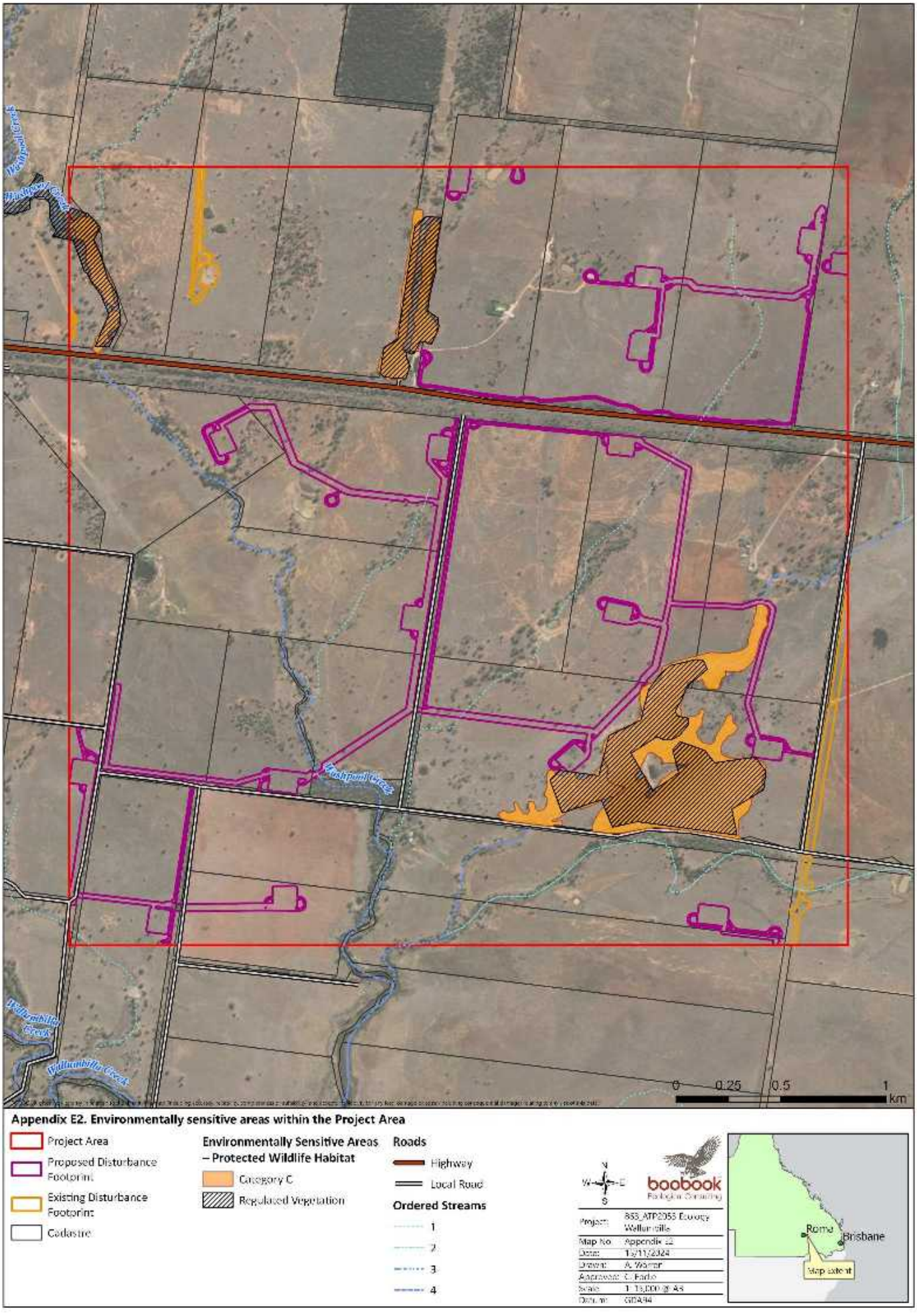
boobook
ecological consulting

0 0.38 0.75 1.5
km

Project	003_ATF2051 Ecology Walumbilla
Map No.	Appendix D
Date	12/06/2023
Drawn	A. Warren
Approved	C. Hollis
Scale	1:15,000 @ A3
Datum	GDA94



Appendix E. Environmentally sensitive areas within the Project Area.


Appendix E2. Environmentally sensitive areas within the Project Area
Project Area
Proposed Disturbance Footprint
Existing Disturbance Footprint
Cadastre
Environmentally Sensitive Areas – Protected Wildlife Habitat
Category C
Regulated Vegetation
Roads
Highway
Local Road
Ordered Streams
1
2
3
4
N
W
E
S
boobook
Ecological Consulting
Project: 853_ATP2053 Ecology Wellcamille
Map No: Appendix E2
Date: 13/11/2024
Drawn: A. Warner
Approved: C. Fardo
Scale: 1: 13,000 @ A3
Datum: GDA94
Roma
Brisbane
Map extent
0
0.25
0.5
1
km

Queensland Government

Department of the Environment, Tourism, Science and Innovation

Environmental Reports

Matters of State Environmental Significance

For the selected area of interest

ATP: 2053

Environmental Reports - General Information

The Environmental Reports portal provides for the assessment of selected matters of interest relevant to a user specified location, or area of interest (AOI). All area and derivative figures are relevant to the extent of matters of interest contained within the AOI unless otherwise stated. Please note, if a user selects an AOI via the "central coordinates" option, the resulting assessment area encompasses an area extending for a 2km radius from the point of interest.

All area and area derived figures included in this report have been calculated via reprojecting relevant spatial features to Albers equal-area conic projection (central meridian = 146, datum Geocentric Datum of Australia 2020). As a result, area figures may differ slightly if calculated for the same features using a different co-ordinate system.

Figures in tables may be affected by rounding.

The matters of interest reported on in this document are based upon available state mapped datasets. Where the report indicates that a matter of interest is not present within the AOI (e.g. where area related calculations are equal to zero, or no values are listed), this may be due either to the fact that state mapping has not been undertaken for the AOI, that state mapping is incomplete for the AOI, or that no values have been identified within the site.

The information presented in this report should be considered as a guide only and a field survey may be required to validate values on the ground.

Please direct queries about these reports to: Planning.Support@detsi.qld.gov.au

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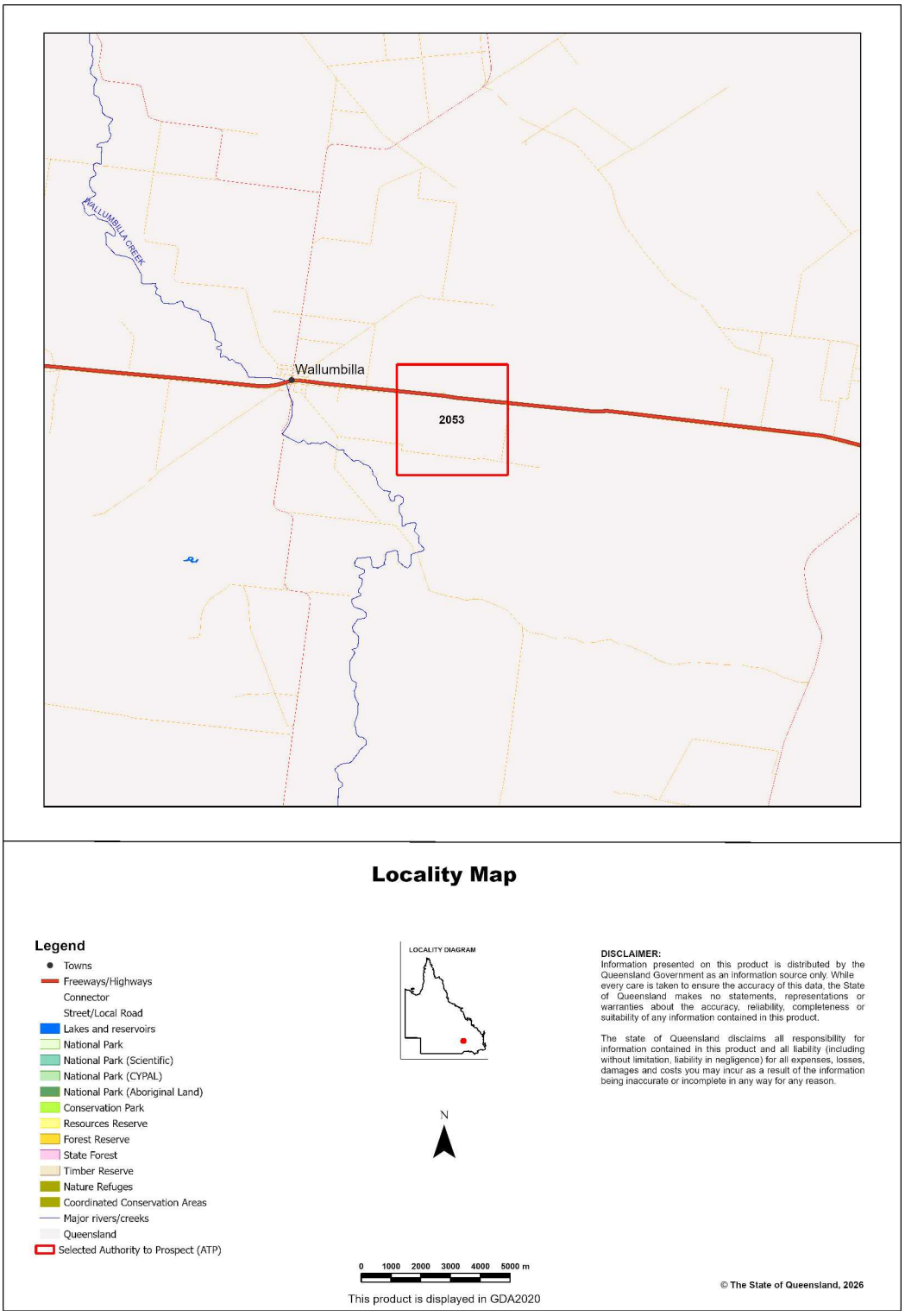
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Assessment Area Details

The following table provides an overview of the area of interest (AOI) with respect to selected topographic and environmental values.

Table 1: Summary table, details for AOI: ATP: 2053, with area 1226.19 ha

Local Government(s)	Catchment(s)	Bioregion(s)	Subregion(s)
Maranoa Regional	Balonne-Condamine	Brigalow Belt	Southern Downs



Matters of State Environmental Significance (MSES)

MSES Categories

Queensland's State Planning Policy (SPP) includes a biodiversity State interest that states:

'The sustainable, long-term conservation of biodiversity is supported. Significant impacts on matters of national or state environmental significance are avoided, or where this cannot be reasonably achieved; impacts are minimised and residual impacts offset.'

The MSES mapping product is a guide to assist implementation of the SPP biodiversity policy. While it supports the SPP, the mapping does not replace the regulatory mapping or environmental values specifically called up under other laws or regulations.

The SPP defines matters of state environmental significance as:

- Protected areas (including all classes of protected area except coordinated conservation areas) under the *Nature Conservation Act 1992;*

- Marine parks and land within a 'marine national park', 'conservation park', 'scientific research', 'preservation' or 'buffer' zone under the Marine Parks Act 2004 ;

- Areas within declared fish habitat areas that are management A areas or management B areas under the Fisheries Regulation 2008;

- *Threatened wildlife under the Nature Conservation Act 1992* and special least concern animals under the Nature Conservation (Wildlife) Regulation 2006;

- Regulated vegetation under the *Vegetation Management Act 1999* that is:

  - Category B areas on the regulated vegetation management map, that are 'endangered' or 'of concern' regional ecosystems;
  - Category C areas on the regulated vegetation management map that are 'endangered' or 'of concern' regional ecosystems;
  - Category R areas on the regulated vegetation management map;
  - Regional ecosystems that intersect with watercourses identified on the vegetation management watercourse and drainage feature map;
  - Regional ecosystems that intersect with wetlands identified on the vegetation management wetlands map;

- Strategic Environmental Areas under the *Regional Planning Interests Act 2014* ;

- Wetlands in a wetland protection area of wetlands of high ecological significance shown on the Map of Queensland Wetland Environmental Values under the Environment Protection Regulation 2019;

- Wetlands and watercourses in high ecological value waters defined in the Environmental Protection (Water) Policy 2009, schedule 2;
- Legally secured offset areas.

MSES Values Present

The MSES values that are present in the area of interest are summarised in the table below:

Table 2: Summary of MSES present within the AOI

1a Protected Areas- estates	0 ha	0.0%
1b Protected Areas- nature refuges	0 ha	0.0%
1c Protected Areas- special wildlife reserves	0 ha	0.0%
2 State Marine Parks- highly protected zones	0 ha	0.0%
3 Fish habitat areas (A and B areas)	0 ha	0.0%
4 Strategic Environmental Areas (SEA)	0 ha	0.0%
5 High Ecological Significance wetlands on the Map of Queensland Wetland Environmental Values	0 ha	0.0%
6a High Ecological Value (HEV) wetlands	0 ha	
6b High Ecological Value (HEV) waterways	0 km	Not applicable
7a Threatened (endangered or vulnerable) wildlife	0 ha	0.0%
7b Special least concern animals	0 ha	0.0%
7c i Koala habitat area - core (SEQ)	0 ha	0.0%
7c ii Koala habitat area - locally refined (SEQ)	0 ha	0.0%
7d Sea turtle nesting areas	0 km	Not applicable
8a Regulated Vegetation - Endangered/Of concern in Category B (remnant)	0 ha	0.0%
8b Regulated Vegetation - Endangered/Of concern in Category C (regrowth)	45.17 ha	3.7%
8c Regulated Vegetation - Category R (GBR riverine regrowth)	0 ha	0.0%
8d Regulated Vegetation - Essential habitat	0 ha	0.0%
8e Regulated Vegetation - intersecting a watercourse	15 km	Not applicable
8f Regulated Vegetation - within 100m of a Vegetation Management Wetland	0 ha	0.0%
9a Legally secured offset areas- offset register areas	0 ha	0.0%
9b Legally secured offset areas- vegetation offsets through a Property Map of Assessable Vegetation	0 ha	0.0%

Additional Information with Respect to MSES Values Present

MSES - State Conservation Areas

1a. Protected Areas - estates

(No results)

1b. Protected Areas - nature refuges

(No results)

1c. Protected Areas - special wildlife reserves

(No results)

2. State Marine Parks - highly protected zones

(No results)

3. Fish habitat areas (A and B areas)

(No results)

Refer to **Map 1 - MSES - State Conservation Areas** for an overview of the relevant MSES.

MSES - Wetlands and Waterways

4. Strategic Environmental Areas (SEA)

(No results)

5. High Ecological Significance wetlands on the Map of Queensland Wetland Environmental Values

(no results)

6a. Wetlands in High Ecological Value (HEV) waters

(no results)

6b. Waterways in High Ecological Value (HEV) waters

(no results)

Refer to **Map 2 - MSES - Wetlands and Waterways** for an overview of the relevant MSES.

MSES - Species

7a. Threatened (endangered or vulnerable) wildlife

Not applicable

7b. Special least concern animals

Not applicable

7c i. Koala habitat area - core (SEQ)

Not applicable

7c ii. Koala habitat area - locally refined (SEQ)

Not applicable

7d. Wildlife habitat (sea turtle nesting areas)

Not applicable

Threatened (endangered or vulnerable) wildlife habitat suitability models

Species	Common name	NCA status	Presence
Boronia keysii	Keys boronia	V	None
Calyptorhynchus lathami	Glossy black cockatoo	V	None
Casuarius casuarius johnsonii	Sthn population cassowary	E	None
Crinia tinnula	Wallum froglet	V	None
Denisonia maculata	Ornamental snake	V	None
Euastacus bindal	Mount Elliot crayfish	CR	None
Euastacus binzayedi		CR	None
Euastacus eungella		E	None
Euastacus hystricosus		E	None
Euastacus jagara	Jagara hairy crayfish	CR	None
Euastacus maidae		CR	None
Euastacus monteithorum		E	None
Euastacus robertsi		E	None
Taudactylus pleione	Kroombit tinkerfrog	E	None
Litoria freycineti	Wallum rocketfrog	V	None
Litoria olongburensis	Wallum sedgefrog	V	None
Macadamia integrifolia		V	None
Melaleuca irbyana	swamp tea-tree	E	None
Macadamia ternifolia		V	None
Macadamia tetraphylla	bopple nut	V	None
Petrogale penicillata	brush-tailed rock-wallaby	V	None
Petrogale coenensis	Cape York rock-wallaby	E	None
Petrogale purpureicollis	purple-necked rock-wallaby	V	None
Petrogale sharmani	Sharmans rock-wallaby	V	None
Petrogale xanthopus celeris	yellow-footed rock-wallaby (Qld subspecies)	V	None
Petaurus gracilis	Mahogany Glider	E	None
Petrogale persephone	Proserpine rock-wallaby	E	None
Phascolarctos cinereus	Koala - outside SEQ*	E	None
Pezoporus wallicus wallicus	Eastern ground parrot	V	None
Xeromys myoides	Water Mouse	V	None

*For koala model, this includes areas outside SEQ. Check 7c SEQ koala habitat for presence/absence.

Threatened (endangered or vulnerable) wildlife species records

(No results)

Special least concern animal species records

(No results)

Shorebird habitat (critically endangered/endangered/vulnerable)

Not applicable

Shorebird habitat (special least concern)

Not applicable

**Nature Conservation Act 1992 (NCA) Status- Endangered (E), Vulnerable (V) or Special Least Concern Animal (SL). Environment Protection and Biodiversity Conservation Act 1999 (EPBC) status: Critically Endangered (CE) Endangered (E), Vulnerable (V)*

Migratory status (M) - China and Australia Migratory Bird Agreement (C), Japan and Australia Migratory Bird Agreement (J), Republic of Korea and Australia Migratory Bird Agreement (R), Bonn Migratory Convention (B), Eastern Flyway (E)

To request a species list for an area, or search for a species profile, access Wildlife Online at:

https://www.qld.gov.au/environment/plants-animals/species-list/

Refer to **Map 3a - MSES - Species - Threatened (endangered or vulnerable) wildlife and special least concern animals** and **Map 3b - MSES - Species - Koala habitat area (SEQ)** and **Map 3c - MSES - Wildlife habitat (sea turtle nesting areas)** for an overview of the relevant MSES.

MSES - Regulated Vegetation

For further information relating to regional ecosystems in general, go to:

https://www.qld.gov.au/environment/plants-animals/plants/ecosystems/

For a more detailed description of a particular regional ecosystem, access the regional ecosystem search page at:

https://environment.ehp.qld.gov.au/regional-ecosystems/

8a. Regulated Vegetation - Endangered/Of concern in Category B (remnant)

Not applicable

8b. Regulated Vegetation - Endangered/Of concern in Category C (regrowth)

Regional ecosystem	Vegetation management polygon	Vegetation management status
11.3.2/11.3.17/11.3.25	O-dom	hvr_oc

8c. Regulated Vegetation - Category R (GBR riverine regrowth)

Not applicable

8d. Regulated Vegetation - Essential habitat

Not applicable

8e. Regulated Vegetation - intersecting a watercourse**

A vegetation management watercourse is mapped as present

8f. Regulated Vegetation - within 100m of a Vegetation Management wetland

Not applicable

Refer to **Map 4 - MSES - Regulated Vegetation** for an overview of the relevant MSES.

MSES - Offsets

9a. Legally secured offset areas - offset register areas

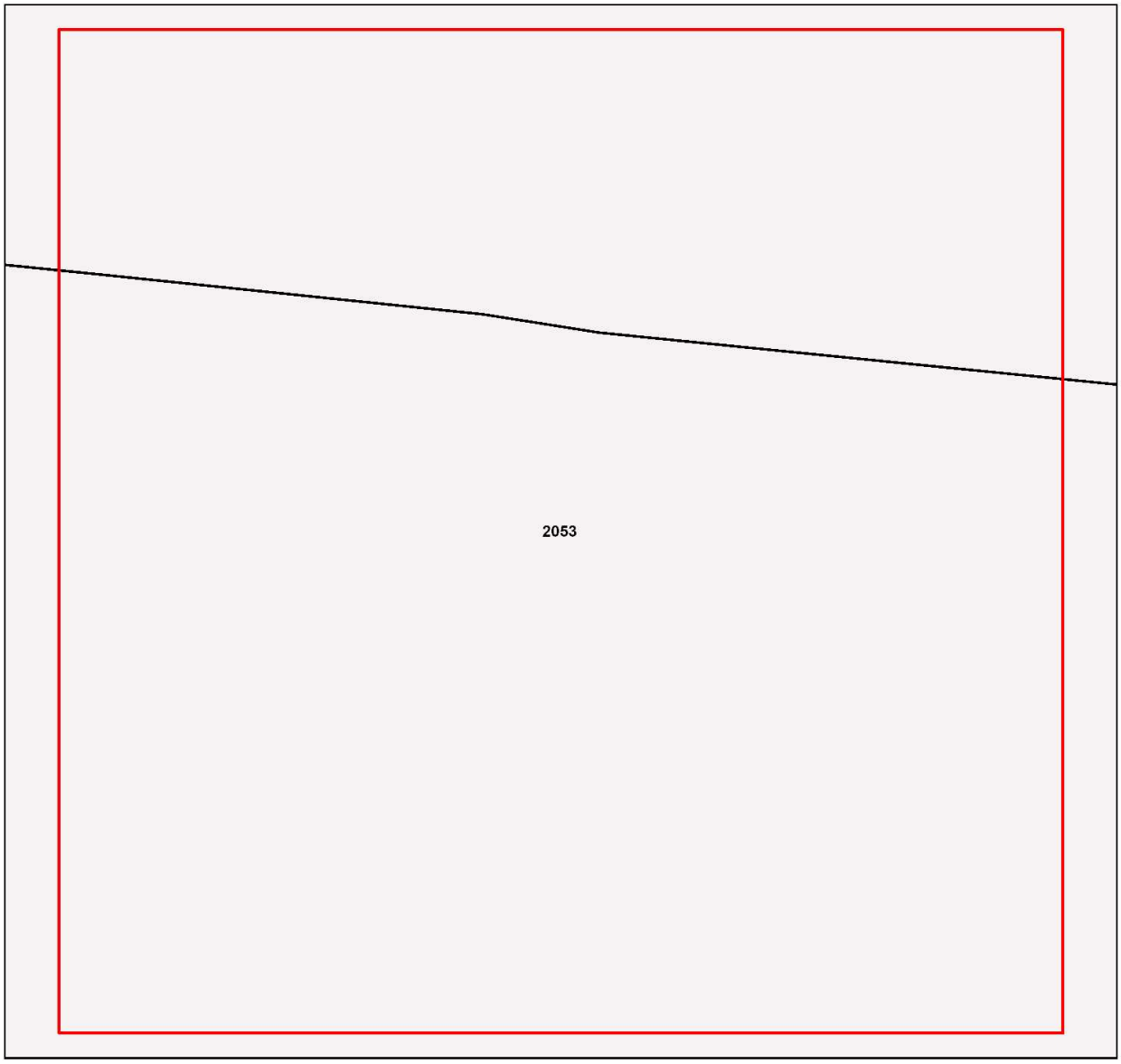
(No results)

9b. Legally secured offset areas - vegetation offsets through a Property Map of Assessable Vegetation

(No results)

Refer to **Map 5 - MSES - Offset Areas** for an overview of the relevant MSES.

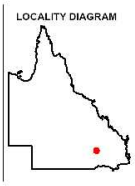
Map 1 - MSES - State Conservation Areas



MSES - State Conservation Areas

- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Protected area (estates, nature refuges, special wildlife reserves)
- Declared fish habitat area (A and B areas)
- Marine park (highly protected)
- Selected Authority to Prospect (ATP)

LOCALITY DIAGRAM



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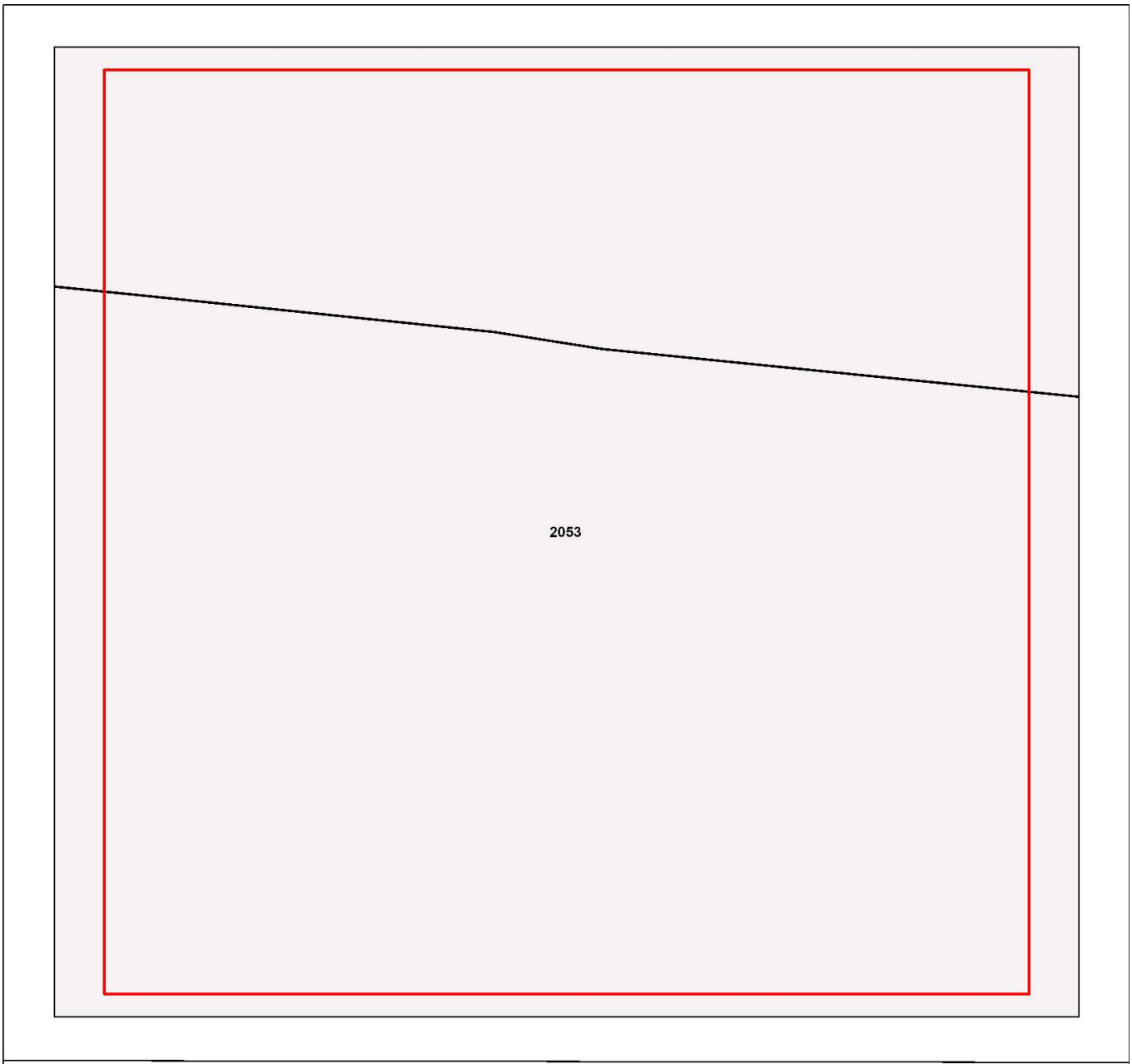
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Map 2 - MSES - Wetlands and Waterways

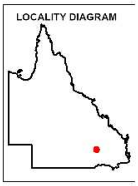


Map 3a - MSES - Species - Threatened (endangered or vulnerable) wildlife and special least concern animals



MSES - Species
Threatened (endangered or vulnerable) wildlife and special least concern animals

- ▲ Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Wildlife habitat (special least concern)
- Wildlife habitat (endangered or vulnerable)
- Selected Authority to Prospect (ATP)



N

0 225 450 675 900 1125 m

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Map 3b - MSES - Species - Koala habitat area (SEQ)



MSES - Species
Koala habitat area (SEQ)

- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Koala habitat area (core)
- Koala habitat area (locally refined)
- Selected Authority to Prospect (ATP)

LOCALITY DIAGRAM



0 200 400 600 800 1,000 m

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The represented layers for SEQ 'koala habitat area-core' and 'koala habitat area- locally refined' in MSES are sourced directly from the regulatory mapping under the Nature Conservation (Koala) Conservation Plan 2017. Whilst every effort is made to ensure the information remains current, there may be delays between updating versions. Please refer to the original mapping for the most recent version. See https://environment.des.qld.gov.au/wildlife/animals/living-with/koalas/mapping

The koala habitat mapping within South East Queensland uses regional ecosystem linework compiled at a scale varying from 1:25,000 to 1:100,000. Linework should be used as a guide only. The positional accuracy of regional ecosystem data mapped at a scale of 1:100,000 is +/- 100 metres.

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Map 3c - MSES - Species - Wildlife habitat (sea turtle nesting areas)



MSES - Wildlife habitat (sea turtle nesting areas)

- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Wildlife habitat (sea turtle nesting areas)
- Selected Authority to Prospect (ATP)

LOCALITY DIAGRAM



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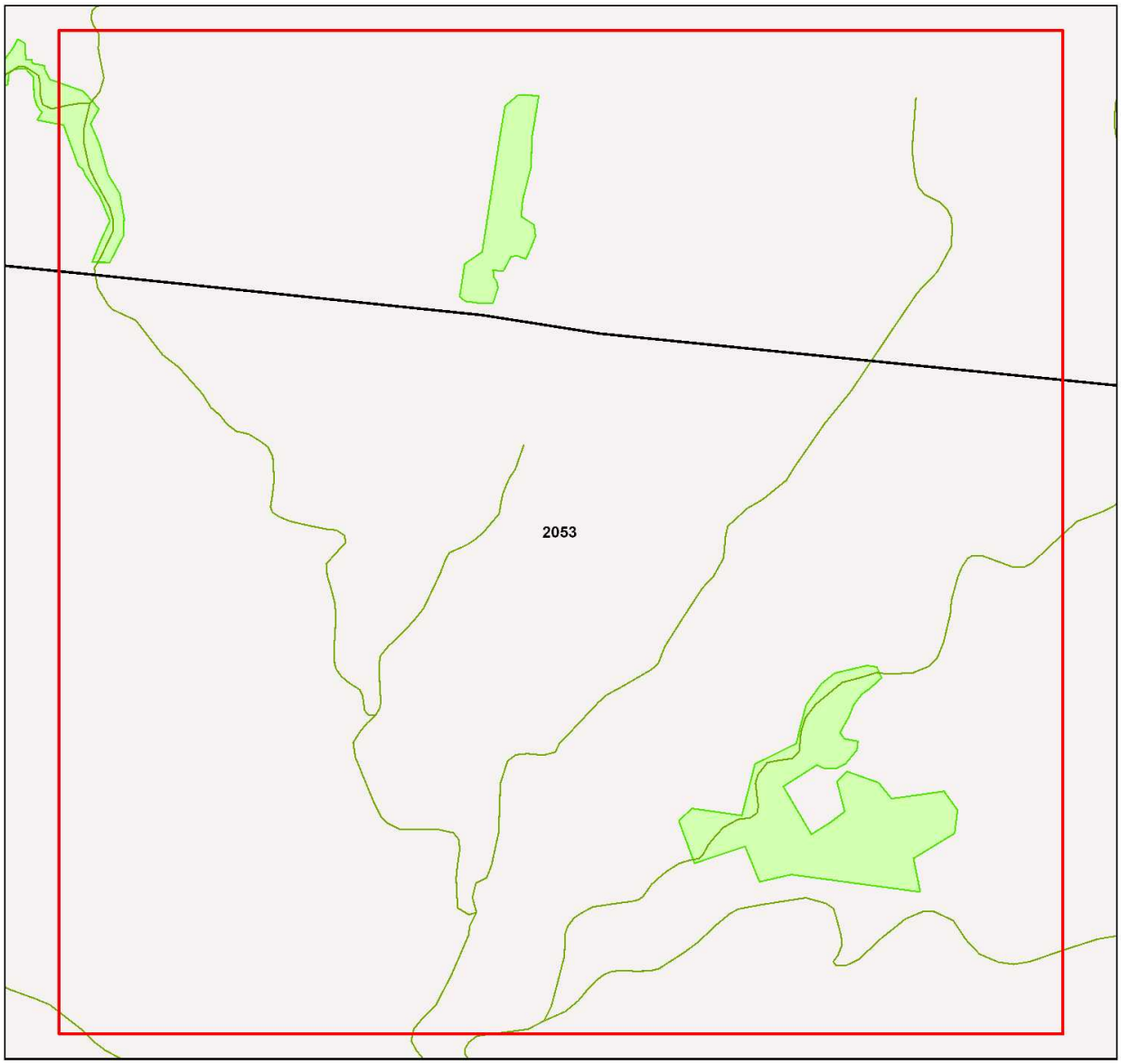
MSES mapping of sea turtle nesting areas identifies beaches where the recorded number of turtle nests are over 1% of the turtle species or genetic stock. The linework is also deliberately extended along nearby rocky coastlines and headlands to recognise that significant numbers of nesting adults and hatchlings can become disoriented by light pollution from development on rocky coastlines and headlands while navigating offshore from nesting beaches.

0 200 400 600 800 1,000 m

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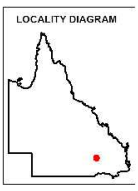
This product is displayed in GDA2020

Map 4 - MSES - Regulated Vegetation



MSES - Regulated Vegetation

- ▲ Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Regulated vegetation (intersecting a watercourse)
- Regulated vegetation (100m from wetland)
- Regulated vegetation (category B - endangered or of concern)
- Regulated vegetation (category C - endangered or of concern)
- Regulated vegetation (category R - GBR riverine)
- Regulated vegetation (essential habitat)
- Selected Authority to Prospect (ATP)



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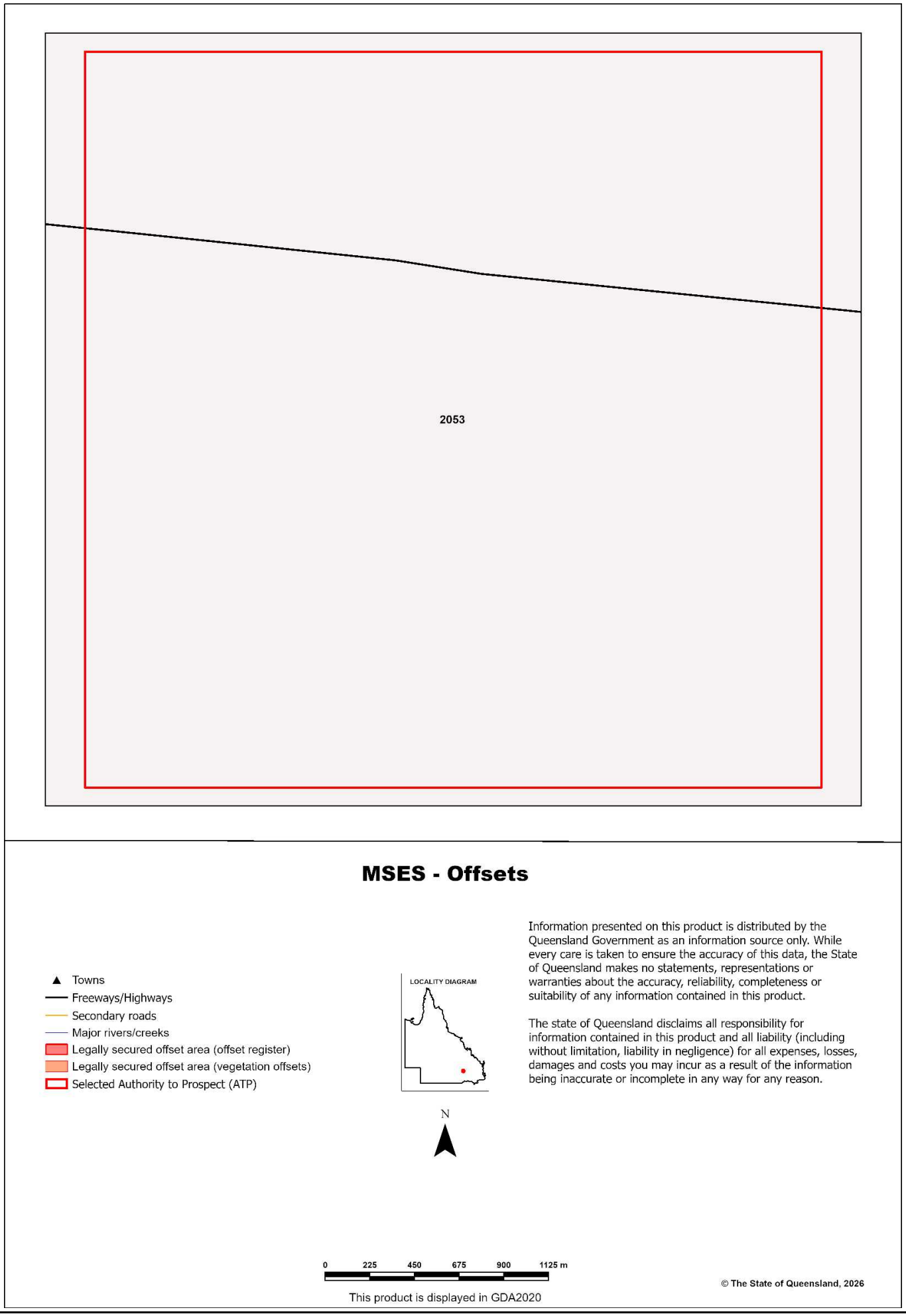
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Map 5 - MSES - Offset Areas



Appendices

Appendix 1 - Matters of State Environmental Significance (MSES) methodology

MSES mapping is a regional-scale representation of the definition for MSES under the State Planning Policy (SPP). Its primary purpose is to support implementation of the SPP biodiversity policy.

MSES mapping does not replace the regulatory mapping or environmental values specifically called up under other laws or regulations.

MSES mapping does not determine whether state or local development assessment is required. For state assessment triggers refer to the Development Assessment Mapping System (DAMS). For local assessment triggers, refer to the relevant local planning scheme.

The Queensland Government's "Method for mapping - matters of state environmental significance can be downloaded from:

http://www.ehp.qld.gov.au/land/natural-resource/method-mapping-mses.html .

Appendix 2 - Source Data

The datasets listed below are available on request from:

http://qldspatial.information.qld.gov.au/catalogue/custom/index.page

- Matters of State environmental significance

Note: MSES mapping is not based on new or unique data. The primary mapping product draws data from a number of underlying environment databases and geo-referenced information sources. MSES mapping is a versioned product that is updated generally on a twice-yearly basis to incorporate the changes to underlying data sources. Several components of MSES mapping made for the current version may differ from the current underlying data sources. To ensure accuracy, or proper representation of MSES values, it is strongly recommended that users refer to the underlying data sources and review the current definition of MSES in the State Planning Policy, before applying the MSES mapping.

Individual MSES layers can be attributed to the following source data available at QSpatial:

MSES layers	**current QSpatial data (http://qspatial.information.qld.gov.au)**
Protected Areas-Estates, Nature Refuges, Special Wildlife Reserves	- Protected areas of Queensland - Nature Refuges - Queensland - Special Wildlife Reserves- Queensland
Marine Park-Highly Protected Zones	Moreton Bay marine park zoning 2008
Fish Habitat Areas	Queensland fish habitat areas
Strategic Environmental Areas-designated	Regional Planning Interests Act - Strategic Environmental Areas
HES wetlands	Map of Queensland Wetland Environmental Values
Wetlands in HEV waters	HEV waters: - EPP Water intent for waters Source Wetlands: - Queensland Wetland Mapping (Current version 5) Source Watercourses: - Vegetation management watercourse and drainage feature map (1:100000 and 1:250000)
Wildlife habitat (threatened and special least concern)	-WildNet database species records - habitat suitability models (various) - SEQ koala habitat areas under the Koala Conservation Plan 2019
VMA regulated regional ecosystems	Vegetation management regional ecosystem and remnant map
VMA Essential Habitat	Vegetation management - essential habitat map
VMA Wetlands	Vegetation management wetlands map
Legally secured offsets	Vegetation Management Act property maps of assessable vegetation. For offset register data-contact DETSI
Regulated Vegetation Map	Vegetation management - regulated vegetation management map

Appendix 3 - Acronyms and Abbreviations

AOI	- Area of Interest
DETSI	- Department of the Environment, Tourism, Science and Innovation
EP Act	- Environmental Protection Act 1994
EPP	- Environmental Protection Policy
GDA2020	- Geocentric Datum of Australia 2020
GEM	- General Environmental Matters
GIS	- Geographic Information System
MSES	- Matters of State Environmental Significance
NCA	- Nature Conservation Act 1992
RE	- Regional Ecosystem
SPP	- State Planning Policy
VMA	- Vegetation Management Act 1999

Appendix E: Water Resources Impact Assessment Report

Klohn Crippen Berger

Santos

Santos Roma Phase 7-7B-SD20 (ATP2053)

Water Resources Impact Assessment to support Environmental Authority Application

Final Rev 00a

ISO 9001 14001 45001

DX70010A03

February 2025

18 February 2025

Santos
32 Turbot Street
Brisbane, QLD
4000

Alex Clarke
Senior Environmental Advisor

Dear Mr. Clarke:

Santos Roma Phase 7-7B-SD20 (ATP 2053) Water Resources Impact Assessment to support Environmental Authority Application
Final Rev00a

KCB Australia Pty Ltd (KCB) is pleased to provide this Final Water Assessment Report to Santos to support the Environmental Authority application to convert ATP 2053 to a Petroleum Lease (PL). Should you have any queries regarding this document, please do not hesitate to contact the undersigned on SLabuschagne@klohn.com or +61 7 3004 0237.

Yours truly,

KCB AUSTRALIA PTY LTD.



Simone Labuschagne M.Sc Pr.Sci.Nat
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EXECUTIVE SUMMARY

Santos and its joint venture partners are proposing a new gas field development located in central-eastern Queensland to supply natural gas to commercial markets. The proposed development will be known as the 'Santos Roma Phase 7-7B-SD20 Development' (hereafter referred to as the Project).

The Project will involve the progressive construction, operation, decommissioning and rehabilitation of up to 24 coal seam gas (CSG) wells, gas and water gathering flowlines and access track infrastructure in petroleum exploration tenure Authority to Prospect (ATP) 2053 (hereafter referred to as the Project Area).

Petroleum exploration activities undertaken by Santos in the Project Area to date include drilling and completion of 5 CSG appraisal wells and construction of associated infrastructure in 2022-2024. These activities are authorised under existing approved Environmental Authority (EA) 0002052. The Project will include the construction/operation of up to 24 CSG wells and their connection to existing approved gas and water gathering lines. The existing 5 wells form part of the proposed 24 CSG wells. Santos is seeking a new EA under the *Environmental Protection Act 1994* (State of Queensland 2024d) to convert the Project Area from an ATP to a new Petroleum Lease (PL) to authorise commercial gas production activities.

In support of the EA application, a water assessment for the Project has been completed and the outcomes of the assessment are presented in this report. The key findings from the assessment are summarised below.

Description of the Project

The Project Area covers approximately 13 km^2 of land located approximately 5 km east of the regional township of Wallumbilla. The project is wholly surrounded by Santos operated Petroleum Leases (PLs) 281, 282, 315, 318 and 1020, authorised under existing *Environment Protection and Biodiversity Conservation Act* (EPBC Act) approvals (EPBC Numbers 2008/4059 and 2012/6615, respectively) and EAs (EPPG00898213 and EPPG00662213), in which Santos is approved to construct/operate up to 4,401 CSG wells.

The Project will include the construction/operation of up to 24 CSG wells and their connection to gas and water gathering lines. CSG and water produced from the Project Area will be sent to existing approved centralised gas and water storage / processing and gas compression facilities located on adjacent Santos owned and operated petroleum tenures. Petroleum activities undertaken on adjacent tenures are authorised under existing EPBC Act approvals and Queensland EAs (as stated above).

Site Conceptualisation

Surface Water Context

The Project Area is located in the upper reaches of the Balonne River sub-basin, which is part of the wider Condamine-Balonne Basin). Key watercourses within the Project Area include Washpool Creek and Middle Creek which are tributaries of Wallumbilla Creek. Watercourse flows in the Project Area are characteristically ephemeral and typically only flow during and immediately following significant rainfall events.

This is a consequence of the Project Area being in the uppermost reaches of the catchment, with limited runoff area. There are no identified third-party surface water users in the vicinity of the Project.

Groundwater Context and Groundwater Dependent Assets

The gas target formation for the Project is the Walloon Coal Measures (WCM) of the Surat Basin. The WCM occur locally at depths greater than 650 meters below ground level (mbGL). The Surat Basin forms part of the Great Artesian Basin (GAB), which comprises several aquifers and aquitards.

Groundwater use in the vicinity (25 km) of the Project is predominately associated with the Mooga Sandstone and the Orallo Formation, followed by the Gubberamunda Sandstone. Most are used for stock and domestic purposes, with 368 water supply bores identified within 25 km of the Project Area. Potential Groundwater Dependent Ecosystems (GDEs) within the Project Area include potential terrestrial GDEs and ephemeral wetlands associated with the surficial deposits (alluvium and Tertiary deposits). There are no spring vents or complexes within 25 km of the Project Area.

Connectivity Between the Alluvium and Underlying Surat Basin Units

Surficial deposits are not recognised to be connected to the Surat Basin units in the Project Area. Surficial deposits in the Project Area are immediately underlain by a tight aquitard (the Doncaster Member of the Wallumbilla Formation) and are vertically separated from the GAB aquifers by thick sequences of several other tight aquitards and partial aquifers. The Mooga Sandstone, the uppermost regional aquifer in the Project Area, is situated at a depth greater than 120 mbGL in the vicinity of the Project. The presence of thick sequences of aquitards further serves to limit the propagation of drawdown from the WCM into the overlying and underlying aquifers.

Potential impacts that may result from Project activities to the hydrological system are summarised below.

Impact Assessment

The Project is located within the Surat Cumulative Management Area (CMA), which was declared in 2011. The Office of Groundwater Impact Assessment (OGIA) was established under the *Water Act 2000* and is responsible for predicting regional impacts on water pressures in aquifers, developing water monitoring and spring management strategies; and assigning responsibility to individual petroleum tenure holders for implementing specific parts of the strategies within the Surat CMA. These predictions, strategies and responsibilities are set out in the Surat CMA Underground Water Impact Report (UWIR), prepared, refined, and maintained by OGIA.

Outputs from the Surat CMA numerical model have been used to predict drawdown impacts to groundwater as a result of the Project. Based on the information provided by Santos and for the purpose of assessing potential impact of CSG water extraction on groundwater resources, OGIA have modelled a Project only scenario, which includes only CSG water production from the Project, and a Cumulative scenario, which includes the simulation of all current and proposed developments (including reasonably foreseeable Santos developments ATPs 1187 and 2052).

Potential impacts to water-dependent assets have been considered with respect to the Queensland Water Act 2000 trigger threshold for springs (0.2 m drawdown) and bores (5 m drawdown in consolidated aquifer; 2 m drawdown in unconsolidated aquifer) using the predicted drawdown for both the Project only and Cumulative scenarios:

- For the Project only scenario, the predicted long-term drawdown impacts associated with the Project are limited to the Springbok Sandstone, the WCM and the Durabilla Formation, located at depths greater than 500 mbGL in the Project Area.
- The Cumulative scenario drawdown results indicate drawdown within the Westbourne Formation, Springbok Sandstone, WCM and Durabilla Formation, located at depths greater than 470 mbGL in the Project Area.
- The Cumulative scenario predicts drawdown greater that 0.2 m in outcropping geological units (Bungil Formation, Mooga Sandstone and Orallo Formation) in an area more than 12 km geologically up-dip and to the north of the Project Area. This drawdown is not associated with the proposed Project but is rather associated with the water production from neighbouring CSG developments operating on tenures located closer to these outcropping units.

This water assessment shows that exceedance of the Water Act 2000 water level trigger / Joint Industry Framework (JIF) GDE risk thresholds is not anticipated for this Project:

- Surficial deposits are not recognised to be connected to the Surat Basin units in the Project Area. There is no predicted Project only drawdown in these surficial deposits. The Project was assessed to not have a significant impact on GDEs.
- Bore triggers are not predicted to be exceeded as a result of the Project only or Cumulative scenario activities.
- Notable wetlands, spring vents or spring complexes are not predicted to be impacted. The Project only contribution to the predicted Cumulative scenario drawdown for watercourse springs is assessed to be negligible.
- Proposed activities do not include planned direct abstraction from, or discharges to, watercourses. Impacts on surface water users, environmental values and spiritual values are not anticipated.
- The use of chemicals poses a low to insignificant risk following adoption of the appropriate standards and implementation of avoidance, mitigation, management and monitoring measures as proposed by Santos.

Avoidance, Mitigation and Management

Santos will adhere to any relevant EA conditions as well as mandatory requirements and guidelines, including the '*Code of Practice for the construction and abandonment of petroleum wells, and associated bores in Queensland Version 2'* (State of Queensland 2019a) applicable Australian Standards for storing and handling applicable materials, *'Manual for Assessing Consequence Categories and Hydraulic Performance of Structures'* (DESI 2024), and *'Streamlined Model Conditions for Petroleum Activities'* (State of Queensland 2024k).

In additional, Santos have developed a comprehensive set of management documents, including an Environmental Management Plan (EMP) (Santos 2024a), with the objective to achieve ongoing environmental compliance with regulatory requirements and to facilitate implementation of best practice environmental management strategies. The EMP includes a set of supporting Environmental Control Plans (ECPs) that detail management actions, responsibility and timing relating to potential impacts.

CSG development on tenures surrounding the Project comprises up to 4,401 CSG wells, which are authorised under existing EPBC Act and EA approvals. These Projects are conditional to the JIF framework (Australian Government 2021). The application of the JIF framework to surrounding development provides comfort that defined environmental outcomes for groundwater (as defined in the JIF) will be achieved.

Monitoring and Reporting

Groundwater monitoring will be undertaken in accordance with the requirements provided as part of the UWIR Water Monitoring Strategy (WMS) (OGIA 2021a), and Santos's Eastern Queensland *Stimulation Impact Monitoring Program* (SIMP) (Santos 2021) and any relevant EA conditions. Sixteen (16) nested WMS UWIR monitoring bores are present within 25 km of the Project Area. The SIMP provides procedures for baseline groundwater bore assessment, stimulation fluid and flowback monitoring, and post-stimulation groundwater bore monitoring.

The EMP for the Project includes ECP 3, which details management actions, responsibility and timing relating to activities that have the potential to impact water resources.

Produced water will be monitored in accordance with any relevant EA conditions, the SIMP and the EMP (Santos 2024a).

Santos will undertake all reporting in accordance with relevant State and Commonwealth legislation and approval conditions, including OGIA as part of the UWIR requirements.

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CLARIFICATIONS REGARDING THIS REPORT

This report is an instrument of service of Klohn Crippen Berger (KCB). The report has been prepared for the use of Santos (Client) for the specific application to support the Environmental Authority application for Roma Phase 7-7B-SD20 (ATP 2053), and it may not be relied upon by any other party without KCB's written consent.

KCB has prepared this report in a manner consistent with the level of care, skill and diligence ordinarily provided by members of the same profession for projects of a similar nature at the time and place the services were rendered; however, the use of this report will be at the user's sole risk absolutely and in all respects, and KCB makes no warranty, express or implied.

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1. The report is to be read in full, with sections or parts of the report relied upon in the context of the whole report.
2. The Executive Summary is a selection of key elements of the report. It does not include details needed for the proper application of the findings and recommendations in the report.
3. The observations, findings and conclusions in this report are based on observed factual data and conditions that existed at the time of the work and should not be relied upon to precisely represent conditions at any other time.
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6. This report is electronically signed and sealed and its electronic form is considered the original. A printed version of the original can be relied upon as a true copy when supplied by the author or when printed from its original electronic file.

TABLE OF ABBREVIATIONS

AEP	Annual exceedance probability
AGDE	Aquatic Groundwater Dependent Ecosystem
ALUM	Australian Land Use and Management
ANZECC	Australian and New Zealand Conservation Council
API	American Petroleum Institute
APLNG	Australia Pacific LNG Pty Limited
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ATP	Authority to Prospect
ATW	Authority to Work
CMA	Cumulative Management Area
Code of Practice	Code of Practice for the construction and abandonment of petroleum wells, and associated bores in Queensland Version 2
Constraints Protocol	Roma Phase 7-7B-SD20 Environmental Protocol for Constraints Planning and Field Development
CRAF	Chemical Risk Assessment Framework
CRAR	Chemical Risk Assessment Report
CRD	Cumulative rainfall departure
CSG	Coal seam gas
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DEE	Department of the Environment and Energy
DEHP	Department of Environment and Heritage Protection (now DETSI)
DESI	Department of Environment, Science and Innovation (now DETSI)
DETSI	Department of Environment, Tourism, Science and Innovation
DNRME	Department of Natural Resources, Mines, and Energy's
DSITI	Department of Science, Information Technology, and Innovation
DST	Drill stem tests
EA	Environmental authority
EC	Electrical Conductivity
ECP	Environmental Control Plan
EMP	Environmental Management Plan
EOW	End of Waste
EP Act	Environmental Protection Act 1994

EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
EP Policy	Environmental Protection (Water and Wetland Biodiversity) Policy 2019
EP Reg	Environmental Protection Regulation 2019
ERA	Environmentally relevant activity
ESA	Environmentally sensitive areas
EV	Environmental Value
GAB	Great Artesian Basin
GDEs	Groundwater dependent ecosystems
GLNG GFD	Gladstone Liquified Natural Gas Field Development
GWDB	Queensland Groundwater Bore Database
HEV	High Ecological Value
HFRA	Hydraulic Fracturing Risk Assessment
IESC	Independent Expert Scientific Committee on Unconventional Gas Development and Large Coal Mining Development
JIF	Joint Industry Framework
KCB	Klohn Crippen Berger
mAHD	metres above Australian Height Datum
mbGL	metres below Ground Level
MNES	Matters of national environmental significance
MSES	Matters of state environmental significance
NICNAS	National Industrial Chemicals Notification and Assessment Scheme
NSMC	Null space Monte Carlo
NWQMS	National Water Quality Management Strategy
OECD	Organisation for Economic Co-operation and Development
OGIA	Office of Groundwater Impact Assessment
P&G	Petroleum and Gas
P&G Act	Petroleum and Gas (Production and Safety) Act 2004
PL	Petroleum Lease
QFAO	Queensland Floodplain Assessment Overlay
QWC	Queensland Water Commission
RDMW	Regional Development, Manufacturing and Water
RE	Regional ecosystem
RMP	Rehabilitation Monitoring Plan
RN	Registered number

ROP	Resource Operations Plan
SDS	Safety Data Sheets
SSMP	Significant Species Management Plan
SI CSG Guideline 1.1	Significant Impact Guidelines 1.1: Matters of National Environmental Significance
SI CSG Guideline 1.3	Significant Impact Guidelines 1.3: Coal seam gas and large coal mining developments – impacts on water resources
SIMP	Stimulation Impact Monitoring Program
The Manual	The Manual for Assessing Consequence Categories and Hydraulic Performance of Structures
TDS	Total Dissolved Solids
TDGE	Terrestrial Groundwater Dependent Ecosystem
UWIR	Underground Water Impact Report
Water Act	Water Act 2000
WCM	Walloon Coal Measures
WMS	Water Monitoring Strategy
WMP	Water Management Plan
WQO	Water quality objectives

1 INTRODUCTION

Santos and its joint venture partners are proposing a new gas field development located in central-eastern Queensland to supply natural gas to commercial markets. The proposed development will be known as the 'Santos Roma Phase 7-7B-SD20 Development' (hereafter referred to as the Project).

The Project will involve the progressive construction, operation, decommissioning and rehabilitation of up to 24 coal seam gas (CSG) wells, gas and water gathering flowlines and access track infrastructure in petroleum exploration tenure Authority to Prospect (ATP) 2053 (hereafter referred to as the Project Area).

KCB Australia Pty Ltd (KCB) has been commissioned by Santos to undertake an assessment of potential water-related impacts of proposed coal seam gas (CSG) production associated with the Project.

1.1 Project Background

The Project is located approximately 45 km east of the township of Roma in the central part of the Surat Basin, Queensland as shown in Figure 1.1. The Project Area is surrounded on all sides by the existing Santos 'Roma' gas field, which includes Petroleum Leases (PLs) 1020, 281, 282, 315, 318.

The Santos Roma gas field and abovementioned PLs are owned and operated by Santos as part of the existing approved Gladstone Liquified Natural Gas Field Development Project (GLNG GFD) (EPBC Numbers 2008/4059 and 2012/6615 and Queensland Environmental Authority (EAs) (EPPG00898213 and EPPG00662213). The Santos GLNG GFD Project consists of 35 petroleum tenures and an authorisation to produce gas from up to 4,401 CSG wells. The Project Area was not included in the scope of the Santos GLNG GFD Project because Santos did not own the tenure at the time of GLNG GFD project application in 2012. ATP 2053 was granted to Santos in 2020. The intent of the Project is to integrate it with existing Santos Roma / GLNG GFD Project gas and water processing infrastructure. Santos is the authorised holder and operator of the Project Area.

Petroleum exploration activities undertaken by Santos in the Project Area to date include drilling and completion of 5 CSG appraisal wells and construction of associated infrastructure in 2022-2024. These activities are authorised under existing approved EA 0002052. The Project will include the construction/operation of up to 24 CSG wells and their connection to existing approved gas and water gathering lines. The existing 5 wells form part of the proposed 24 CSG wells. Santos is seeking a new EA under the *Environmental Protection Act 1994* (EP Act) (State of Queensland 2024d) to convert the Project Area from an ATP to a PL and to authorise commercial gas production activities.

To enable commercial gas production activities within the Project Area, Santos will apply for new PL, granted under Chapter 2 of the *Petroleum and Gas (Production and Safety) Act 2004* (P&G Act) (State of Queensland 2020j) to replace the existing ATP. Further, to authorise petroleum production activities on the new PL, Santos will also need to apply for a new EA under the EP Act.

Further detail on project infrastructure is provided in Section 3.

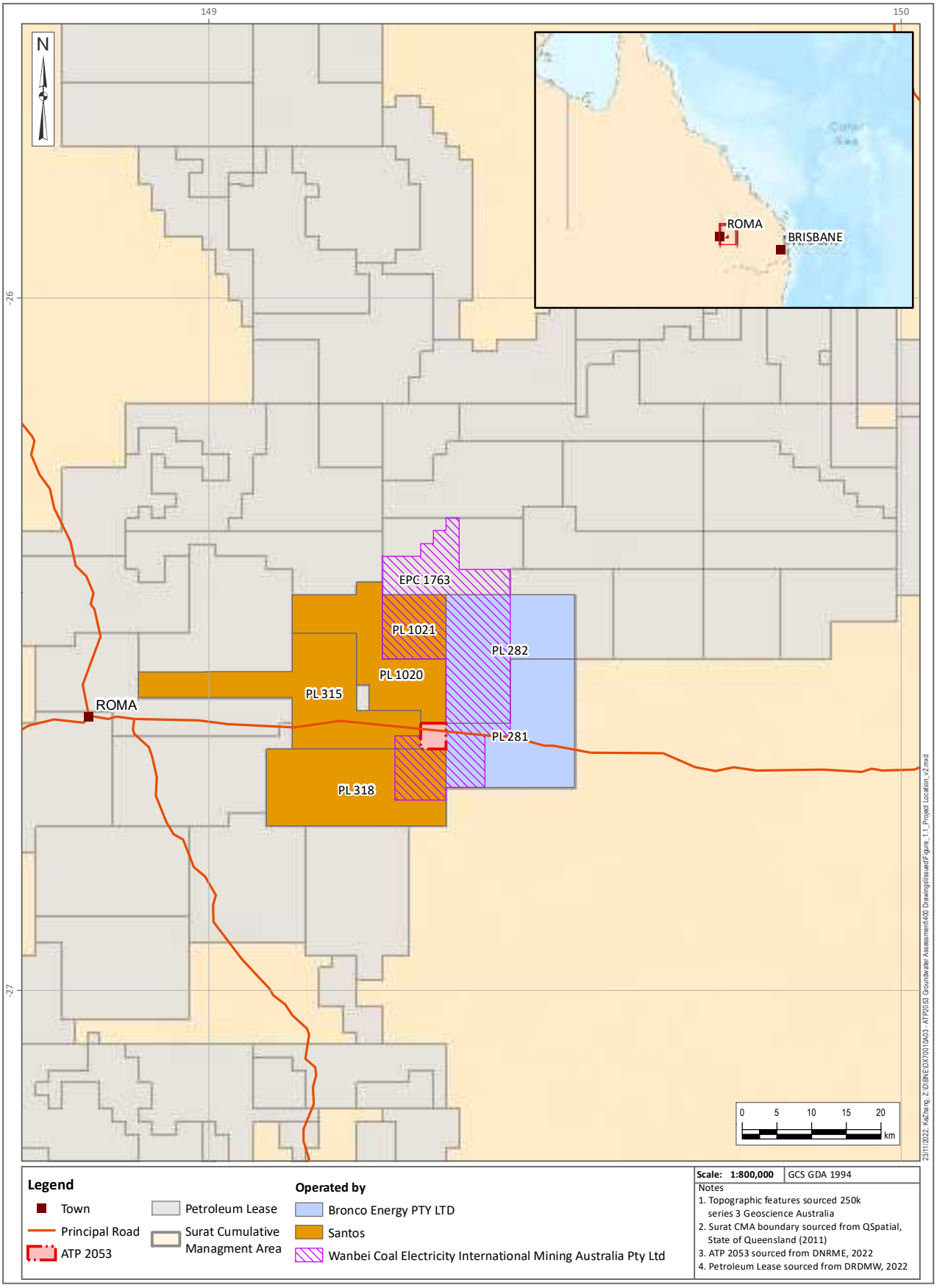


Figure 1.1 Project Location

1.2 Report Structure

This report has been prepared to accompany the EA application to the Queensland Department of Environment, Tourism, Science, and Innovation (DETSI) and is provided as supporting information with content related to groundwater and surface water, including description of baseline conditions and impact assessments, which has been undertaken in accordance with relevant legislation and guidelines (Section 2).

Section 1: Introduction to the Project, report purpose, and structure.

Section 2: Regulatory Framework, including an overview of the relevant Queensland and Commonwealth legislation related to water and CSG development / production.

Section 3: Project Description.

Section 4: Methodology for the assessment of the existing environment and environmental values; and impact assessment approach.

Section 5: Existing Environment, including a review of the topography, climate, land use.

Section 6: Hydrological setting and summary of surface water receptors and users.

Section 7: Hydrogeological setting and summary of groundwater receptors and users.

Section 8: Numerical Groundwater Modelling, including predicted extent of groundwater drawdown.

Section 9: Impact Assessment, which includes both Project only and Cumulative impacts.

Section 10: Mitigation, Management, and Monitoring.

2 REGULATORY FRAMEWORK

This water report has been prepared with consideration to key policies and legislation from the Commonwealth of Australia and the State of Queensland. This section provides an overview of applicable legislation / policies to this assessment.

2.1 Commonwealth Legislation

2.1.1 Environment Protection and Conservation Act 1999

The EPBC Act (Commonwealth of Australia 2024) is the central piece of environmental legislation at the Commonwealth level. It provides for the protection of environmental values, including matters of national environmental significance (MNES). Actions that are likely to have a significant impact on MNES are subject to the assessment and approval process under this Act. Water resources in relation to large coal mining and CSG development projects are a MNES. The Project constitutes a CSG development under the EPBC Act, and as such is being referred to the DCCEEW.

The regulatory guideline relevant to the Project, developed from the amendment to the EPBC Act identifying water resources as being a MNES, is the *Significant impact guidelines 1.3: Coal seam gas and large coal mining developments – impacts on water resources* (SI CSG Guideline 1.3) (Commonwealth of Australia 2022).

2.2 State Legislation

2.2.1 Petroleum and Gas (Production and Safety) Act 2004

The *Petroleum and Gas (Production and Safety) Act 2004* (P&G Act) (State of Queensland 2020j) is an Act relevant to exploring for, recovering and transporting by pipeline, petroleum and fuel gas, and ensuring the safe and efficient undertaking of those activities. The key purpose of this Act is to facilitate and regulate the undertaking of responsible petroleum activities and the development of a safe, efficient, and viable petroleum and fuel gas industry.

The P&G Act identifies underground water rights for petroleum tenures, and states that the holder of a petroleum tenure may take or interfere with underground water in the area of the tenure if the taking or interference happens during the course of, or results from, the carrying out of another authorised activity for the tenure.

The P&G Act prescribes mandatory compliance with the Queensland Department of Natural Resources, Mines, and Energy's (DNRME) *Code of Practice for the construction and abandonment* of petroleum wells, and associated bores in Queensland Version 2 (Code of Practice) (State of Queensland 2019a). The purpose of this code is to ensure that all petroleum wells, CSG wells and associated bores are constructed, maintained and abandoned to a minimum acceptable standard resulting in long-term well integrity, containment of petroleum and gas (P&G) and the protection of groundwater resources.

2.2.2 Water Act 2000

General Purpose of the Water Act

The Water Act 2000 (State of Queensland 2024m) is an Act to provide for the sustainable management of water and the management of impacts on underground water, among other purposes. This Act provides a framework for:

- The sustainable management of Queensland's water resources by establishing a system for the planning, allocation, and use of water;
- The sustainable and secure water supply and demand management for designated regions;
- The management of impacts on underground water caused by the exercise of underground water rights by the resource sector; and
- The effective operation of water authorities.

This Act covers water in a watercourse, lake or spring, underground water (or groundwater), overland flow water, or water that has been collected in a dam.

Water Act and Petroleum and Gas Activities

The Water Act 2000 provides for the management of the impacts on underground water caused by the exercise of underground water rights by resource tenure holders, which are regulated under the P&G Act 2004. The Act also outlines the requirements for make good agreements, associated with the impacts to underground water.

Chapter 3 of the Water Act 2000 has a stated purpose to provide for the management of impacts on underground water caused by the exercise of underground water rights by resource tenure holders, which includes petroleum tenure holders. To achieve the stated purpose, a regulatory framework is provided which requires:

- Resource tenure holders to monitor and assess the impacts of the exercise of underground water rights on water bores and to enter into make good agreements with the owners of the groundwater bores as necessary;
- The preparation of Underground Water Impact Reports (UWIR) that establish underground water obligations, including obligations to monitor and manage impacts on aquifers and springs; and
- Managing the cumulative impacts of the activities of two or more resource tenure holders' underground water rights on underground water.

Under this regulatory framework, where there is an area of concentrated development, a CMA can be declared. The Project Area is located within the Surat CMA, which was declared by the Queensland Government in 2011. The Office of Groundwater Impact Assessment (OGIA) was established under the Water Act 2000 and is responsible for predicting regional impacts on water pressures in aquifers; developing water monitoring and spring management strategies; and, assigning responsibility to individual petroleum tenure holders for implementing specific parts of the strategies within CMAs. These predictions, strategies and responsibilities are set out in the Surat CMA UWIR, prepared, and maintained by OGIA.

The Surat CMA UWIR was first published by Queensland Water Commission (QWC) in 2012 (QWC 2012a) to assess the cumulative impacts to the Surat and southern Bowen Basin, as a result of the expansion of CSG production by multiple, adjacent developers. A second and third UWIR was published by OGIA in 2016 (OGIA 2016c) and 2019 (OGIA 2019a), with the most recent coming into effect in May 2022 (OGIA 2021g).

OGIA also provide tenure holders with their obligations to comply with the Surat CMA UWIR Water Monitoring Strategy (WMS) (OGIA 2021a). The WMS includes:

- Installation, maintenance and collection of data from the groundwater monitoring network including water pressure and water chemistry;
- Monitoring of associated water volumes;
- A program for baseline assessment; and
- Tenure holder reporting of the data and activities relating to the above components.

OGIA has also provided Santos with groundwater modelling outputs from the 2021 UWIR numerical model to inform this assessment, which is further detailed in Section 8.

Trigger Thresholds

Under Section 362 of the Water Act 2000, a bore trigger threshold, for a consolidated aquifer, of 5 m applies (2 m for an unconsolidated aquifer). The 5 m threshold represents the maximum allowable groundwater level decline in a groundwater bore, due to petroleum tenure holders' activities, prior to triggering an investigation into the water level decline.

Under Section 379 of the Water Act 2000 a spring trigger threshold for an aquifer applies. This includes vent springs / complexes and watercourse spring (i.e., gaining streams). The threshold value is 0.2 m and represents the maximum allowable decline in the water level of an aquifer in connection with a spring, at the spring location, prior to triggering an investigation into the water level decline. The threshold value may change for an area if a regulation or prescribed threshold exists.

The Joint Industry Framework[1] (JIF) (Australian Government 2021) defines the threshold for aquatic and terrestrial DGEs as consistent with the spring trigger threshold, i.e., a drawdown exceeding 0.2 m at the location of the GDE that is caused by CSG development.

2.2.3 Environmental Protection Act 1994

The Environmental Protection Act 1994 (EP Act) (State of Queensland 2024d) is an Act with the objective to protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (ecologically sustainable development).

The EP Act states that 'to carry out an environmentally relevant activity (ERA) an environmental authority (EA) is required'. A resource activity, specifically a petroleum activity, is defined as an ERA.

[1] The purpose of the JIF is to establish a consistent post-approval framework for the management of impacts on groundwater caused by CSG developments within the Surat Cumulative Management Area (CMA) that are subject to approvals under the EPBC Act.

Environmental Authority

The Project approval status is discussed in Section 1.1 and 3.3. Santos is seeking a new EA under the *Environmental Protection Act 1994* to convert the Project Area from an ATP to a PL and to authorise commercial gas production activities.

The application must include the following items as detailed in Section 125 (Requirements for application generally) of the Act:

- Include an assessment of the likely impact of each relevant activity on the environmental values, including:
  - A description of the environmental values likely to be affected by each relevant activity;
  - Details of any emissions or releases likely to be generated by each relevant activity;
  - A description of the risk and likely magnitude of impacts on the environmental values;
  - Details of the management practices proposed to be implemented to prevent or minimise adverse impacts; and
  - Details of how the land, the subject of the application, will be rehabilitated after each relevant activity ceases.

Under the *Environmental Protection Act 1994*, streamlined model conditions for petroleum activities have been developed for incorporation into EA's (State of Queensland 2024l). The streamlined conditions are based on acceptable management approaches and constraints to protect environmental values.

2.2.3.1 Regulations and Policies Under the EP Act

Environmental Protection Regulation 2019

The *Environmental Protection Regulation 2019* (EP Reg)(State of Queensland 2023) is a subordinate legislation which supports the operation of the EP Act and prescribes the detail for the processes contained in the Act.

Section 28 of the EP Reg is relevant to this application and includes the documents prescribed for an application for an EA for a CSG activity.

Environmental Protection (Water and Wetland Biodiversity) Policy 2019

The purpose of the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* (State of Queensland 2019d) is to achieve the object of the EP Act in relation to waters and wetlands; protecting Queensland's water environment while allowing for development that is ecologically sustainable.

Coal Seam Gas Water Management Policy 2012

The primary objective of the *Coal Seam Gas Water Management Policy 2012* (State of Queensland 2012) relates to the management and use of CSG water under the EP Act. The role of the policy is to:

- Clearly state the government's position on the management and use of CSG water;

- Guide CSG operators in managing CSG water under their EA; and
- Ensure community understanding about the government's preferred approach to managing CSG water.

The *End of Waste Code Irrigation of Associated Water* (including coal seam gas water) (State of Queensland 2019c) and *End of Waste Code Associated Water* (including coal seam gas water) (State of Queensland 2024b) support the objective of the *Coal Seam Gas Water Management Policy 2012*, by specifying the standards required to be met where associated water is to be used for beneficial purposes.

2.2.4 Water Supply (Safety and Reliability) Act 2008

The *Water Supply (Safety and Reliability) Act 2008* (State of Queensland 2017c) is an Act that provides for the safety and reliability of water supply. The purpose of this Act is achieved primarily by providing:

- A regulatory framework for providing water and sewerage services in the State, including functions and powers of service providers;
- A regulatory framework for providing recycled water and drinking water quality, primarily for protecting public health;
- The regulation of referable dams;
- Flood mitigation responsibilities; and
- The protection of the interests of customers of service providers.

The key component of the Act relevant to the Project relates to the regulation of referable dams.

2.2.5 Sustainable Planning Act 2009

The *Sustainable Planning Act 2009* (State of Queensland 2017a) has a purpose to achieve ecological sustainability by managing the process by which development takes place, including ensuring the process is accountable, effective and efficient and delivers sustainable outcomes; managing the effects of development on the environment, including managing the use of premises; and continuing the coordination and integration of planning at the local, regional and State levels.

This act is relevant to the Project in terms of the proposed infrastructure associated with CSG production.

2.3 Environmental Values and Water Resource Management

2.3.1 Overview

The EP Act defines an Environmental Value (EV) as:

- A quality or physical characteristic of the environment that is conducive to ecological health or public amenity or safety; or
- Another quality of the environment identified and declared to be an environmental value under an environmental protection policy or regulation.

Under the EP Act, the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* (EP Policy) is established as subordinate legislation to achieve the objective of the Act in relation to Queensland waters. The purpose of the EP Policy is achieved by:

- Identifying EVs and management goals for Queensland waters;
- Stating water quality guidelines and water quality objectives to enhance or protect the environmental values;
- Providing a framework for making consistent, equitable and informed decisions about Queensland waters; and
- Monitoring and reporting on the condition of Queensland waters.

2.3.2 Surface and Groundwater Environmental Values

The EP Policy for the Maranoa-Balonne Rivers Basin (State of Queensland 2020a) provides defined EVs and water quality objectives (WQOs) for surface and groundwater under Schedule 1 of the policy. The Project Area is located within Maranoa-Balonne Rivers sub-basin in the Queensland Murray-Darling and Bulloo Basins. EVs for the Maranoa-Balonne Rivers sub-basin are presented in Table 2.1.

Table 2.1 Environmental Values for the Maranoa-Balonne Rivers Basin Surface Waters within the vicinity of the Project Area (State of Queensland 2020a)

Water	Sub-catchment	Environmental Values											
		Aquatic Ecosystem	Irrigation	Farm Supply / Use	Stock Water	Aquaculture	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Drinking Water	Industrial Use	Cultural, Spiritual, And Ceremonial Values
Maranoa and Balonne Rivers Basin (WQ4222)													
Surface Water	Bungil Creek	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Yuleba Creek	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓

✓ means the EV is selected for protection. Blank indicates that the EV is not chosen for protection.

EVs have also been prepared for the Maranoa-Balonne River Basin groundwater systems (State of Queensland 2020a). The EVs have been developed for alluvial and fractured rock systems, and the deposits overlying the Great Artesian Basin (GAB). Units underlying the GAB are also considered.

Table 2.2 presents the draft groundwater EVs for each of the categories outlined in the policy (State of Queensland 2020b; 2020c; 2020d; 2020e; 2020f; 2020g; 2020h; 2020i).

Table 2.2 Environmental Values for the Maranoa-Balonne Rivers Basin Groundwater Within the Vicinity of the Project Area

Water	Environmental Values											
	Aquatic Ecosystem	Irrigation	Farm Supply / Use	Stock Water	Aquaculture	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Drinking Water	Industrial Use	Cultural, Spiritual, and Ceremonial Values
Queensland Murray-Darling and Bulloo Basins Groundwater (GWQ41461) – Alluvial Zones												
Upper Balonne	✓		✓	✓						✓		✓
Sediments Overlying GAB Zones (GWQ4163)												
Weathered Alluvium	✓	✓	✓	✓	✓					✓	✓	✓
Upper GAB Zone Central (GWQ4164)												
Central Upper Cretaceous Aquitard	✓	✓	✓	✓						✓	✓	✓
Main GAB Aquitard Zone (GWQ4165)												
Eastern Wallumbilla Outcrop	✓		✓	✓						✓		✓
Mid GAB Aquifer Zones (GWQ4166)												
Central Mooga and Orallo Outcrops	✓		✓	✓						✓		✓
North Wallumbilla Bungil and Mooga (continued)	✓		✓	✓						✓		✓
Northern Surat Thickest Bungil and Mooga	✓	✓	✓	✓						✓		✓
Lower GAB Zone (GWQ4167)												
Central Surat Springbok Area (continued)	✓	✓	✓	✓	✓					✓		✓
Basal GAB Zones (WQ4168)												
Eastern Central Area	✓	✓	✓	✓						✓	✓	✓
Earlier Basins Partially Underlying the GAB Zones (GWQ4169)												
Bowen Basin (continued)	✓			✓								✓

✓ denotes the EV is selected for protection. Blank indicates that the EV is not chosen for protection.

2.3.3 Water Quality Objectives – Groundwater and Surface Water

Water Quality Objectives (WQO) to protect the EVs are defined in *The Environmental Protection (Water and Wetland Biodiversity) Policy 2019 - Maranoa-Balonne Rivers Basin Environmental Values and Water Quality Objectives* (State of Queensland 2020a) and *The Environmental Protection (Water and Wetland Biodiversity) Policy 2019 - Queensland Murray-Darling and Bulloo Rivers Basins Groundwater Environmental Values and Water Quality Objectives* (State of Queensland 2020a). A summary of the WQOs in the Maranoa-Balonne Rivers Basin are provided below:

- Groundwater:
  - WQOs for aquatic ecosystems applicable to groundwater where groundwater interacts with surface water, the groundwater quality should not compromise identified EVs and WQOs for those waters.
- Surface Water:
  - Where the aquatic ecosystem has high ecological value the WQO is to maintain the existing water quality, habitat, biota, flow and riparian areas.
  - For Yuleba Creek (gauge 422219A) sub-basin waters the aquatic ecosystem is described as having high ecological value and described as moderately disturbed, and specific water quality guidelines have been produced (Table 3 of State of Queensland 2020).
  - For the protection for human consumption, objectives as per the Australian drinking water guidelines (ADWG) (NHMRC 2011) and Australia New Zealand Food Standards Code.
  - For suitability for industrial use there are no WQOs as water quality requirements vary within the industry.
  - For aquaculture, WQOs are provided (Tables 11-13 of State of Queensland 2020) and should be followed with the ADWG and Australia New Zealand Food Standards Code.
  - For secondary contact and visual recreation, objectives as per NHMRC (2011).
- Surface waters and groundwater:
  - For drinking water, local WQOs exist which relate to before and after water treatment and are based on a number of guidelines / legislation including the ADWG (NHMRC 2011).
  - WQOs to protect or restore indigenous and non-indigenous cultural heritage should be consistent with relevant policies and plans.
  - For irrigation, WQOs exist for metals, pathogens and other indicators in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ 2000).
  - For stock watering, objectives exist for faecal coliforms, total dissolved solids, metals, and other objectives based on guidelines presented in ANZECC & ARMCANZ (2000).
  - For farm use / supply, objectives are as per the guidelines in ANZECC & ARMCANZ (2000).

- For primary contact recreation objectives as per NHMRC (2011) and for freshwater objectives exist for cynobacteria / algae.

2.3.4 Water Resource and Resource Operations Plans

Water Plan (Great Artesian and Other Regional Aquifers) 2017

Groundwater in the Great Artesian Basin is managed within the *Water Plan (Great Artesian Basin and Other Regional Aquifers) 2017* (State of Queensland 2017b), under the Water Act 2000. The purpose of the plan is:

- To define the availability of water in the plan area;
- To provide a framework for sustainably managing water and the taking of water; and
- To identify priorities and mechanisms for dealing with future water requirements.

Water Plan (Condamine and Balonne) 2019

The surface water resource of the Maranoa-Balonne Sub-Basin is managed under the *Queensland Water Resource Plan* framework as part of the Water Plan *(Condamine and Balonne)* (State of Queensland 2019f). The purpose of the plan is to provide a framework for the allocation and sustainable management of surface and overland flow water in the plan area and to meet future water requirements including the protection of natural ecosystems and security of supply to water users as required by the Water Act 2000.

Condamine and Balonne Water Resources Plan 2019

The Project Area falls within the Condamine and Balonne Tributaries Water Management Area and is managed under the *Queensland Water Resource Plan* framework as part of the *Condamine-Balonne Water Resources Plan 2019* (State of Queensland 2019b). The *Queensland Water Resource Plan* was accredited by the Australian Government minister as being consistent with the Basin Plan and commenced on 21 September 2019. The key function of the *Queensland Water Resource Plan* is to provide the operating and environmental management rules and monitoring requirements to resource operations licence holders.

2.4 Application Requirements – Water

Environment Protection Act 1994

Section 126 and 126A of the EP Act outlines the application requirements related to CSG activities.

The requirements of Section 126 relate to the management of CSG water. These are addressed in the Roma Phase 7-7B-SD20 Proposed Produced Water Management Plan (WMP) (WRM 2024).

Section 126A outlines the requirements for applications involving the exercise of underground water requirements. These requirements are outlined in Table 2.3 and include reference to sections of the report where these items are addressed.

Table 2.3 Key *Environmental Protection Act 1994* Statutory Requirements

EP Act Section	Requirement	Reference
126A(2) (a)	The application must also state the following- any proposed exercise of underground water rights during the period in which resource activities will be carried out under the relevant tenure	Section 3
126A(2) (b)	The areas in which underground water rights are proposed to be exercised	Section 3
126A(2) (c)	For each aquifer affected, or likely to be affected, by the exercise of underground rights- ▪ A description of the aquifer; ▪ An analysis of the movement of underground water to and from the aquifer, including how the aquifer interacts with other aquifers and surface water; ▪ A description of the area of the aquifer where the water level is predicted to decline because of the exercise of underground water rights; and ▪ The predicted quantities of water to be taken or interfered with because of the exercise of underground water rights during the period in which resource activities were carried out.	Section 7 Section 3
126A(2) (d)	The environmental values that will, or may, be affected by the exercise of underground water rights and the nature and extent of the impacts on the environmental values;	Section 2, 6, 7 and 9
126A(2) (e)	Any impacts on the quality of groundwater that will, or may, happen because of the exercise of underground water rights during or after the period in which resource activities are carried out;	Section 9
126A(2) (f)	Strategies for avoiding, mitigating or managing the predicted impacts on the environmental values stated for paragraph (d) or the impacts on the quality of groundwater mentioned in paragraph (e).	Section 10

Application Requirements – Guideline

The State of Queensland have published a guideline under the Act for 'Application Requirements for Activities with Impacts to Water' (State of Queensland 2024g), which outlines the information to be provided to support an EA application for activities with impacts to water. The requirements of this guideline have been considered and addressed as part of this assessment.

3 PROJECT DESCRIPTION

3.1 Project Location and Regional Overview

The Project Area covers approximately 13 km^2 of land located 45 km east of the township of Roma and 5 km east of the regional township Wallumbilla, in southeast Queensland. The Project location is provided in Figure 1.1.

A summary of the regional Project setting is provided below, with further details included in the remainder of the report.

- The gas producing targets for the Project are within the Walloon Coal Measures (WCM), of the Middle Jurassic.
- The Project Area is located in the Balonne River sub-basin (within the wider the Condamine-Balonne Basin), and within the Condamine and Balonne Tributaries sub-catchment, which forms part of the larger Queensland Murray-Darling and Bulloo Basins (Section 6).
- Surficial potential groundwater systems within the vicinity of the Project Area include Quaternary deposits associated with Wallumbilla Creek and its tributaries, as well as other unconsolidated Quaternary sediments. Within the Project Area, Cretaceous units are also present at surface (Section 7.1.1).
- Water-dependent assets identified in the Project Area include third-party groundwater bores and potential terrestrial groundwater dependent ecosystems (GDEs) (Section 7.11 and 7.107.11).

Other Developments

The Project Area is located in the vicinity of the other petroleum projects and resource tenures, including:

- Santos owns and operates PLs 281, 282, 315, 318 and 1020 which surround the Project Area on all sides. As discussed in Section 1.1, these PLs are part of the existing Santos Roma gas field and are authorised under existing EPBC Act approvals (EPBC Numbers 2008/4059 and 2012/6615), and Queensland EAs (EPPG00898213 and EPPG00662213). The intent of the Project is to integrate it with existing Santos gas and water processing infrastructure. Santos is the authorised holder and operator of the Project Area.
- Coal exploration (EPC 1763), operated by Wanbei Coal Electricity International Mining Australia Pty Ltd since 2009 is located within the Project and to the northeast and south.
- Other reasonably foreseeable developments further afield and to the east of the Project include Santos owned and operated ATPs 1187, 2052 and 2054.

3.2 Project Components

The Project will involve the progressive construction, operation, decommissioning and rehabilitation of up to 24 CSG wells and associated petroleum activities and infrastructure. Hydraulic fracture stimulation may be used to complete wells as required. Single and multi-well leases are proposed. Construction and commercial gas production is expected to occur from mid-2025. Well development will be phased to optimise gas production.

CSG and water produced from the Project Area will be sent to existing approved centralised gas and water storage / processing and gas compression facilities located on adjacent Santos owned and operated petroleum tenures. As discussed in Section 1.1 and 3.1, petroleum activities on adjacent tenures are authorised under existing EPBC Act approvals and EAs. The Project will include the following components (but not limited to):

- Well leases (single and multi-well leases).
- Water / gas gathering lines, trunklines and pipelines.
- Roads and access tracks.
- Other supporting infrastructure:
  - Temporary water storage tanks;
  - Temporary workers camps;
  - Power and communications lines; and
  - Other incidental and ancillary petroleum activities.

3.3 Project Approval Status

As discussed in Section 1.1, petroleum exploration activities undertaken by Santos in the Project Area to date include drilling and completion of 5 CSG appraisal wells (RM23-21-1, RM23-43-1, RM23-42-1, RM23-41-1 and RM23-46-1) and construction of associated infrastructure in 2022-2024. These activities are authorised under existing approved EA 0002052. The existing 5 wells form part of the proposed 24 CSG wells.

To enable commercial gas production activities within the Project Area, Santos will apply for new PL, granted under Chapter 2 of the P&G Act (State of Queensland 2020j) to replace the existing ATP. Further, to authorise petroleum production activities on the new PL, Santos will also need to apply for a new EA under the EP Act (State of Queensland 2024d).

3.4 Project Activities and Infrastructure

An detailed overview of Project activities is provided in the Roma Phase 7-7B-SD20 Environmental Management Plan (EMP)(Santos 2024a)(Appendix V). Due to the characteristics of the geological formations located within the Project Area, all proposed CSG wells may require hydraulic fracturing to produce commercially viable gas volumes / rates.

3.4.1 CSG Production Wells and Water Production

Groundwater abstraction is required as part of the CSG production process. Groundwater is abstracted (pumped) from production wells to depressurise the target production coal seams. Depressurisation generates gas flow and sustains groundwater flow from the well to maintain the target producing operational pressure for each production well. A summary of the proposed production wells is provided in the following:

- CSG production wells will be drilled and constructed in accordance with the Code of Practice (State of Queensland 2019a). The purpose of this code is to ensure that all petroleum wells, CSG wells and associated bores are constructed, maintained and

abandoned to a minimum acceptable standard resulting in long-term well integrity, containment of petroleum and the protection of groundwater resources.

- A total of 24 wells (two wells are multi-wells comprising two wells each) are proposed to be developed. All wells are anticipated to be commissioned over a period of four months (6 wells per month) (subject to drill rig availability and logistical requirements).
- Hydraulic fracture stimulation will be used to complete wells as required. This will be conducted in accordance with the Code of Practice.
- A risk assessment of chemicals proposed to be used in CSG operations (drilling and completions, and hydraulic fracturing) has been completed for the Project. Refer to the *Chemical Risk Assessment - Santos Roma Phase 7B-SD20 Development* (EHS Support 2024a).
- Subject to relevant approvals, gas production and its associated water extraction will commence from mid-2025.
- The operating life of individual CSG production wells is anticipated to be approximately 30-50 years.

The management of produced water is described in the *Roma Phase 7-7B-SD20 proposed produced water management* (WMP) (WRM 2024) and summarised in this section.

The majority of produced water generated from the Project will be transferred to existing approved Roma gas field water storage (Pickanjinnie and / or Raslie Dams) and treatment facilities located adjacent to the Project Area on PLs 314 and 315 via new and existing water gathering infrastructure.

The Santos Roma gas field, including the abovementioned PLs 314 and 315, and existing water storage and treatment facilities, are owned and operated by Santos as part of the existing approved projects. In future, produced water from the Project Area may potentially be processed elsewhere, subject to environmental approvals.

Site water balances are undertaken for all Project phases at these water management facilities to ensure adequate storage and treatment capacity is available, and this will include consideration of produced water transferred from the Project.

Produced water volumes and rates are predicted using a stochastic reservoir modelling tool which produces probabilistic distributions applied to several key reservoir parameters (i.e. permeability, porosity and net coal). The model predictions generate production profiles (type curves).

These production profiles are used in field development planning to provide a water forecast. Type curves are updated during the life of the Project as more information (e.g. further and refined key reservoir parameters) becomes available.

Figure 3.1 presents the predicted 50th percentile (P50) water production forecast for the Project. Peak water production is predicted to occur in January 2028 at 0.24 ML/day (7.12 ML/month). The total volume of produced water for the duration of the Project is estimated to be 645 ML.

The combined P50 Roma Phase 7-7B-SD20 water production forecast and Roma field water production forecast indicate a peak in December 2027 at 12.43 ML/day (368 ML/month) as shown in Figure 3.2.

Anticipated climate change trends (refer to Section 5.1.1) indicate decreased annual rainfall and increased annual evaporation over time for low and high emissions scenarios. These scenarios would result in smaller volumes in all water storages; therefore, not adopting these climate change forecasts is considered to be conservative to forecast future storage volumes, and capacities using the water balance model.

Water balance simulations for P15 and P85 historic rainfall years were run to coincide with the year in which the Phase 7-7B-SD20 Stage 2 peak flow within the Roma total flow occurred. These simulations represent minimum and maximum historical rainfall years. There were no water balance model simulations that predicted dam or tank overflows.

Table 3.1 outlines the expected water quality for the Project, based on Myalla (PL 282: neighbours the Project diagonally to the northeast) and Washpool Creek (PL 318: neighbours the Project to the south) well data. Produced water quality is slightly alkaline with elevated chloride and sodium concentrations, which contribute to elevated TDS / EC levels.

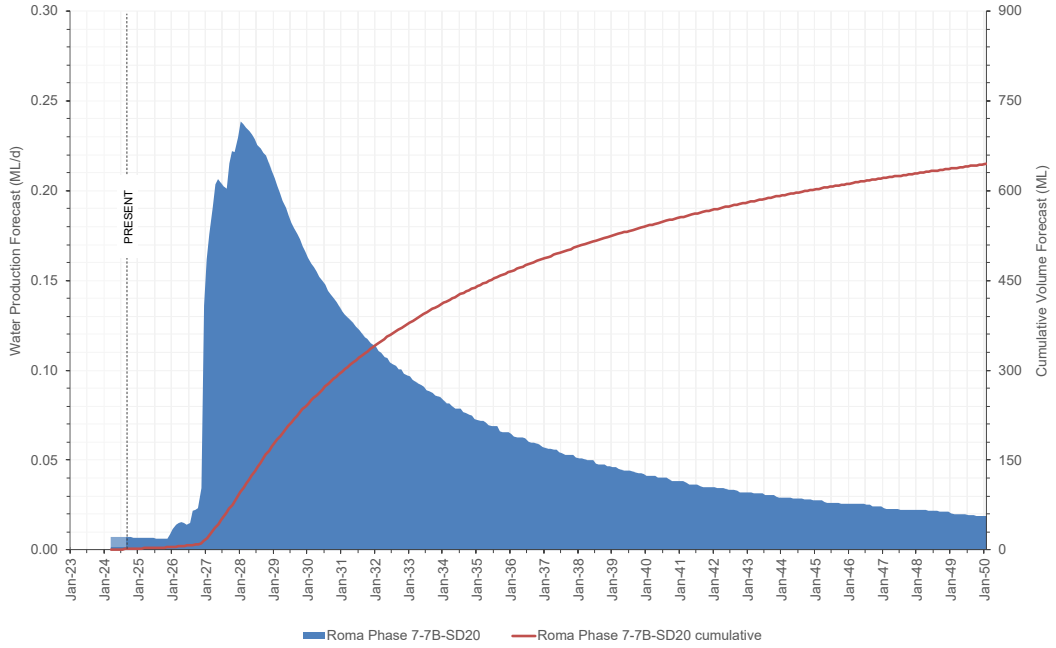


Figure 3.1 Roma Phase 7-7B-SD20 P50 water production forecast (WRM 2024)

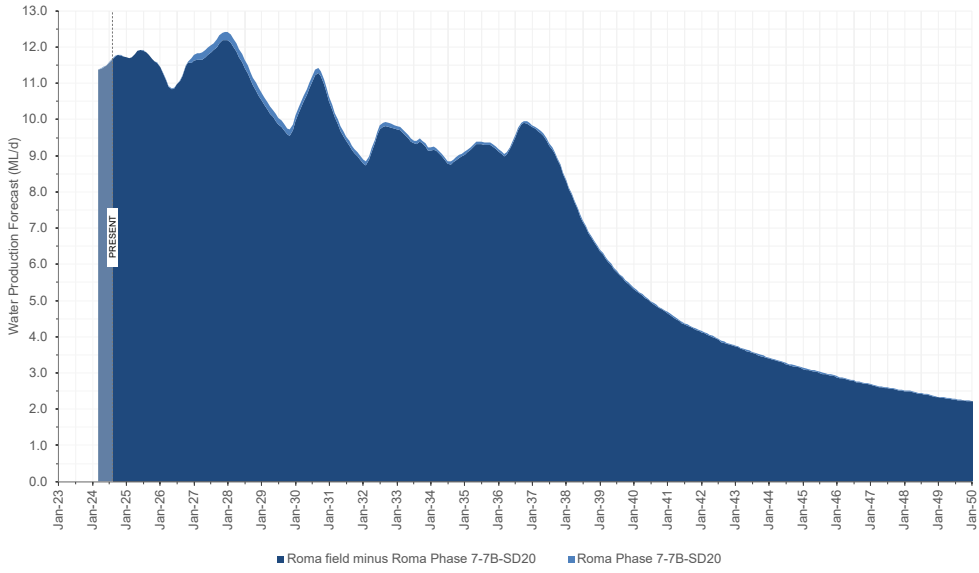


Figure 3.2 Roma Phase 7-7B-SD20 + Roma field P50 water production forecast (WRM 2024)

Table 3.1 Roma Phase 7-7B-SD20 Expected Water Quality (WRM 2024)

Analyte	Dissolved or total	Limit of detection	Min.	P10	Median	P90	Max.	Sample count
Boron (mg/L)	Dissolved	0.05	<0.05	0.563	0.71	0.857	0.92	44
	Total	0.05	<0.05	0.623	0.71	0.827	0.91	44
Calcium (mg/L)	Dissolved	1	3	7	14	41.8	355	59
Chloride (mg/L)	Null	1	848	1,376	2,550	5266	17,600	69
Electrical Conductivity @ 25°C (µS/cm)	Null	1	3,970	5,366	8,140	14300	49,800	69
Fluoride (mg/L)	Null	0.1	0.4	0.73	1.65	3.14	4.10	44
Magnesium (mg/L)	Dissolved	1	<1	1.8	3	10	82	59
pH – Lab (pH Unit)	Null	0.01	7.65	7.756	8.17	8.526	8.84	59
Potassium (mg/L)	Dissolved	1	9	24	55	392.2	2,120	59
Sodium (mg/L)	Dissolved	1	848	1,186	1,760	3340	10,000	59
Sodium Adsorption Ratio	Dissolved	0.01	79	85.08	105	125.4	162	15
	Null	0.01	90.4	95	121	140.7	190	40
Strontium (mg/L)	Dissolved	0.001	1.33	1.779	3.795	17.48	52	44
	Total	0.001	1.33	1.926	4.335	17.06	51	44
Sulfate as SO_4^2 (mg/L)	Dissolved	1	<1	<1	<1	13.6	66	59
Total Dissolved Solids (Calc.) (mg/L)	Null	1	2,580	2,726	3,960	6400	6,820	15
Total Dissolved Solids @ 180°C (mg/L)	Total	5	2,600		2,970		4,510	4
	Total	10	2,840	3,522	5,290	10433	32,600	50
Suspended Solids (mg/L)	Null	5	<5	16.2	142	2888	259,000	65

Produced Water Management

Produced water from the Project will be managed as follows (also refer Roma water management schematic in Figure 3.3):

- Produced water from the Project Area will be gathered to Pickanjinnie or Raslie Dam (located on adjacent PL 315).
- The bulk of produced water from Pickanjinnie / Raslie Dams will be transferred to the existing water management facilities located on PL 314.
- Produced water will also be extracted from Pickanjinnie / Raslie Dams as required to supply field water usage demands (e.g. dust suppression and construction water supply) in accordance with the conditions of EA EPPG00898213.On PL 314, produced water from Pickanjinnie / Raslie Dams will be processed through, or bypassed around, the desalination unit, Roma Reverse Osmosis Plant (ROP), which comprises of fines and sludge removal and a ROP. ROPs are used where necessary to achieve the requisite water quality for beneficial reuse of water. ROPs work by partitioning select constituents entrained within produced water into a waste stream (reverse osmosis (RO) concentrate) leaving a permeate stream of significantly better-quality water.
- The permeate stream from the ROP is blended with produced water to achieve the required water quality objectives for the intended beneficial use of the water (land amendment irrigation and operational purposes). The RO concentrate stream is stored within brine storage dams on PL 314.
- The blended permeate and produced water stream is distributed to several irrigation dams and irrigation areas on PL 314.
- The blended water is irrigated on a third-party property in accordance with the Queensland Government's *End of Waste Code Irrigation of Associated Water (including coal seam gas water)* (ENEW07546918).
- There is currently 490 hectares of Land Amendment Irrigation (LAI) area located on Santos owned as well as third-party properties in the Santos project area. This area is required to maximise the beneficial use from all water directed through the centralised facilities.
- Land amendment irrigation (LAI) describes the application of stoichiometric amounts of agricultural amendments (sulphur and gypsum) to treat the soil prior to the application of irrigation water. This is undertaken to manage risks to soil structure and crop health due to the quality of the irrigation water. Fertilised Rhodes grass is irrigated with irrigation management activities maintaining soil salinity (ECse) within the tolerances stated within the ANZECC 2000 guidelines.

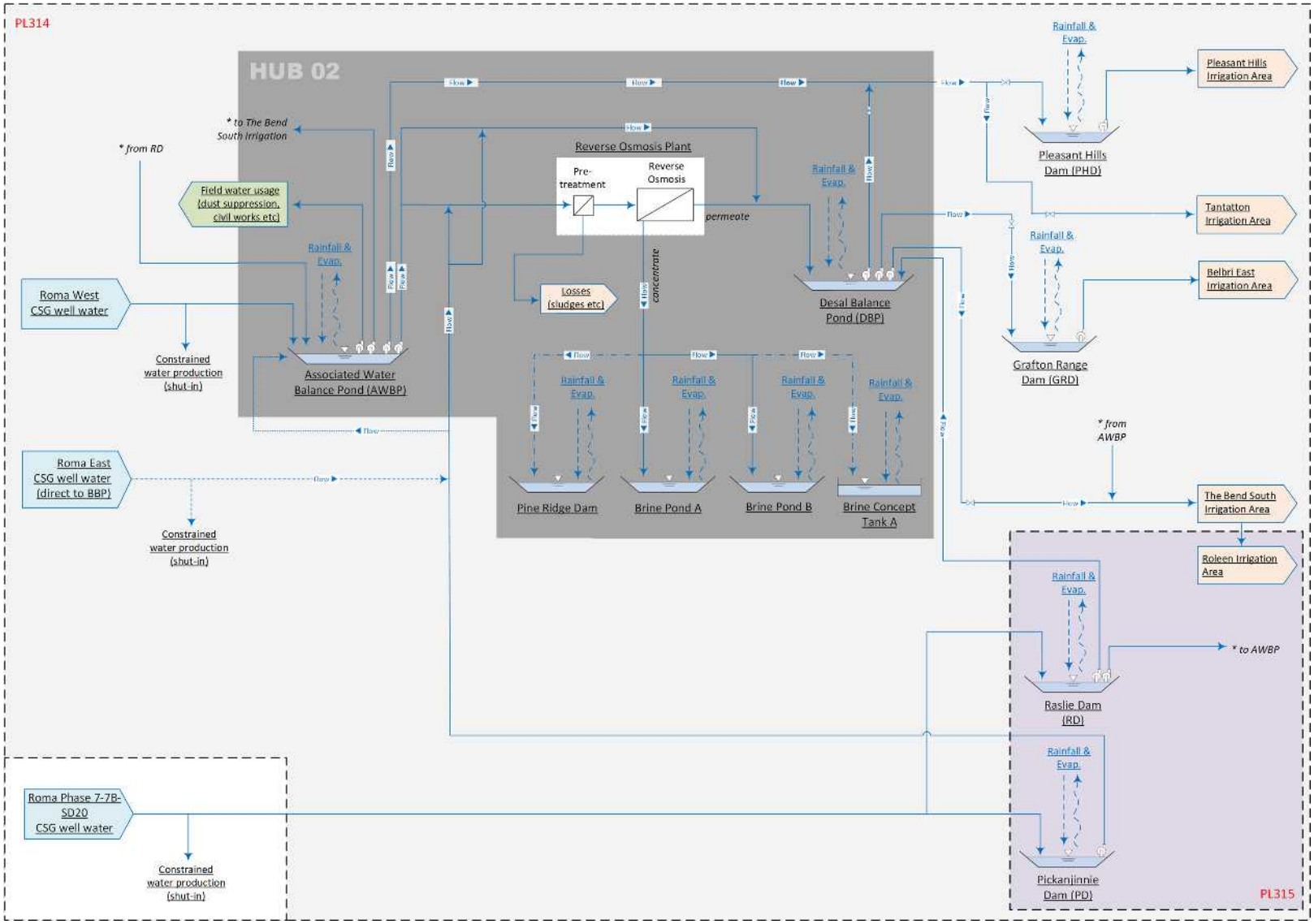


Figure 3.3 Roma Water Management Schematic (PL314) (WRM 2024)

Key attributes of the various water storage facilities are summarised in Table 3.2.

All water storage dams described in Table 3.2 are designed and operated as 'regulated structures' in accordance with the requirements of the EP Act. All storage tanks are designed and constructed to relevant Australian Standards.

Table 3.2 Santos Regulated Water Storages Affected by the Project (WRM 2024)

Asset	Purpose	Storage Construction	Linear Composition	Leak Detection Type	Maximum Operating Storage Volume (ML)
ROMA ROP CSG Water Management Pond	Produced water storage	In ground and above ground	Clay and HDPE	Leak detection layer and seepage bores	116
ROMA ROP Desalinated Water Pond	Permeate water storage	In ground and above ground	Clay and HDPE	Seepage bores	155
ROMA ROP Brine containment Pond A	Brine / concentrate storage	In ground and above ground	Clay and HDPE	Leak detection layer and seepage bores	324
Roma ROP Brine Containment Pond B	Brine / concentrate storage	In ground and above ground	Clay and HDPE	Leak detection layer and seepage bores	321
Pleasant Hills Dam	Irrigation water storage	In ground and above ground	Clay and HDPE	Seepage bores	170
Grafton Range Dam	Irrigation water storage	In ground and above ground	Clay and HDPE	ELIMS testing and seepage bores	170
Pine Ridge Dam	Brine / concentrate storage	In ground and above ground	Clay and HDPE	Leak detection layer and seepage bores	165
ROMA ROP Brine Concept Tank	Brine / concentrate storage	Above ground tank	Double walled liner	Leak detection layer	47
Raslie Dam	Produced water storage	Above ground	Clay and HDPE	Seepage bores	185
Pickanjinnie Dam	Produced water storage	In ground and above ground	Clay and HDPE	Seepage bores	177

Roma gas field water storage (produced water, permeate and brine) dams are classified as 'Regulated Structures' under EAs EPPG00898213 and EPPG00662213. Further, Roma water storage dams have been designed and constructed (and certified) in accordance with *The Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (version 5.03) (DESI 2024) hereinafter referred to as 'The Manual'.

The Roma dams have been designed as turkey nest structures for the containment of produced water / permeate / brine. A portion of the dam crest storage is below existing ground level in an excavated void. Overland flows have been diverted away from the storages by diversion bunds designed to divert peak flows up to and including 0.0005 Annual Exceedance Probability (AEP) (1 in 2,000 year). The turkey's nest design and diversion of overland flow results in only rainfall that falls within the dam crest entering the storages.

The water storages are operated such that once a Maximum Operating Volume (MOV) is reached, water flows into the storage must cease (i.e. wells turned down) until the volume returns to below the MOV. Above the MOV there is a Design Storage Allowance (DSA) volume available (designed to store a 100% runoff from a 3-month wet season, in accordance with The Manual) before the Full Supply Volume (FSV) (spillway level) is reached. This is designed to specifically minimise the likelihood of release from a regulated dam.

Above the MOV is the Mandatory Reporting Level (MRL) which is the level at which the remaining volume is equivalent to the Extreme Storm Storage (ESS) allowance (short-duration, intense rainfall event). When MRL is reached, Santos must notify the Department of Environment, Tourism, Science and Innovation (DETSI) immediately to minimise actual or potential environmental harm.

In summary, the water storages have significant 'freeboard' available to store intense rainfall events for the site-specific wet season (3-month period during summer).

3.4.2 Salt Balance

Large scale produced water treatment is not proposed to be undertaken within the Project Area. Therefore, no brine or residual salt will be generated, stored or otherwise managed in the Project Area.

Produced water from Project will be transferred to existing Roma gas field water storage and treatment facilities located on PLs 314 and 315 for treatment (as described in Section 3.4.1). The resulting treated water permeate will be stored in a dam and used for beneficial purposes. The brine will be stored in regulated brine storage which will naturally concentrate the brine over time. The final stage will be crystallisation of a solid salt for beneficial reuse or disposal to a licensed landfill. The treatment processes, and storage and management of brine and salt, are not located within the Project and are therefore not part of the proposed action. Details of these processes are included in the *Revised Coal Seam Gas Water Monitoring and Management Plan GLNG Project EPBC* (2008/4059) (Santos 2023b).

The Roma ROP has the capacity to process up to 7.5 ML/day of produced water. Figure 3.4 shows the ROP has sufficient capacity to manage the Project and Roma forecast water production for P50 climatic conditions.



Figure 3.4 Flow into ROP with and without the Project (Roma Phase 7-7B-SD20) Flows (WRM 2024)

Figure 3.5 shows forecast brine volumes to be contributed by the Project and Roma field and indicates there is sufficient brine storage capacity to manage the combination of Roma and the Project forecast brine production, for P50 climatic conditions.

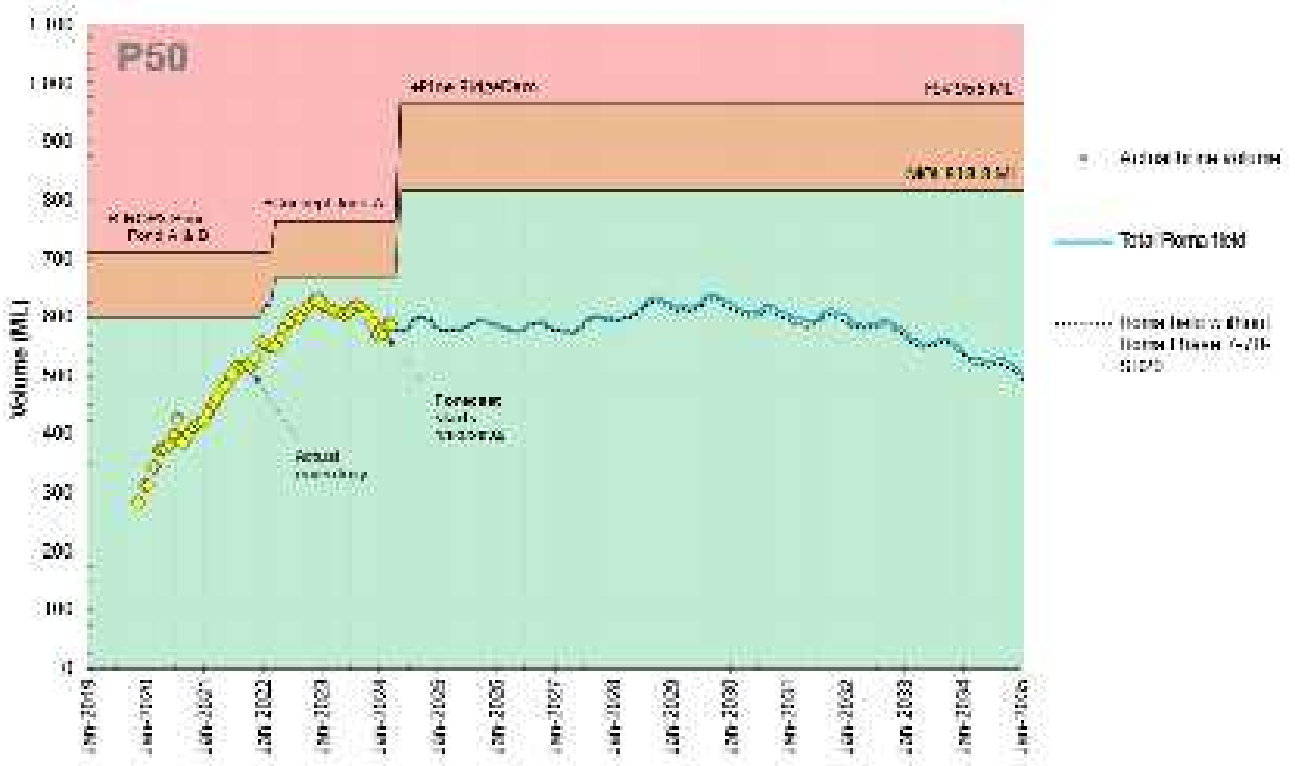


Figure 3.5 Brine Inventory (WRM 2024)

The Project is forecast to add approximately 82 tonnes of salt to the brine storages located on PL 314. This represents about 0.1% of the salt stored in Roma brine storages.

3.4.3 Waste Management and Rehabilitation

On PL 314 the Roma ROP permeate flushes are transferred to brine storages – refer to Section 3.4.2 for a description of the management of this waste.

The Roma ROP Actiflo sludge and treated oily water is transferred to the Roma ROP CSG Water Management Pond which then either gets treated through the Roma ROP or bypassed for blending with permeate and irrigation. At the end of the life of the Roma ROP CSG Water Management Pond, all liquid and solid material will be removed from the dam prior to rehabilitation. The liner will be removed and transported to a regulated waste facility for disposal. These treatment processes and resultant waste are not located within the Project and are therefore not part of the proposed action.

3.4.4 Water Use During Project Development

As discussed in Section 6.6, the Project Area occurs within the Condamine and Balonne Tributaries WMA CBT-02, which is an unsupplemented surface water trading zone.

Santos estimates it will require approximately 158 ML of water to develop the Project (24% of estimated produced water volume). Water will be utilised during construction and operation to support development, maintenance, dust suppression, drilling, hydraulic stimulation and construction activities.

Santos will preferentially utilise produced water generated from and located in the Project Area and surrounding approved Santos and JV partner-owned tenures, in accordance with EA conditions.

Santos is not expecting to require additional water allocations / licenses to develop the project, nor is Santos expecting to require notable surface water take from landholder dams to develop the project.

Further, produced water may be sourced from on-site temporary water storage tanks (concrete panel tanks for similar) (henceforth referred to as ‘tanks’) in accordance with EA conditions. The tanks will comply with relevant Australian Standards.

Santos would only extract water from farm dams for construction purposes with the permission from the landholder when water supplies are abundant of appropriate quality for the proposed use/ activities.

It is noted that some landholders may require Santos to use water sourced on-site for drilling and construction activities, particularly where a landholder holds organic certification for the property.

4 METHODOLOGY

4.1 Existing Environment and Environmental Values

The existing environment across the Project area was considered through a desktop assessment to establish the baseline groundwater conditions, EVs, and potential receptors. The assessment area, for the purposes of this report, includes the surface water features within the Project area, hydrogeological units underlying the Project within the Surat Basin and overlying Quaternary deposits. For the identification of groundwater receptors relevant to this Project, a 25 km buffer around the Project area (which also includes ATP 2053) was established to capture potential adjacent groundwater receptors that may be impacted by the proposed development.

Primary data and information utilised in this assessment are listed below.

A preliminary desktop assessment utilised data and information provided by Santos, OGIA and publicly available reports and data. Primary data and information utilised in this assessment includes:

- 1:100 000 scale geological maps for the Surat Basin, including the Detailed Surface and solid Geology – Queensland (State of Queensland 2018a).
- Registered bore data from the Queensland Groundwater Bore Database (GWDB) (State of Queensland 2024j).
- The Queensland Spring Database provides a comprehensive catalogue of springs and potential GDEs at fixed locations in Queensland. The Queensland Spring Database is updated annually (Queensland Herbarium 2021).
- Department of Science, Information Technology, and Innovation (DSITI) Queensland Groundwater Dependent Ecosystem Mapping (State of Queensland 2018c), which indicates the locations of potential GDEs at a catchment scale (both surface expression and terrestrial).
- Surface water flow and quality data sourced from the Queensland Government Water Monitoring Information Portal (State of Queensland 2024n).
- Local Climate, including temperature, precipitation and evaporation data from SILO (Department of Environment and Science 2024).
- Surat CMA aquifer attribution dataset, provided by OGIA (OGIA 2024).
- Petroleum well completion reports, sourced from Queensland QDEX database.

Documents

- Underground Water Impact Report (UWIR) for the Surat CMA (OGIA 2019c).
- Underground Water Impact Report (UWIR) for the Surat CMA (OGIA 2021g).
- Updated Geology and Geological Model for the Surat Cumulative Management Area (OGIA 2019e).
- Regional Flow Systems and Potentiometry in Queensland's Surat and southern Bowen Basins (OGIA 2021c).

- Surat CMA and its groundwater systems (OGIA 2021d).
- Water Act 2000 (State of Queensland 2024m) Guidelines: baseline and bore assessments and make good requirements (State of Queensland 2024f; 2024e; 2024h).
- Hydrogeological Conceptualisation Report for the Surat CMA (OGIA 2016a).
- Surat CMA UWIR Water Monitoring Strategy (WMS) (OGIA 2021a).
- The Joint Industry Framework (JIF) (Australian Government 2021).
- Code of Practice for the construction and abandonment of coal seam gas and petroleum wells, and associated bores in Queensland Version 2 (State of Queensland 2019a).
- Queensland CSG Water Management Policy (DEHP 2012).
- Queensland Streamlined Model Conditions for Petroleum Activities (State of Queensland 2024k).
- Queensland CSG water management: Measurable criteria (DES 2013).
- Queensland Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (State of Queensland 2019d).
- Hydraulic Fracturing Risk Assessment – Santos Eastern Queensland Rev 1 (HFRA) (EHS Support 2021).
- Eastern Queensland Stimulation Impact Monitoring Program (SIMP) (Santos 2021).
- Baseline Assessment Plan (BAP) for ATP 2052 and ATP 2053 (Santos 2022).
- Roma Phase 7-7B-SD20 Chemical Risk Assessment Framework (CRAF) (Santos 2024f).
- Roma Phase 7-7B-SD20 Chemical Risk Assessment Report (CRAR) (EHS Support 2024a).
- Roma Phase 7-7B-SD20 Proposed Produced Water Management Plan (WMP) (WRM 2024).
- Roma Phase 7-7B-SD20 Ecological Assessment Report (EAR) (Boobook 2024b).
- Roma Phase 7-7B-SD20 Rehabilitation Monitoring Plan (RMP) (Santos 2024d).
- Roma Phase 7-7B-SD20 Environmental Protocol for Constraints Planning and Field Development (Constraints Protocol) (Santos 2024b).
- Roma Phase 7-7B-SD20 Significant Species Management Plan (SSMP) (Santos 2024e).
- Roma Phase 7-7B-SD20 Environmental Management Plan (EMP) (Santos 2024a).

4.1.1 Bore Baseline Assessment

The Water Act 2000 requires Santos to undertake baseline assessments of existing water bores located within the Project Area. Baseline assessment of the two existing water bores located within the Project Area is discussed in Section 7.11.3.

4.2 Impact Assessment

4.2.1 Groundwater

Based on information provided by Santos and as broadly described in Section 3 (e.g., number and location or wells, productions scheduling and durations), OGIA simulated the predictive model scenario for the Project using the regional groundwater flow model that underpins the Surat CMA UWIR. Outputs from the model have been used to predict drawdown impacts to groundwater as a result of the Project. OGIA have modelled a Project only scenario, which includes only CSG water production from the Project, and a Cumulative scenario, which includes the simulation of all current and proposed developments (including reasonably foreseeable Santos developments ATPs 1187 and 2052).

Outputs from the modelling have been processed by KCB for this assessment, and the results considered as part of this assessment (Section 8 and 9).

The assessment criteria used to consider the groundwater drawdown impacts associated with the Project refers to the Water Act 2000, trigger thresholds, as outlined in Section 2.2.2:

- Bore trigger thresholds, represents the maximum allowable groundwater level decline in a groundwater bore, due to petroleum tenure holders' activities, prior to triggering an investigation into the water level decline. These triggers are based on:
  - For a consolidated aquifer – 5 m
  - For an unconsolidated aquifer – 2 m
- Spring trigger threshold represents the maximum allowable decline in the water level of an aquifer in connection with a spring, at the spring location, prior to triggering an investigation into the water level decline.
  - Spring – 0.2 m

An assessment of the potential impacts also includes the development of the conceptual understanding of the system, in particular, hydraulic connection between identified receptors and the hydrostratigraphic units being drawn down/depressurised.

Other potential impacts associated with the Project in relation to groundwater are presented in Section 9, with the relevant mitigation, management and monitoring measures to address these potential impacts provided in Section 10.

4.2.2 Surface Water

Potential impacts that may result from Project activities to the hydrological system are summarised below. These potential impacts are associated with the general construction and day-to-day operations of CSG surface facilities rather than CSG production; and could comprise:

- Alteration of a watercourse character or changes to riparian buffers due to construction works and / or infrastructure; and
- Altered surface water runoff characteristics from construction / developed areas.

The proposed Project does not include planned material discharges / abstraction from natural surface water systems or interaction with surface water bodies and therefore direct impacts to surface water from Project activities are not anticipated. A review of other potential impacts to surface water as a result of the Project are discussed in Section 9. Potential impacts are managed and mitigated by adopting and implementing the appropriate monitoring, management, and mitigation strategies (Section 10).

4.2.3 Chemical Contamination

A CRAF has been developed to guide the assessment of risk associated with chemicals used during CSG operations (drilling and completions, and hydraulic fracturing) for the Project.

The CRAF incorporates best practice risk assessment methodology for the assessment of potential impacts associated with the use of chemicals to MNES and MSES. The CRAF is based on existing Santos approved chemical risk assessment frameworks and aligns with best practice methodologies. Further, a Project specific CRAR (EHS Support 2024a) has been developed in accordance with the requirements of the CRAF to identify the potential risks and effects of chemicals used during CSG operations (drilling and completions, and hydraulic fracturing) specific to the Project.

The CRAF / CRAR assessment process is designed to align with national guidance and other regulatory frameworks and assesses the full lifecycle of chemicals that are stored, transported, handled, used and / or disposed during or following drilling and completions, and hydraulic fracturing activities.

The CRAR summarised the potential risks and effects of chemicals used during the life cycle of CSG extraction to MNES / MSES as identified in the EAR (Boobook 2024b).

The life cycle of drilling, completions and hydraulic fracturing was assessed specifically for the Project and included:

- Storage, usage (e.g., blending, injection), and recovery of chemicals throughout operations;
- Beneficial reuse of recovered drilling fluids and cuttings for well lease rehabilitation; and
- Storage of produced water.

A high level overview of Project activities including the installation of gas field infrastructure, well drilling and completion, hydraulic fracture stimulation, production operations and decommissioning and rehabilitation is provided in EMP (Santos 2024a) and RMP (Santos 2024d).

In addition to the CRAF / CRAR, EMP and RMP, a Hydraulic Fracturing Risk Assessment (HFRA) has been completed for Santos's Eastern Queensland activities which includes the Project (EHS Support 2021). The HFRA describes the process by which hydraulic fracturing is conducted and monitored. It addresses the regulatory requirements of Santos' Eastern Queensland EAs and synthesizes the findings of several hydraulic fracturing risk assessments completed to date.

5 EXISTING ENVIRONMENT

The topography of the Project Area is generally gently sloping with an elevation of between 300 – 350 metres above Australian Height Datum (mAHD), as shown in Figure 5.1. The elevation of the wider Project Area increases to 450 – 600 mAHD in the north and 350 – 400 mAHD to the east and southeast. The lower lying drainage to the southwest / south ranges between 250 – 300 mAHD and is associated with the watercourses discussed later in Section 6.2.1.

5.1 Climate

The climate of the Project Area is classified as subtropical with a moderately dry winter based on the modified Köppen classification system (BOM 2005). Climate statistics sourced from SILO (Scientific Information for Land Owners) are presented in Table 5.1, for the climate station Wallumbilla Post Office (43038). SILO data is an enhanced synthetic climate database that provides a daily time series of data at a point location consisting of station records which have been supplemented by interpolated estimates when observed data are missing. Wallumbilla Post Office climate station is located 3 km west of the Project Area as shown on Figure 5.1.

Table 5.1 Climate Statistics for Wallumbilla Post Office (43038)

Statistic Element	Wallumbilla Post Office (43038)			
	Mean Daily Maximum Temperature (°C)	Mean Daily Minimum Temperature (°C)	Mean Monthly Rainfall (mm)	Mean Monthly Evaporation (mm)
Period of Record	1889-2023	1889-2023	1889-2023	1889-2023
January	34.0	20.2	77.0	261.4
February	33.0	19.7	76.9	202.5
March	31.3	17.4	63.4	200.5
April	27.9	12.9	32.1	144.9
May	23.5	8.3	34.0	100.9
June	20.0	5.2	35.2	73.4
July	19.6	3.8	34.1	81.0
August	21.8	5.1	24.1	113.9
September	25.8	9.0	29.0	165.4
October	29.4	13.5	50.4	212.0
November	32.0	16.8	62.7	234.2
December	33.7	19.0	75.3	258.4
Annual	27.6	12.6	592.7	2042.3

* Data range: 1/1/1889 – 4/2/2023

Mean maximum temperatures range between 34°C in the summer months and 20°C in the winter months. Mean minimum temperatures range between 20°C in the summer months and 4°C in the winter months. The highest average monthly rainfall occurs during October to March (50 – 77 mm), with the lowest average monthly rainfall occurring during April and August (24 – 35 mm).

The highest monthly evaporation occurs during the summer months (October to March, 200 – 259 mm), while the lowest evaporation occurs during the winter months (April to September, 73 – 165 mm).

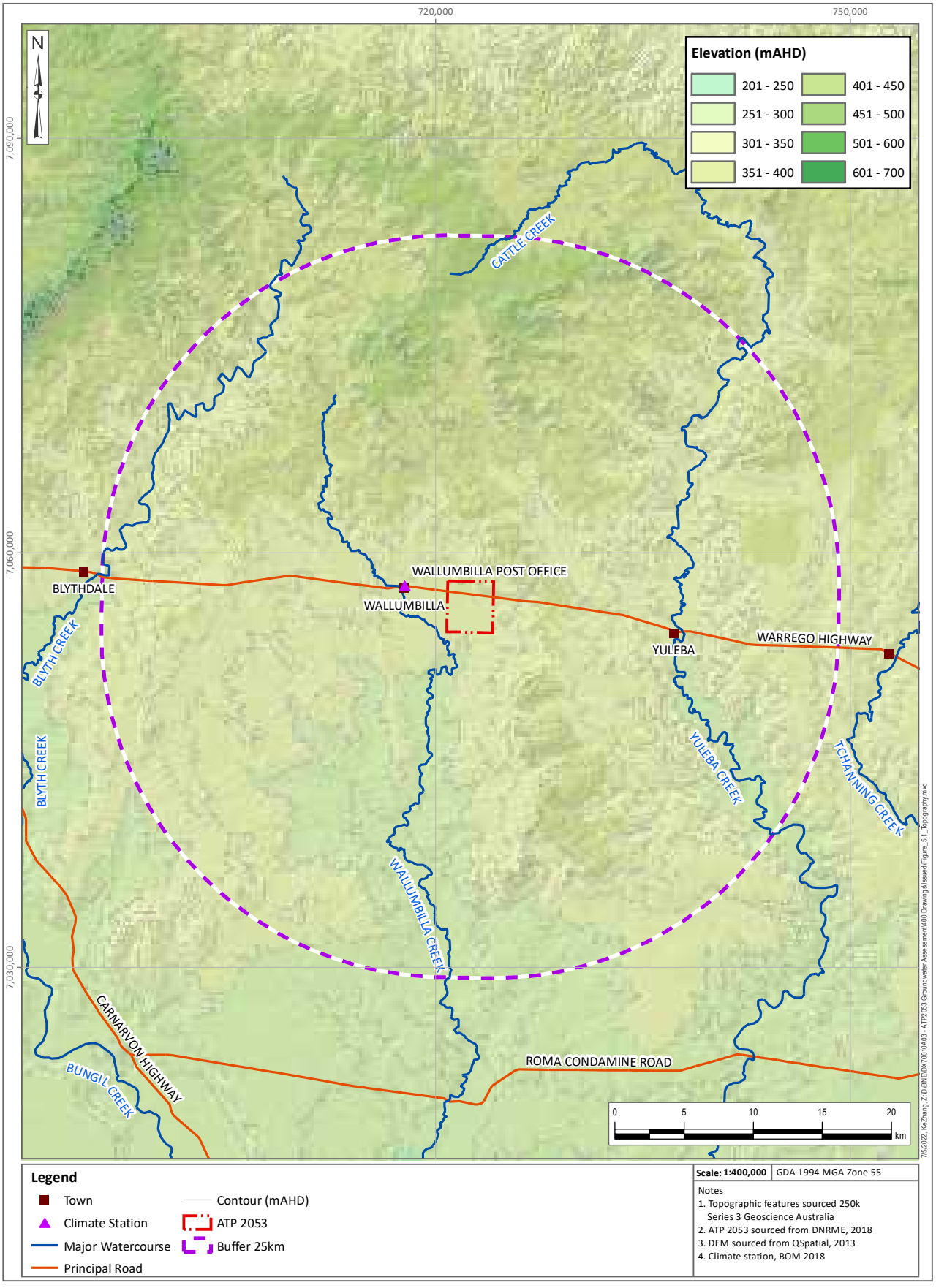


Figure 5.1 Topography within the Vicinity of the Project Area

Figure 5.2 presents daily rainfall between January 1963 and February 2023 for Wallumbilla Post Office climate station, and a rainfall excess / deficit trend for the same period. Rainfall excess / deficit trends present a running deviation of long-term actual rainfall against the average. This provides seasonal-scale identification of trends (wet / dry) and longer term (e.g. decadal) deviation from average conditions. These trends result in a natural tempering of peaks for rainfall events and therefore support the correlation of rainfall events to aquifer responses.

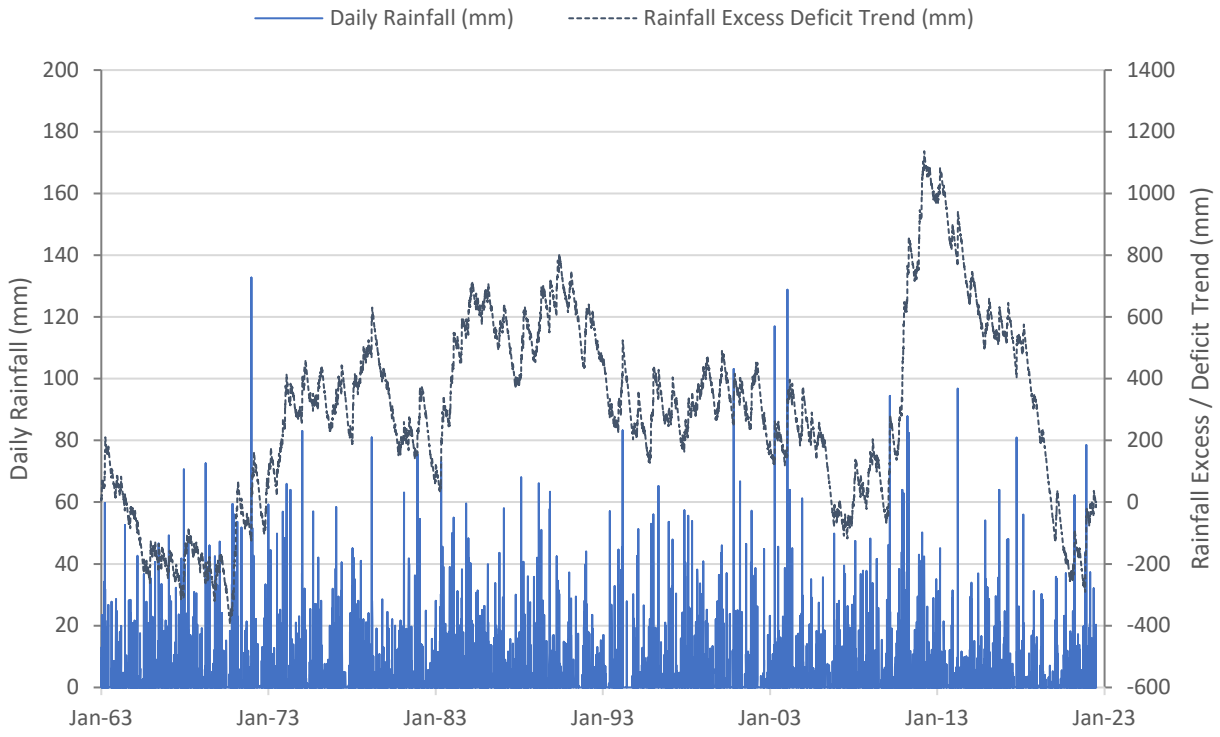


Figure 5.2 Daily Rainfall and Rainfall Excess / Deficit Trend (Wallumbilla Post Office 43038)

Observations from the rainfall excess / deficit (CRD) trend include:

- The overall rainfall trend is characterised by the cyclic nature of the wet and dry seasons, with fluctuations of 150 -200 mm evident across the record.
- The 2010 / 2011 above average rainfall resulted in 900 mm increase in the rainfall excess / deficit trend.
- The general rainfall excess / deficit trend increased gradually between 1970 and 1990, where after it decreased gradually until 2010.
- Between 2010 and 2012 the rainfall excess / deficit trend increased steeply in response to above average rainfall, followed by a steady decline and trend reversal in 2021.

5.1.1 Climate Change

The Queensland Government has developed an interactive map to help understand the impact of climate change for specific council regions (State of Queensland 2024a).

The Project Area is located in the Central Queensland region, which is potentially subject to the following predicted climatic scenario in 2050, under a modelled high emissions case:

- 1.9ºC increase in median annual temperature (1.4ºC for low emissions case);
- 8% decrease in median annual rainfall (2% for low emissions case); and
- 7% increase in median annual evaporation (5% for low emissions case).

These trends (decreased annual rainfall and increased annual evaporation) are also evident in the low and high emissions case for 2030, 2070 and 2090. The low and high emission cases forecast a reduction in rainfall and an increase in evaporation.

Individual rainfall events are naturally highly variable, and this will continue to be a factor that requires careful consideration in future, especially since the intensity of heavy rainfall events are likely to increase under climate change conditions. Furthermore, groundwater recharge may be expected to decrease under these conditions.

5.2 Land Use

Land use information specific to the Project Area has been sourced from the Queensland Government datasets (DES 2018a). The land use dataset classifies land use type using the Australian Land Use and Management (ALUM) Classification system which provides a nationally consistent method to collect and present land use information in Australia. This classification system categorises 32 land use classes and subclasses. There are six primary classes used in the ALUM classification system, and these are further divided into secondary and Tertiary classes. A description of the primary classes (ABARES 2010) is detailed below:

- Conservation and natural environments – Land is used primarily for conservation purposes, based on the maintenance of essentially natural ecosystems already present.
- Intensive uses – Land is subject to substantial modification, generally in association with closer residential settlement, commercial or industrial uses.
- Production from dryland agriculture and plantations – Land is used mainly for primary production, based on dryland farming systems.
- Production from irrigated agriculture and plantations – Land is used mainly for primary production, based on irrigated farming.
- Production from relatively natural environments – Land is used mainly for primary production based on limited change to the native vegetation.
- Water – Although primarily land cover types, water features are regarded as essential to the classification.

Figure 5.3 presents the land use in the vicinity of the Project Area, with a summary of the land use distribution (area and percentage) (DES 2018a) directly within the Project Area provided in Table 5.2. There are three types of primary land use within the Project Area. The dominant land use is production from relatively natural environments specifically grazing from native vegetation (94%). Grazing modified pastures and cropping is also undertaken in 4% of the Project Area, with intensive uses only constituting 0.8%.

Table 5.2 Summary of the Current Land Use within the Project Area

Land Use Category			Area (km^2)	Percentage of Total Area
Primary	Secondary	Tertiary		
Intensive uses	Services	Recreation and Culture	0.10	0.80%
Production from dryland agriculture and plantations	Cropping	Cropping	0.12	1.01%
	Grazing modified pastures	Woody fodder plants	0.50	4.12%
Production from relatively natural environments	Grazing native vegetation	Grazing native vegetation	11.54	94.07%
Total			12.26	100%

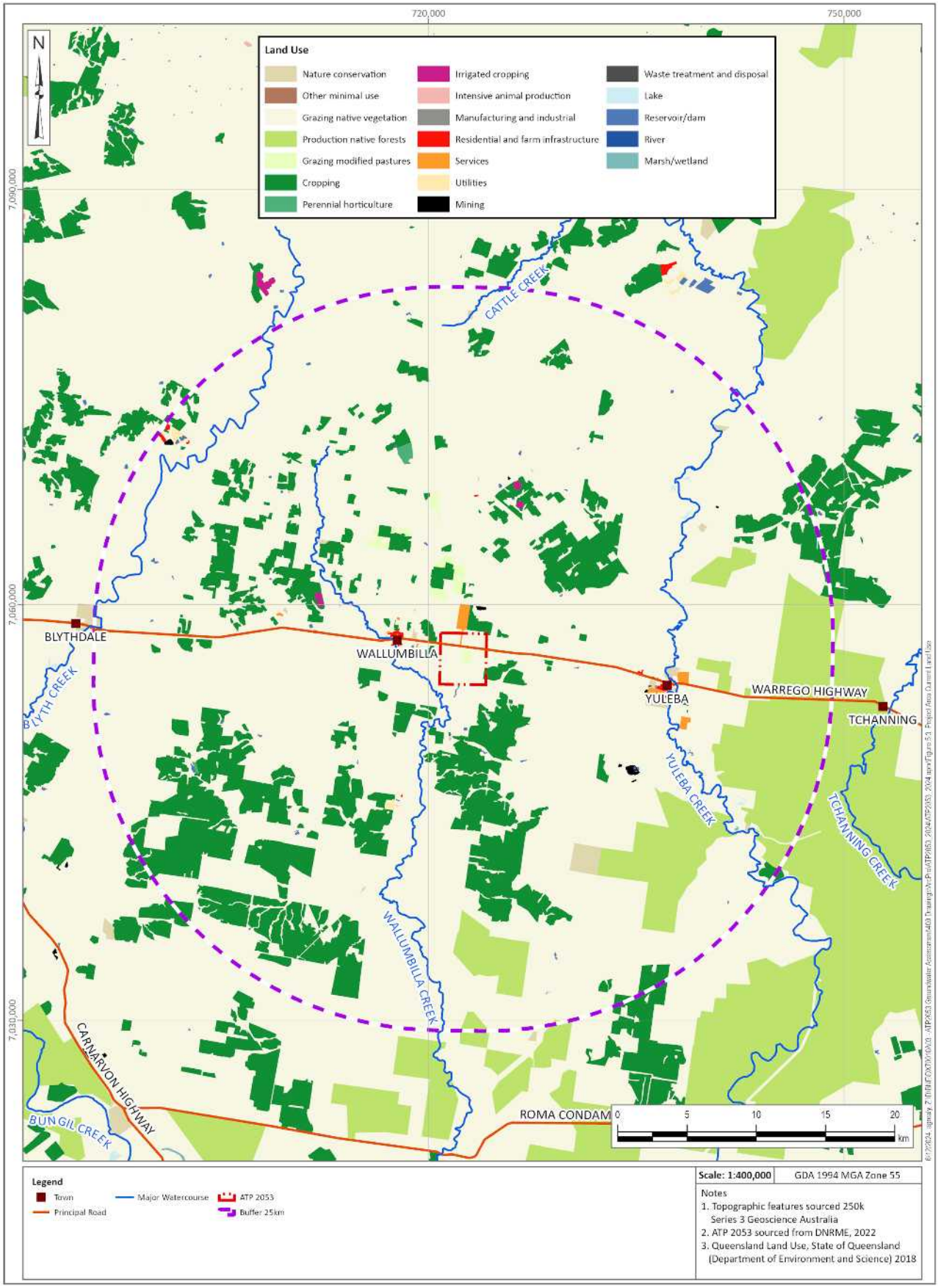


Figure 5.3 Project Area Current Land Use

6 HYDROLOGICAL SETTING

6.1 Location and Catchment Context

The Project Area is located in the Balonne River sub-basin (within the wider the Condamine-Balonne Basin). The Condamine-Balonne Basin covers an area of 136,649 km^2 (in Queensland) and represents 14 % of the larger Murray-Darling Basin. The majority of the Condamine-Balonne Basin is located in Queensland, with 16% in New South Wales (Commonwealth of Australia 2020). The Balonne River flows east to west until Surat where it flows towards the southwest. Many tributaries flow into the Balonne River. The Balonne River flows into Lake Kajarabie (Beardmore Dam) near St George (approximately 140 km to the southwest of the Project Area), before becoming a braided network of channels, waterholes and floodplains that form the Narran, Bokhara, Ballandool and Culgoa Rivers, and Briarie Creek.

Major river sub-catchments within the vicinity of the Project Area include:

- Balonne River sub-catchment which includes upper Balonne River tributaries; and
- Yuleba Creek sub-catchment.

6.2 Key Surface Water Bodies

6.2.1 Watercourses

Key watercourses within / in close proximity to the Project Area are shown in Figure 6.1, and include:

- Washpool Creek: is a minor creek, which originates 5 km north of the Project Area and flows through the Project Area before joining Wallumbilla Creek 2 km south of the Project Area.
- Wallumbilla Creek: originates 16 km northwest of the Project Area and flows south – southeast close to the township of Wallumbilla. The creek continues to flow south before reaching the Balonne River confluence downstream of Yuleba Creek, 54 km south of the Project Area.
- Middle Creek: is a tributary of Wallumbilla Creek, which originates 15 km northwest of the Project Area and flows south between the township of Wallumbilla and the Project Area before joining Wallumbilla Creek 2 km west of the Project Area.

Other watercourses in the greater area include:

- Yuleba Creek is identified by the Water Act 2000 as a major watercourse and flows for approximately 187 km from near the Great Dividing Range before joining the Balonne River 45 km south of Yuleba. Yuleba Creek originates close to the Balonne River catchment area. Yuleba Creek flows predominately south, close to the township of Yuleba, located 13 km east of the Project Area and joins the Balonne River, 46 km southeast of the Project Area.

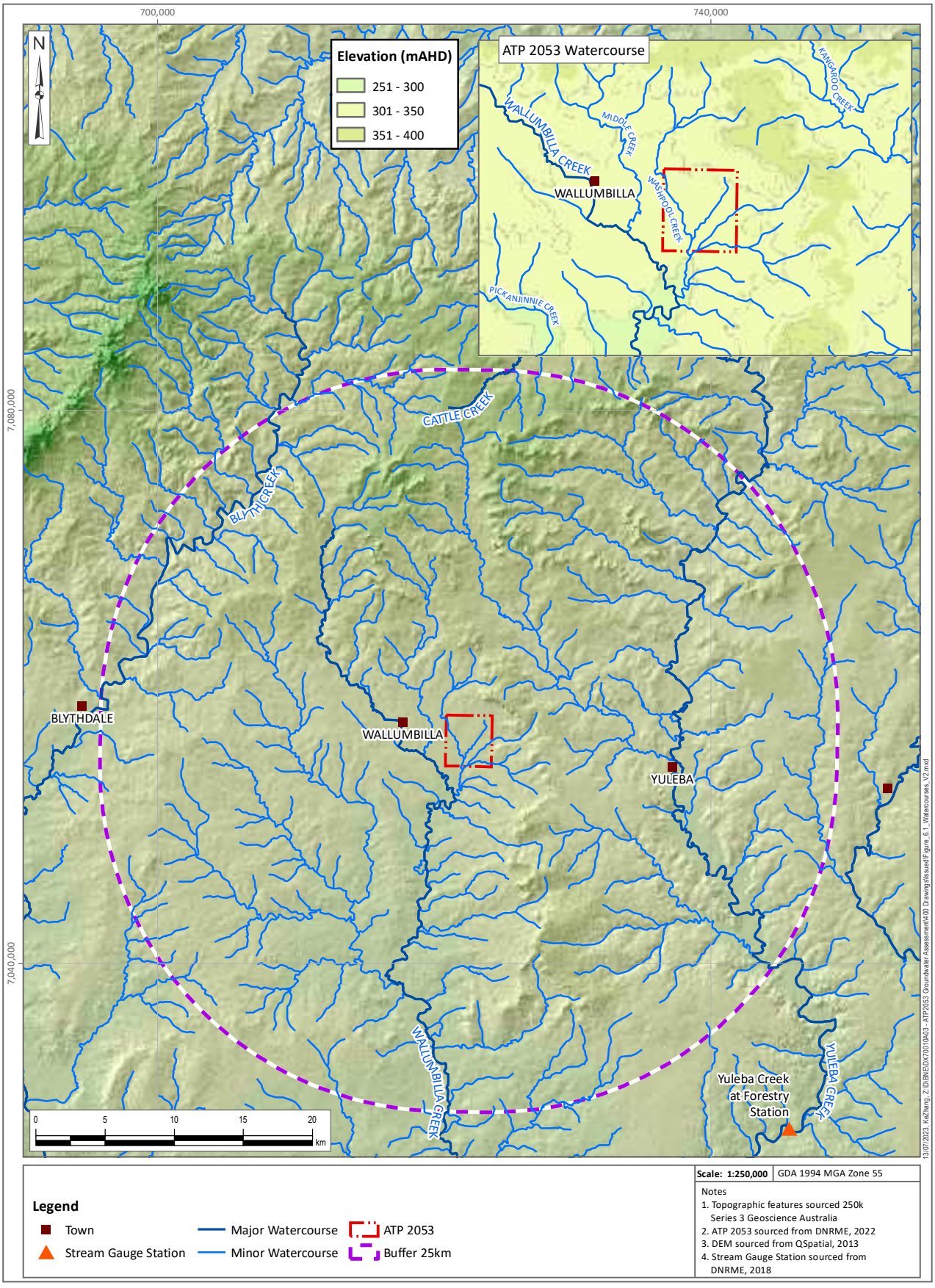


Figure 6.1 Watercourses in the Vicinity of the Project Area

The watercourses in close vicinity to the Project Area are classified as Stream Order 1 to Stream Order 5 based on the Strahler method (DNRM 2010). A list of watercourses and associated stream orders within the Project Area are presented in Table 6.1.

Table 6.1 Stream Order Classification

Sub-Catchment	Stream	Stream Order(s)
Yuleba (Balonne-Condamine Basin)	Washpool Creek	1, 2, 3
	Wallumbilla Creek	3, 4
	Middle Creek	2,3

6.2.2 Wetlands

Wetlands listed in the '*Directory of Important Wetlands in Australia*' (Environment Australia 2001) are not identified to be located in or within 25 km of the Project Area, respectively. The closest wetlands are located more than 120 km from the Project Area and are therefore not considered material to this assessment.

No wetlands of High Ecological Significance or wetlands of General Ecological Significance, as shown on a Map of Referable Wetlands (DETSI 2024a), were mapped by the EAR as present within the Site (Boobook 2024b).

A review of the Project Area on the Queensland Government's interactive wetland mapping website 'Wetland Info' (DETSI 2024b) was undertaken. Wetland Info mapping indicated the Project Area includes lacustrine, riverine and minor palustrine wetlands as shown in Figure 6.2.

Lacustrine wetlands are open water dominated systems (e.g. dams and lakes). In turn, palustrine wetlands lack open or flowing water (e.g. marsh or bogs). The Project Area is also identified to contain four areas that may include wetlands (indicated as remnant regional ecosystems (REs) containing 1-50% wetlands). Potential wetlands (1-50%) are also indicated along the banks of Middle and Wallumbilla Creeks located 1 km to the west of the Project Area.

Ground-truthed vegetation surveys undertaken by the EAR identified several wetlands of limited extent and general ecological significance within the Project Area. Ground-truthed wetlands are shown in Figure 7.28.

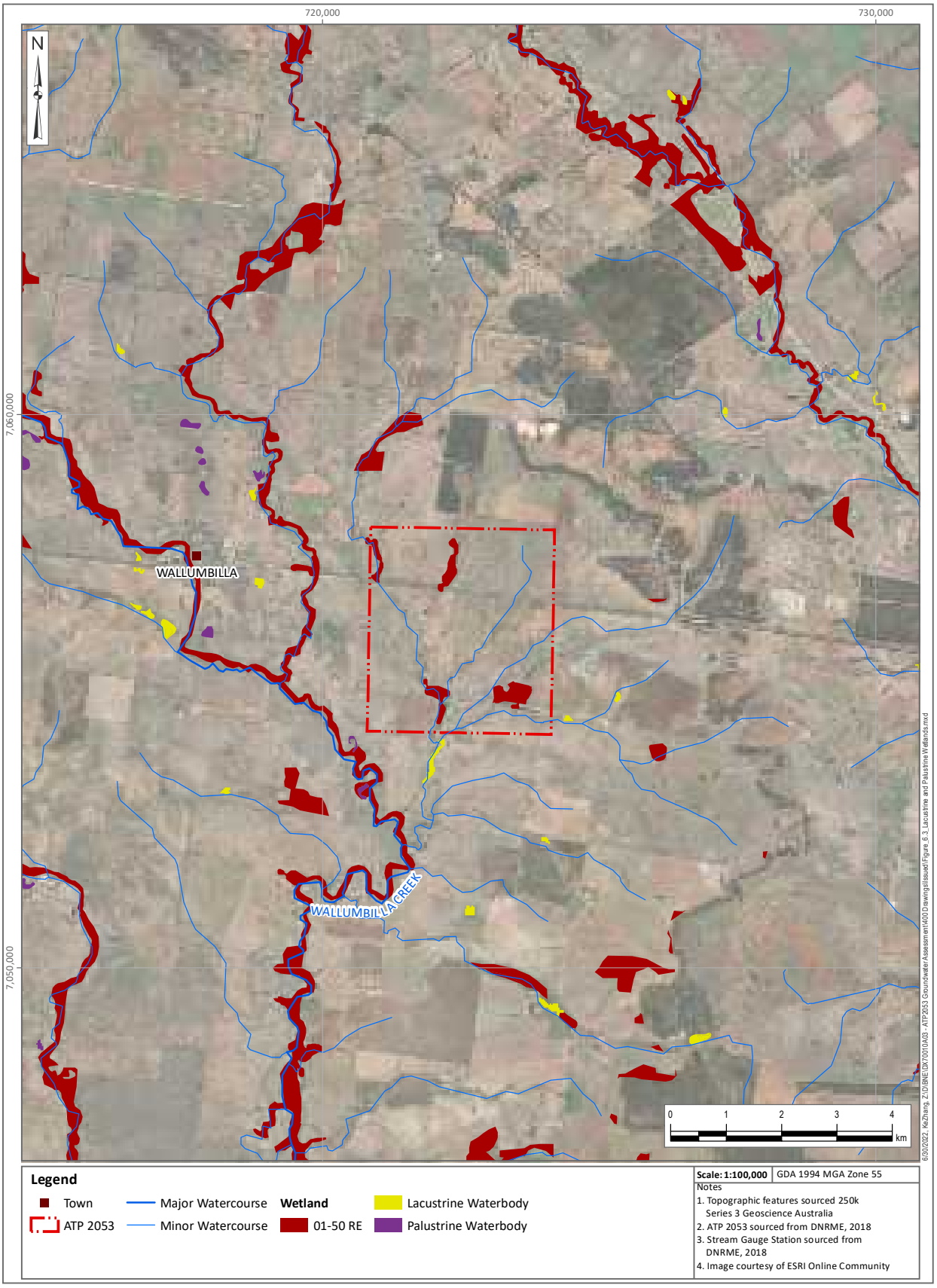


Figure 6.2 Location of Mapped Lacustrine and Palustrine Wetlands in Relation to the Project Area

6.3 Geomorphology

The Condamine-Balonne rivers catchment is one of the largest catchments in the Murray-Darling Basin. The main rivers of the catchment, the Condamine and the Maranoa Rivers, arise in elevated areas of Queensland. However, two-thirds of the catchment, is flat floodplain country, with a complex system of rivers and creeks joining and breaking away from the Balonne River.

Detailed geomorphological descriptions of the creeks within the Project Area were not available at the time of report compilation. An elevation section including Washpool Creek and its tributaries sourced from Google Earth indicate that the creeks beds are gently sloping and open.

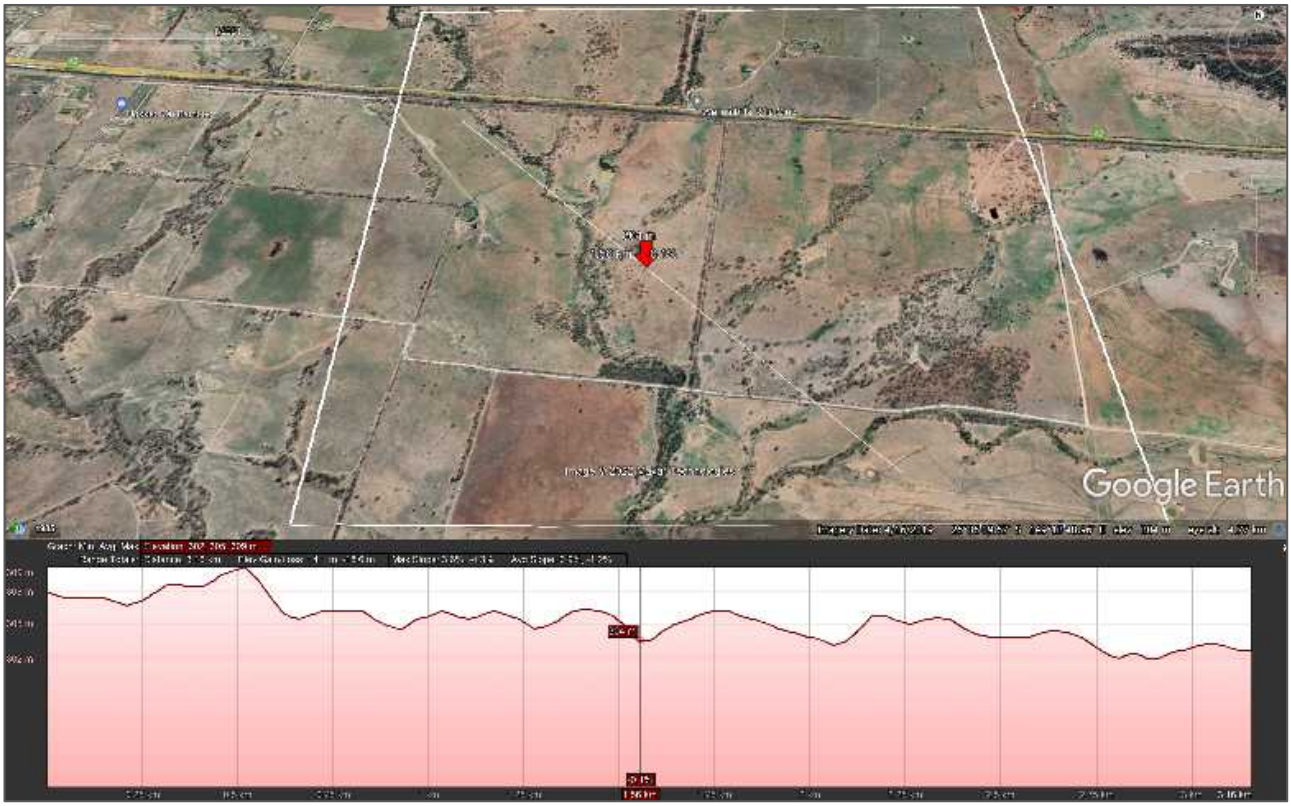


Figure 6.3 Elevation Profile (Google Earth 2022)

6.4 Flood Regime

Floodplain mapping sourced from the Queensland Government (State of Queensland 2022a) is presented in Figure 6.4. The mapped data indicates that Wallumbilla Creek and Washpool Creek floodplain areas cover a portion of the south and southwest corner of the Project Area.

Flood modelling maps are available through Queensland Globe (State of Queensland 2022c). Flood modelling mapping for a 1% AEP, or 1 in 100-year flood, are available. The mapping indicates that for a 1 in 100-year flood event, flooding may occur in Wallumbilla Creek and Yuleba Creek (5 km east of the Project Area) as well as in branching tributaries, including Washpool Creek and Middle Creek. Flooding of these tributaries during a 1 in 100-year flood event is identified in the southern extent of the Project Area. In tributaries, flood depths are generally less than 0.8 m, while in the main channels of Wallumbilla Creek and Middle Creek, flood depths are generally less than 2.0 m, but in some areas, such as at the Wallumbilla Creek and Middle Creek confluence, it can be greater than 2.0 m.

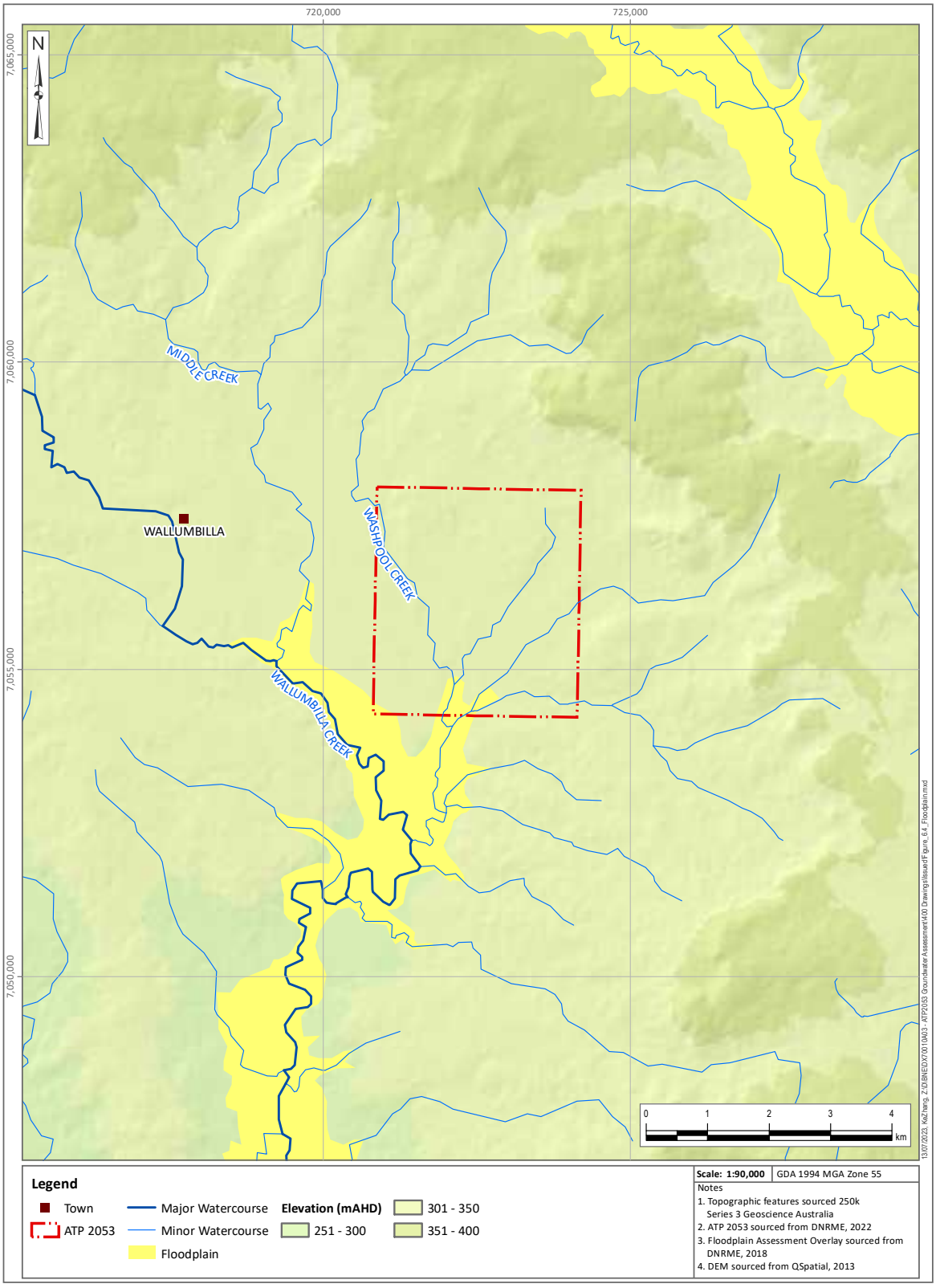


Figure 6.4 Floodplain Assessment Overlay – Flood Extent for 1% AEP

6.5 Surface Water Flow

6.5.1 Watercourse Classification

Hydrologic flow can be classified into three regimes; permanent, semi-permanent and ephemeral based on Kennard et al. (2010):

- Permanent: Stream discharge persists during both high-rainfall (typically summer wet season) and low rainfall (typically winter dry season) periods. During drought years, some 'cease to flow' periods may occur, however non-flowing, connected pools will persist throughout the waterway channel.
- Semi-Permanent: A watercourse that contains water for more than 70% of the time on average. These watercourses experience high discharges during heavy rainfall periods (i.e. summer wet season), however are typically reduced to a series of disconnected, non-flowing series of pools during the dry season.
- Ephemeral: These watercourses will typically only experience surface water flow during or immediately after heavy or sustained rainfall events (i.e. summer wet season). Following periods of flow surface water will persist in the form of non-flowing, disconnected pools separated by dry / exposed stream beds. Surface water (flowing or non-flowing) is only present for a small part of the hydrological cycle.

The watercourses within the Project Area are characteristically ephemeral and typically flow only during significant runoff events.

6.5.2 Flow and Discharge

There are no Department of Regional Development, Manufacturing and Water (DRDMW) surface water gauges located within the Project Area. The closest gauge in the relevant catchment (Balonne-Condamine) is located 32 km southeast of the Project Area. Table 6.2 provides details of this station, with its location shown on Figure 6.1 and a discussion of the data provided below.

Table 6.2 Summary of Surface Water Gauge (State of Queensland 2022c)

Basin	Sub-Basin	Gauge Number	Gauge Name	Easting[1]	Northing[1]	Status	Period of Operation	Location in Relation to Project Area
Balonne-Condamine	Upper Balonne River Tributaries	422219A	Yuleba Creek at Forestry Station	745678	7028063	Open	September 1972 to present	32 km SE, Downstream

[1]Coordinates in GDA94, Zone 55.

Yuleba Creek at Forest Station (422219A)

Surface water flow and stage height data is available for Yuleba Creek (422219A) between September 1972 and July 2022. The flow gauge is located 20 km upstream of the confluence of Yuleba Creek with the Balonne River.

The monthly median discharge for Yuleba Creek (422219A) is shown in Figure 6.5 and indicates the majority of flow occurring during December to March in response to wet season rainfall events, highlighting the highly ephemeral nature of the watercourse. Creek flow in the dry season (April to November) is generally zero or close to zero. The stage height data presented in Figure 6.6 highlights the seasonality of the flow in the creek.

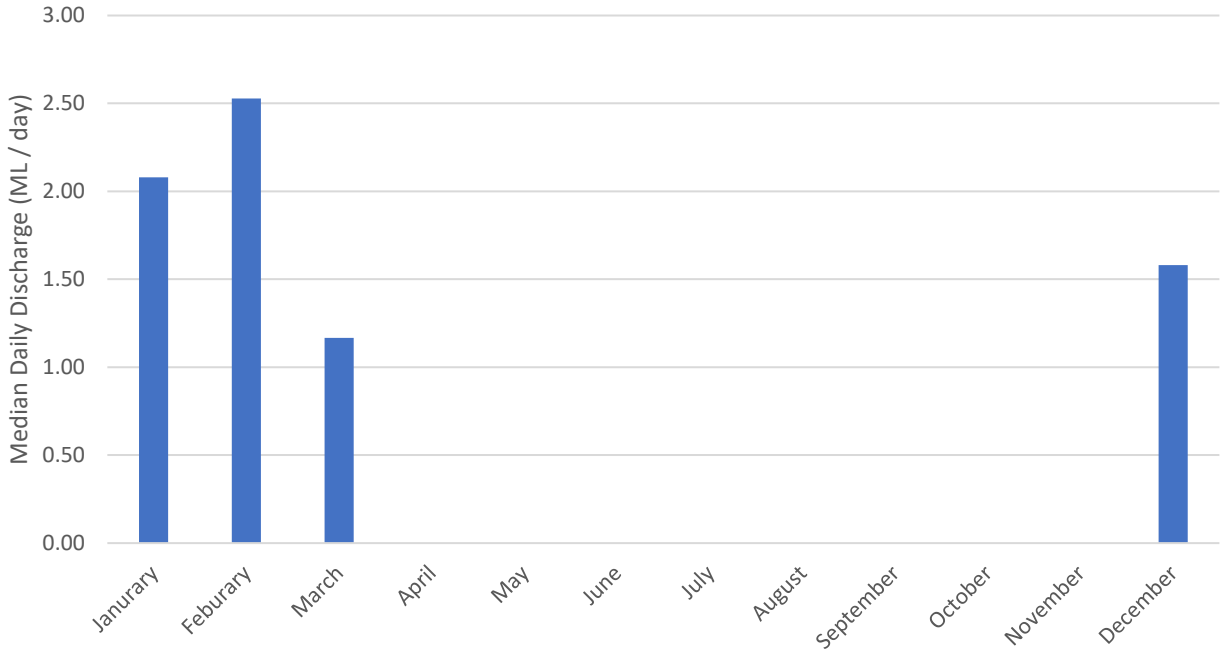


Figure 6.5 Monthly Mean Daily Discharge at Yuleba Creek at Forestry Station (422219A), 1972 to 2022

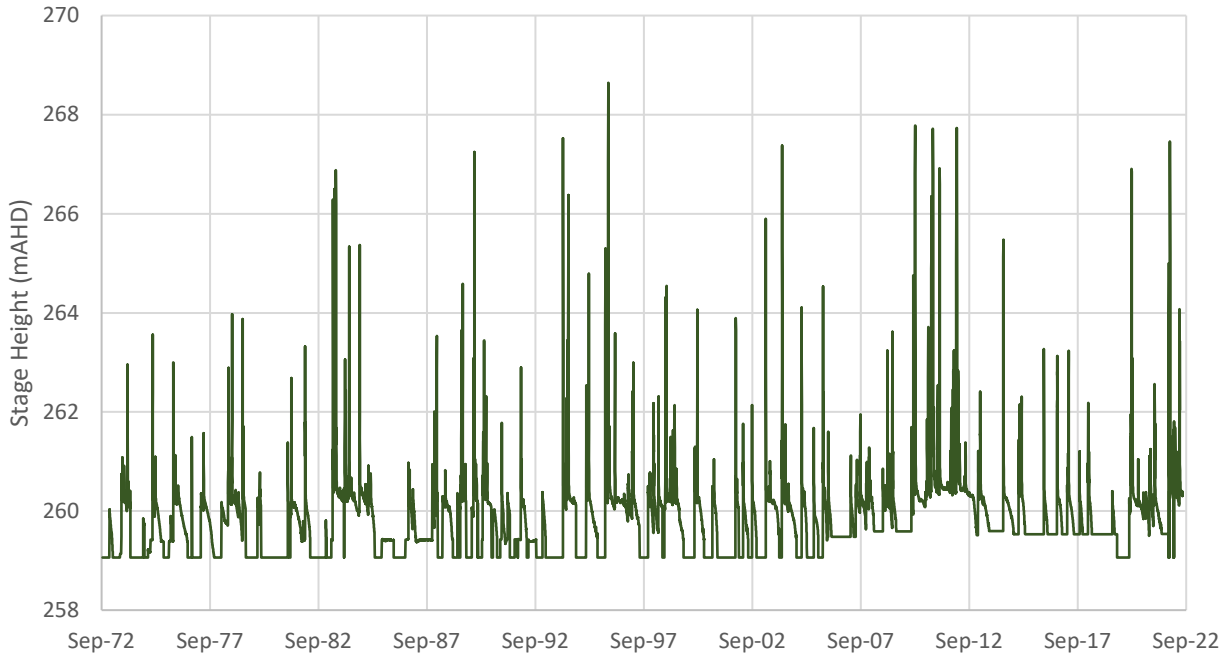


Figure 6.6 Stage Height at Yuleba Creek at Forestry Station (422219A), Downstream of the Project Area

The cumulative exceedance probability for the average daily recorded flow is shown in Figure 6.7 and indicates that flows are present in Yuleba Creek, downstream of the Project Area, for 27% of the gauged period. The flow, which is exceeded 5% of the time, is approximately 108 ML/day which is also identified as a flow equalled, or not exceeded 95% of the time, based on the available records. This highlights the ephemeral nature of the watercourse.

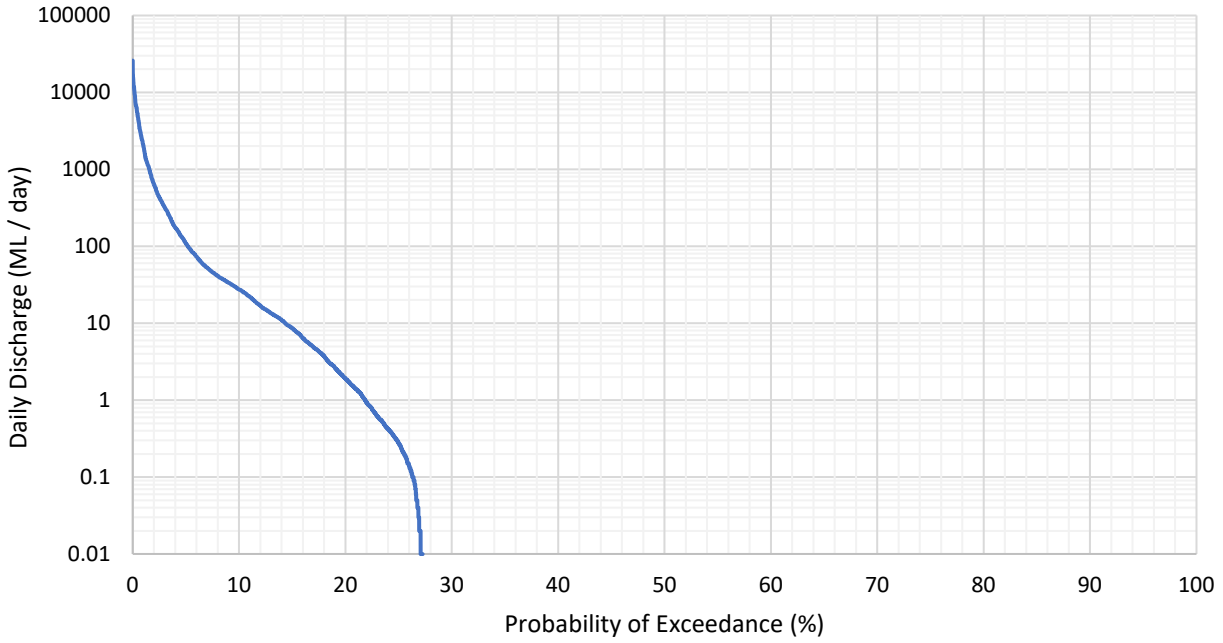


Figure 6.7 Cumulative Exceedance Probability for Recorded Daily Discharge at Yuleba Creek at Forestry Station (422219A)

6.5.2.1 Surface Water Quality

Surface water quality data was sourced from the Queensland Government for the flow gauge at Yuleba Creek at Forestry Station (422219A). Data is available between 1973 and 2010 and summarised in Table 6.3.

Table 6.3 Summary of Surface Water Quality for Yuleba Creek at Forestry Station (422219A)

Parameter	Count	5th Percentile	95th Percentile	Mean	Standard Deviation
Field EC @ 25°C	9	90.4	260.6	158.7	69.7
Turbidity (NTU)	6	55.3	100.0	87.8	21.5
Colour True (Hazen units)	4	24.7	70.0	52.8	23.6
Water Temperature (°C)	19	12.4	27.2	22.0	5.9
Field pH (pH units)	10	6.7	7.8	7.3	0.4
Total Alkalinity as $CaCO_3$ (mg/L)	10	20.5	102.4	52.2	31.2
TDS (mg/L)	10	61.2	227.5	127.9	62.1
Calcium as Ca soluble (mg/L)	10	4.7	19.6	9.9	6.1
Chloride as Cl (mg/L)	10	5.5	51.4	23.2	18.5
Magnesium as Mg soluble (mg/L)	10	2.0	8.9	4.7	2.8
Potassium as K (mg/L)	10	3.7	7.3	5.2	1.3
Sodium as Na (mg/L)	10	9.5	39.2	21.1	11.6
Sulfate as SO_4 (mg/L)	10	2.2	13.1	7.9	3.9
Fluoride as F (mg/L)	7	0.1	0.1	0.1	0.0
Iron as Fe soluble (mg/L)	7	0.4	5.5	2.7	2.1

Time series data is not available for Yuleba Creek (422219A), however intermittent electrical conductivity (EC) data is available from 1973 to June 2010 and is presented in Figure 6.8. The data shows the EC ranges between 72 and 455 µS/cm. The mean daily flows are also included in Figure 6.8 and highlights the relationship between the EC and surface water flow.

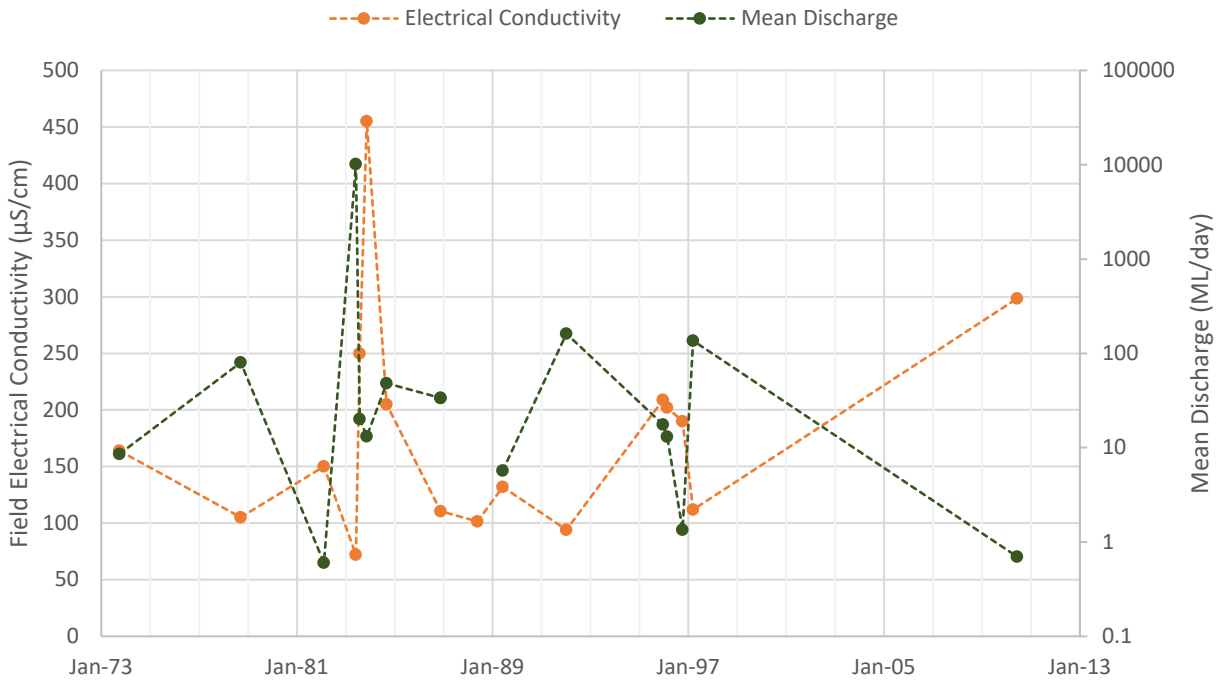


Figure 6.8 Electrical Conductivity from Yuleba Creek at Forestry Station (422219A)

Piper and Durov diagrams have been prepared for surface water quality monitored at Yuleba Creek (422219A) flow gauge Figure 6.9. The surface water is characterised as sodium-potassium - bicarbonate water type.

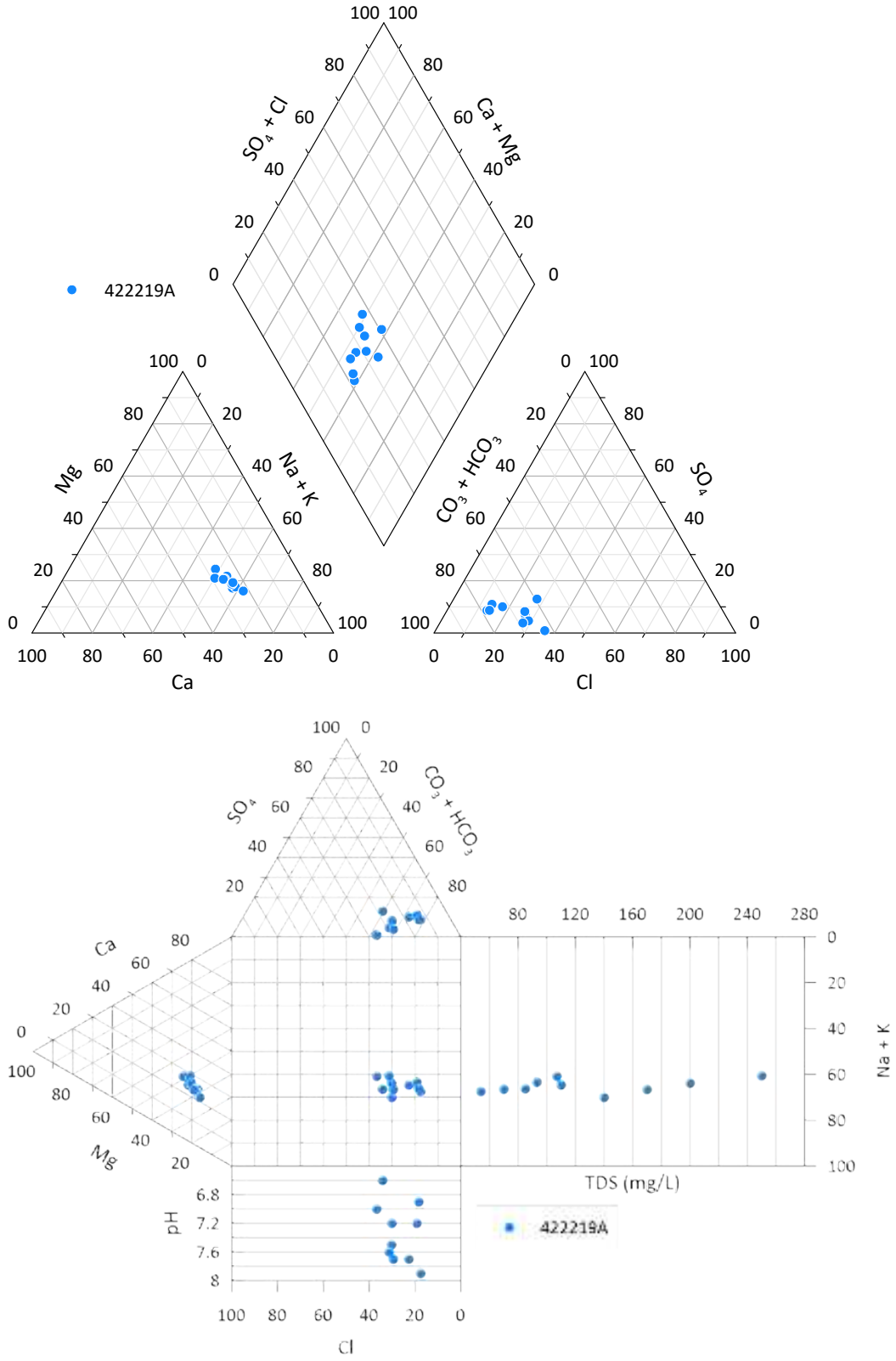


Figure 6.9 Piper and Durov Diagrams for Surface Water Samples from Yuleba Creek at Forestry Station (422219A)

6.6 Current Surface Water Stressors

Water management in the Condamine-Balonne catchment is described by the Murray-Darling Basin Authority (Commonwealth of Australia 2021). While a few main waterways of the Condamine-Balonne rivers catchment flow to the Barwon–Darling River system, most end in lakes and wetlands in southwest Queensland and northwest New South Wales.

The Condamine-Balonne catchment is home to almost 10% of the population of the Basin. Toowoomba, the largest centre, has a population of around 150,000. The region is significant for its agricultural diversity, with a wide range of winter and summer crops produced on the Darling Downs, as well as very large cotton production areas in the west.

The lands of the Condamine-Balonne catchment have been important to First Nations people for thousands of years. Many First Nations people retain a connection with the region, and their history, culture and livelihoods are closely intertwined with its river systems.

Land use in the catchment is dominated by cattle and sheep grazing on dryland pasture. Grain and cotton crops are a significant contributor to the regional economy and are grown under dryland and irrigated farming respectively.

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) reports, on average 53% of available surface water from the Condamine-Balonne catchment was extracted for use annually, which is extremely high compared with other catchments in the Basin. Surface water use is on average 82% of the total water use (surface and groundwater). The high level of use in the Condamine-Balonne catchment has significantly reduced end-of-system flows, particularly into the Narran Lakes system.

6.7 Aquatic Ecology

6.7.1 AquaBAMM Desktop Assessment

The aquatic habitat of watercourses in the Condamine-Balonne catchment comprises water channels during flowing conditions, as well as isolated perennial waterholes present during dry season. The lacustrine wetlands may also provide a habitat for aquatic fauna and flora. The watercourses across the Project Area are expected to be highly ephemeral, with streamflow only expected following rainfall events. Ephemeral streams can support invertebrate communities although flow intermittence has been linked to reduced taxa richness (Stubbington et al. 2017).

AquaBAMM is the state endorsed method for identifying and assessing wetlands in Queensland. AquaBAMM is also a decision support tool that utilises existing information and expert input to assess conservation value in aquatic ecosystems. The output of the AquaBAMM method is an Aquatic Conservation Assessment (ACA) for a specified study area (State of Queensland 2019e). The ACA for the wetlands of the Queensland Murray-Darling Basin was published in July 2011 (DERM 2011). ACAs provide a source of baseline, wetland conservation / ecological information to support natural resource management and planning processes. The ACAs assess riverine and non-riverine (palustrine and lacustrine) wetlands separately. The riverine or non-riverine wetlands within the sub-catchment units are then assigned an AquaScore based on an assessment of eight criteria. The criteria are:

- Naturalness aquatic;
- Naturalness catchment;
- Diversity and richness;
- Threatened species and ecosystems;
- Priority species and ecosystems;
- Special features;
- Connectivity; and
- Representativeness.

The AquaScore represents the overall conservation value of a sub-catchment unit and varies from very low to very high.

Wallumbilla and Yuleba Creeks, and their tributaries, are identified to have a medium to high riverine AquaScore. Non-riverine wetlands of limited extent with a very low to medium AquaScore are also indicated to occur at the Project Area. The upper catchment of Wallumbilla Creek (located to the northwest of the Project Area) has been identified as an area containing riverine 'special features' by flora, fauna and ecology expert panels. Special features are areas considered to be of the highest ecological importance (State of Queensland 2019).

6.7.2 Site-Specific Assessment

Ecological assessment of the Project Area, as documented by the EAR, included a desktop assessment followed by a field survey with a focus on verification of desktop findings. Additional findings of significance were also noted. No specific stream assessments were undertaken within the scope of works(Boobook 2024b).

The EAR (Boobook 2024b) does not identify MNES or MSES threatened aquatic fauna or flora to be present within the Project Area extent.

6.8 Existing Surface Water Users

Wallumbilla Creek occurs within Zone 2 of the Condamine – Balonne Tributaries Water Management Area (WMA), as defined under the Condamine-Balonne Water Resources Plan (State of Queensland 2019b). Yuleba and Wallumbilla Creeks occur within the Condamine and Balonne Tributaries WMA CBT-02, which is an unsupplemented surface water trading zone (where water entitlements for unsupplemented surface water (natural flow) may be traded). Tradeable water allocations in the Condamine and Balonne Tributaries Zone 2 total 22,162 ML/year (Figure 6.10).

Both creeks flow south before joining the Balonne River 50 km south of the Project Area within the Condamine-Balonne WMA – Zone CBU-07 (also an unsupplemented surface water trading zone). Details of CBU-07 are listed in Table 6.4.

Table 6.4 Water Management Area for Water Allocation (State of Queensland 2019f)

WMA	AMTD[2] (km)	Flow Management Location	Location in Relation to Project Area
CBU-07	466.8 – 405.2	The Balonne River, from the confluence of Yuleba downstream to Surat Weir	46 km south southeast

There are no surface water supply schemes present within 90 km of the Project Area and no surface water users within 15 km of the Project Area.

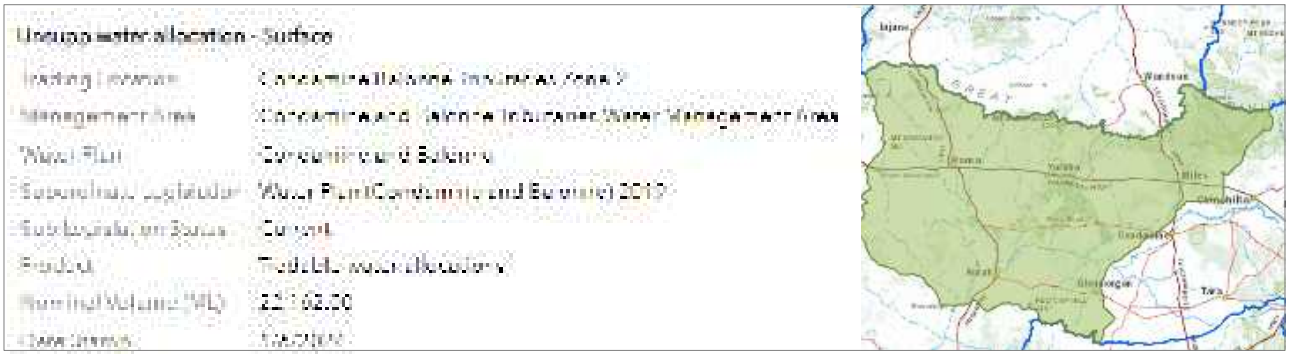


Figure 6.10 Unsupplemented Water Allocation – Condamine and Balonne Tributaries Zone 2

[2] Adopted Middle Thread Distance: the distance in kilometres, measured along the middle of the watercourse, that a specific point in the watercourse is from the water course mouth or confluence with a main water course

7 HYDROGEOLOGICAL SETTING

7.1 Geological Setting

7.1.1 Regional Geology

The Project Area is located within the geographical extent of the Surat Basin, a basin of Jurassic-Cretaceous age, which is underlain by the Permo-Triassic Bowen Basin. Cenozoic-age formations are present overlying the Surat Basin formations. The Bowen Basin, which contains up to 10 km of terrestrial and shallow marine sediments, is elongated, trending north-south, and extending over 160,000 km^2 from central Queensland, south beneath the Surat Basin, into New South Wales where it eventually connects with the Gunnedah and Sydney basins (PM Green 1997; Korsch Totterdell 2009 and OGIA 2019a). The southern Queensland and northern-most New South Wales portion of the Bowen Basin is overlaid by up to 2.5 km of Early Jurassic to Early Cretaceous Surat Basin sedimentary sequences (Fielding et al. 2000; Korsch and Totterdell 2009), followed by Cenozoic-age formations comprising unconsolidated alluvial sediments (sand, silt and clay), which have been deposited along pre-existing watercourses (OGIA 2019a).

The Surat Basin underlies approximately 180,000 km^2 of southeast Queensland and is connected to the Eromanga Basin in the west, the Clarence-Moreton Basin in the east and Mulgildie Basin to the northeast (KCB 2016). Deposition of the Surat Basin was relatively continuous and widespread. Deposition in the basin commenced with the onset of a period of passive thermal subsidence over much of eastern Australia. During the Early Jurassic, deposition was mostly fluviolacustrine, while, by the Middle Jurassic, coal swamp environments predominated over much of the basin, except in the north where fluvial sedimentation continued (Geoscience Australia 2017; OGIA 2016c).

There are currently no formally recognised sub-basins for either the Bowen or Surat Basins. However, the Bowen and Surat Basins are divided into distinct regions based on the structural features that control both the location and thickness of the sedimentary sequences. The Project Area is located in the Maranoa-Balonne-Condamine subregion, in the centre of the Surat CMA, on the far western flanks of the Taroom Trough (Exon 1976a). The surface geological map within the vicinity of the Project Area is shown in Figure 7.2.

The Taroom Trough is the major sediment depositional centre in the basin and extends throughout the Maranoa-Balonne-Condamine subregion (Draper 2013; Cadman, Pain, and Vuckovic 1998). It formed during crustal extension in the Late Carboniferous to Early Permian (McKellar 1998). The Taroom Trough is bounded to the east by a line of faults along the margins of basement blocks, created by the half-graben structure. Dips seldom exceed 15°, but fault displacements are as much as 2,000 m. The structures in the Bowen Basin are generally reflected in the overlying Surat Basin sequence.

7.1.2 Geological Structures

The Hutton-Wallumbilla Fault is a regional scale fault trending in an northwest-southeast direction; with the displacement on the fault reported as 450 m in the Bowen Basin units, but less than 100 m in the overlying Surat Basin units (Draper 2013).

Major deformation occurred in the late Triassic with reactivation after the deposition of the Surat Basin sediments. Copley et al. (2017) suggest that the fault was reactivated in the Cenozoic, but with only a small fraction of the amplitude of the Triassic deformation.

The southeasterly extent of the Hutton-Wallumbilla Fault is indicated to occur 4 km northwest of the Project Area. Structural elements directly within the Project Area are discussed in Section 7.2.

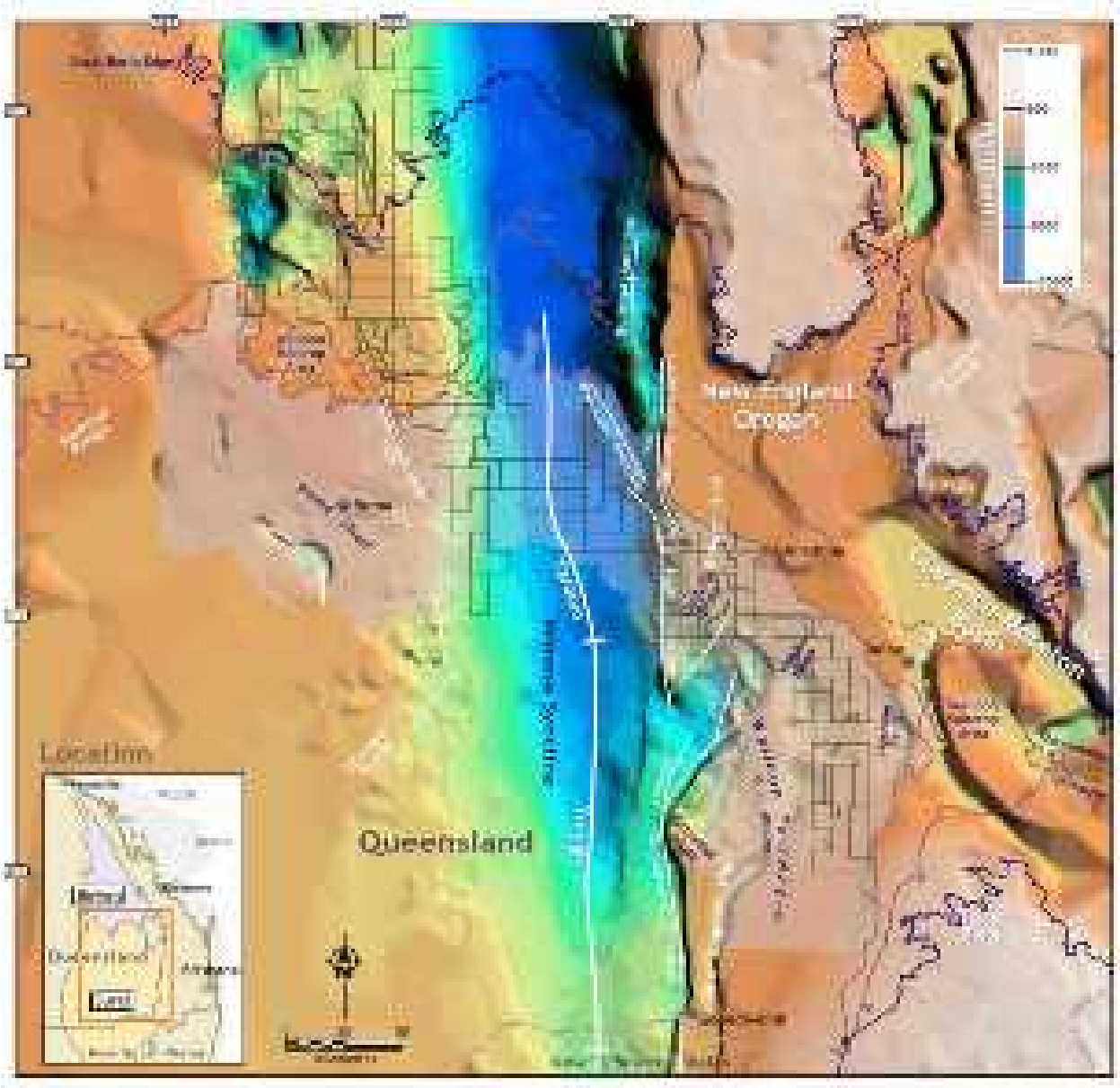


Figure 7.1 Key Structural Features of the Surat Basin (Frogtech 2012; Origin Energy 2023)

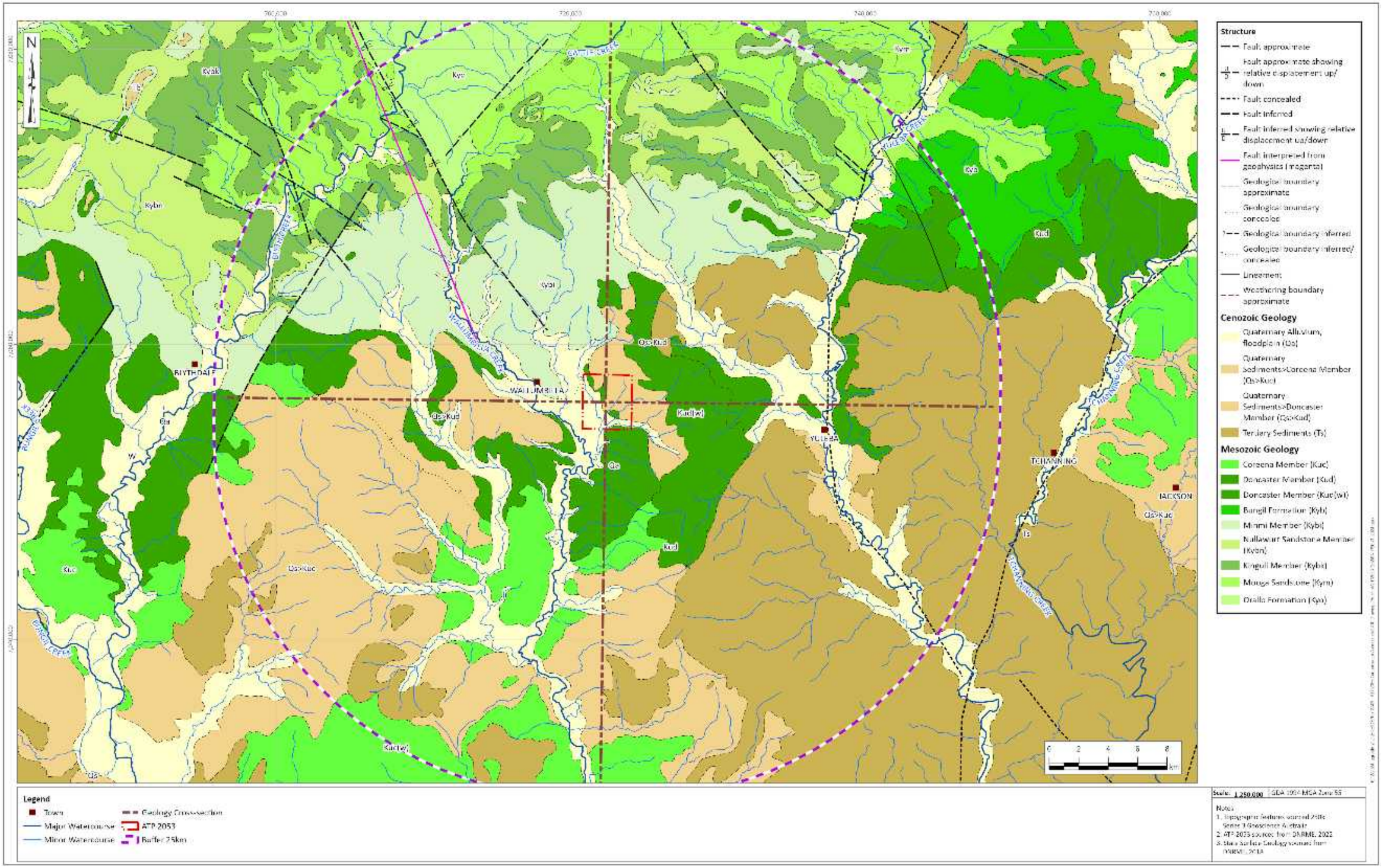


Figure 7.2 1: 100,000 Surface Geology and Cross Section Locations in Vicinity of the Project Area (State of Queensland 2018b)

7.1.3 Regional Hydrostratigraphy

The Surat Basin forms part of the Great Artesian Basin (GAB), which comprises several aquifers and confining aquitards. Aquifers of the Surat Basin are a significant source of water used for stock, public water and domestic supply.

OGIA (OGIA 2021h) presents the hydrostratigraphy of the Surat and Bowen Basin as shown in Table 7.1. Stratigraphic units of relevance to the Project Area include:

- Quaternary alluvial deposits located along Wallumbilla Creek and major tributaries;
- Cenozoic sediments;
- Cretaceous sediments of Wallumbilla Formation and Blythesdale Group; and
- Jurassic aged sediments of the Gubberamunda Sandstone, Westbourne Formation, Springbok Sandstone, the WCM, Eurombah / Durabilla Formation, Hutton Sandstone, Evergreen Formation and Precipice Sandstone.

OGIA have collected an additional 4,000 permeability measurements since 2019 and have reclassified formations to account for heterogeneity present in the hydrostratigraphic units. The definitions as proposed by OGIA (OGIA 2021h) are:

- *Regional aquifer*: high transmissivity, bore yields that are vertically and laterally consistent at a regional scale, e.g. Precipice Sandstone;
- *Partial aquifer*: medium transmissivity, bore yields that are vertically and laterally inconsistent at a regional scale and exhibiting a high degree of heterogeneity, e.g. Hutton Sandstone;
- *Tight aquifer*: medium to low transmissivity, bore yields that are regionally inconsistent and exhibiting a high degree of heterogeneity e.g. Springbok Sandstone;
- *Interbedded aquitard*: similar to a tight aquifer but with thin, spatially limited water-yielding zones are interbedded in an otherwise tight aquitard, e.g. WCM; and
- *Tight aquitard*: predominantly low permeability, regionally extensive and thick formations.

Table 7.1 Stratigraphic Column for the Project Area (OGIA 2021h)

Age		Formation			Hydrostratigraphic Description (OGIA 2021)		Relevance to Project Area	
Quaternary		Alluvium			Partial Aquifer		Mapped associated with watercourses	
		Unconsolidated sediments					Deposits across Project Area	
		Tertiary Sediments					3 km to the northeast and 8 km to east	
Cretaceous	Early	Wallumbilla Formation	Coreena Member		Tight Aquitard	Partial Aquifer	Outcrops 7 km south	
			Doncaster Member			Tight Aquitard	Outcrops within Project Area	
		Blythesdale Group	Bungil Formation	Kingull Member	Partial Aquifer		Outcrops 9 km north	Outcrops 20 km northwest
				Minmi Member			Outcrops 2 km north	
				Nullawurt Sandstone Member			Outcrops 14 km northwest	
			Mooga Sandstone		Regional Aquifer		Outcrops 16 km north	
			Orallo Formation		Tight Aquitard		Outcrops 26 km north	
Jurassic	Late		Gubberamunda Sandstone		Regional Aquifer		Outcrops 31 km north	
		Westbourne Formation			Tight Aquitard		Outcrops 33 km north	
		Springbok Sandstone			Tight Aquifer		Outcrops 38 km north	
	Middle	Walloon Subgroup	Walloon Coal Measures		Productive Coal Seam		Target CSG formation	
			Eurombah / Durabilla Formation		Tight Aquitard		Underlying aquitard of regional relevance	
		Hutton Sandstone	Upper Hutton Sandstone		Partial Aquifer		Underlying aquifer of regional relevance	
			Lower Hutton Sandstone		Tight Aquifer			
	Early	Evergreen Formation	Upper Evergreen FM		Tight Aquitard		Regional Relevance	
			Boxvale Sandstone		Partial Aquifer			
			Lower Evergreen FM		Tight Aquitard			
		Precipice Sandstone			Regional Aquifer		Regional Relevance	

A summary of each of these units is provided in the following sections (from youngest to oldest).

Alluvium *Partial / Regional Aquifer*

Quaternary-age alluvium is mapped as occurring within the Project Area (Figure 7.2). These alluvial deposits are associated with Washpool Creek, Middle Creek and Wallumbilla Creek and associated major tributaries. The alluvium consists of unconsolidated clay, silt, sand and gravel. The sediments in major river channels in the Surat CMA are typically between 14 - 26 m thick and narrow (OGIA 2019a), with the alluvium thickness decreasing in the smaller tributaries.

No bores within the Project Area are screened in the alluvium, thus the alluvial thickness is not known for Washpool Creek, Middle Creek and Wallumbilla Creek.

Cenozoic Sediments *Not Specified*

Thin accumulations of Cenozoic unconsolidated and semi-consolidated residual and colluvial sheetwash sediments occur within, and in the vicinity of the Project Area, at thicknesses of less than 50 m (OGIA 2019a).

The Wallumbilla Formation *Partial Aquifer (Coreena Member Only)*

The Wallumbilla Formation is sub-divided in two sequences, the Coreena and Doncaster Members. The upper Member (Coreena) is siltstone-dominated with minor coal seams. The lower Member (Doncaster) is mudstone dominated (OGIA 2016a).

The Coreena Member comprises interbedded siltstone, mudstone and fine to very fine-grained labile sandstone, limestone and coal deposited from shallow marine lagoons, shoreline swamps and estuaries, most likely reflecting a regional marine regression. The siltstone is in part calcareous, grading to silty limestone. The thickness of the Coreena Member averages 70 m and is conformably overlain by the Surat Siltstone (OGIA 2016a).

The Doncaster Member (which outcrops / sub-crops in the Project Area) comprises dominantly blue-grey mudstone with glauconitic siltstone and fine-grained sandstone. The Doncaster Member accumulated with a rapid marine transgression with deep water conditions in the centre of the basin, grading to shallow marine coastal environments around the margins (Exon 1976). Average thickness of the member is between 100 m and 150 m(OGIA 2016a).

The Doncaster Member of the Wallumbilla Formation is a tight aquitard. The Coreena Member is a partial aquifer.

The Bungil Formation *Partial Aquifer*

The Bungil Formation conformably overlies the Mooga Sandstone and outcrops 20 km northwest of the Project Area. This unit comprises interbedded fine-grained lithic sandstones, siltstones and mudstones with minor quartzose sandstone present. Day (1964b) identified three members: the Minmi, Nullawurt Sandstone and Kingull members, however, these are not easily recognised in the subsurface (Green et al. 1997, Exon 1976). Deposition of the Bungil Formation represents the initial marine transgression into the Surat Basin (OGIA 2016a). The Bungil Formation is considered as an aquifer.

The Mooga Sandstone *Regional Aquifer*

The Mooga Sandstone generally conformably overlies the Orallo Formation, with local disconformities (Exon 1976b). Deposits tend toward fine to medium grain size sand, although siltstones, mudstones, and shale are present (Exon 1976b). The Mooga Sandstone is at the base of the fifth major sedimentary cycle in the Surat Basin and was deposited in southwesterly flowing braided to meandering stream environments. (Exon 1976) recognised three major sub-units in outcrop. The upper Mooga Sandstone and lower Mooga Sandstone are considered aquifers. The middle Mooga Sandstone consists of siltstones, mudstones, and shale and is considered an aquitard. The Mooga Sandstone is considered a regional aquifer.

The Orallo Formation *Tight Aquitard*

The Orallo Formation conformably overlies the Gubberamunda Sandstone. It was deposited in a relatively low energy fluvial environment with local ponding (Green 1997). The Orallo Formation consists of fine to coarse-grained sandstone interbedded with clay, siltstone, silty mudstone, bentonite clay, and coal (OGIA 2016a). The Orallo Formation is considered a tight aquitard.

Gubberamunda Sandstone *Regional Aquifer*

Regionally, the Gubberamunda Sandstone conformably overlies the Westbourne Formation, but locally, is disconformable, particularly around the margins of the basin (Green 1997). It was deposited by braided and meandering stream systems draining surrounding highlands (Exon 1976). Consistent with a fluvial depositional environment, repeated packages of siltstone and fine to coarse sandstone were deposited. Deposits of carbonaceous shale along with minor coal fragments are typically present. The Gubberamunda Sandstone is considered a usable aquifer.

Westbourne Formation *Tight Aquitard*

The Westbourne Formation conformably overlies the Springbok Sandstone. It was deposited in an environment with characteristics consistent with a low energy, lacustrine deltaic plain (Green 1997). The Westbourne Formation comprises predominately siltstone layers with thick interbeds of fine to medium-grained sandstone and minor mudstone. Small coal fragments, lenses and lamina are common throughout the formation. Within the GAB sequence, the Westbourne Formation is considered an aquitard.

Springbok Sandstone *Tight Aquifer*

The Springbok Sandstone overlies the WCM and was deposited by streams and includes overbank and swamp deposits in the upper part of the unit which indicates streams becoming less energetic with time (Exon 1976). The Springbok Sandstone consists mostly of feldspathic sandstones, commonly with calcareous cement (Green 1997). At the basin scale, the sandstones range from very fine to coarse-grained, although some very coarse-grained, poorly sorted pebbly beds also occur. Minor interbedded siltstones, mudstones, and thin coal seams are also present, primarily in the upper part of the unit. Within the GAB, the Springbok Sandstone is considered a usable water source, however it is highly variable in hydraulic properties and yield across the basin. The Springbok Sandstone also has a very high content of mudstone and siltstone at many locations with very low permeability (OGIA 2016a).

The Walloon Coal Measures *Productive Coal Seam; Interbedded and Leaky Aquitard*

The WCM of the Surat Basin are the target gas production formation for the Project. Within the WCM, the two coal-dominated formations are the Juandah Coal Measures and the Taroom Coal Measures, as presented in Figure 7.3. A low permeability sandstone, siltstone and mudstone typically forms the base and is known as the Durabilla / Eurombah Formation. The WCM were deposited in a low energy meander-belt river system, with the coal layers deposited mainly in an overbank environment (Exon 1976). Comprising of very fine to medium-grained argillaceous, siltstone, mudstone, and coal with minor calcareous sandstone, impure limestone, and ironstone (Swarbrick 1973). Typically, the coal layers are positioned in the upper half to three-quarters of the coal measures, with mudstones, siltstones and lithic sandstones dominant in the lower part. At a regional scale the WCM are considered an interbedded aquitard (OGIA 2021h).

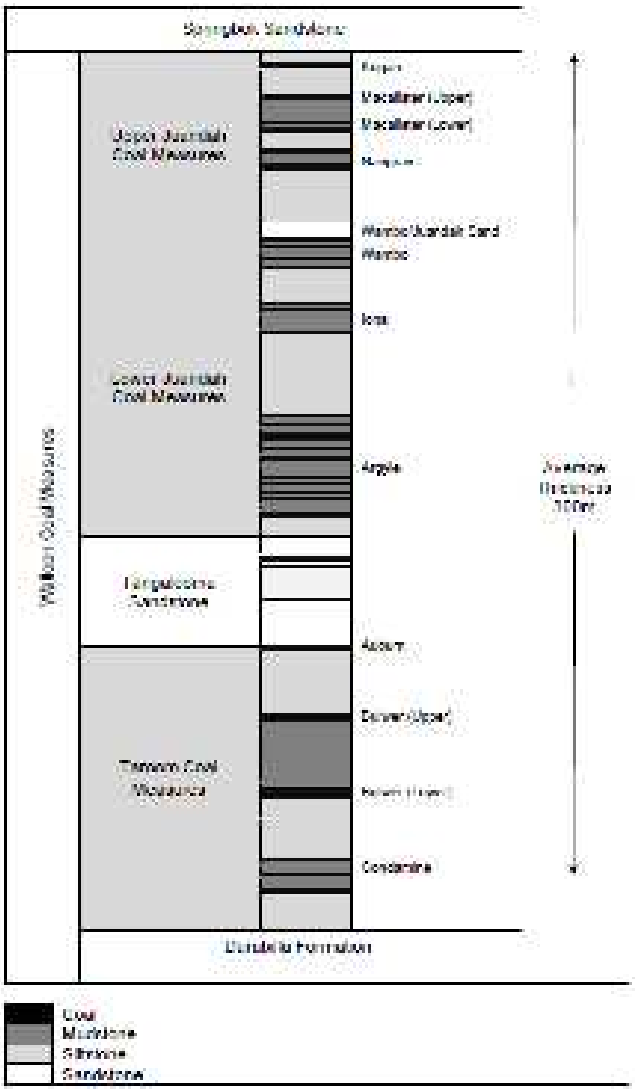


Figure 7.3 Stratigraphy of the WCM (OGIA 2021g) after (Hamilton, Esterle, and Sliwa 2014)

The Surat Basin is underlain by sediments of the Bowen Basin at depth. The Bowen Basin contains the Late Permian aged Bandanna Formation which is another coal-bearing horizon. The Bandanna Formation is not targeted for gas production by the Project.

Eurombah / Durabilla Formation *Tight Aquitard*

The Eurombah Formation, often referred to as the Durabilla Formation, conformably overlies the Hutton Sandstone. The depositional environment for this unit was fluvial with periods of rapid sedimentation. It is often difficult to differentiate the Eurombah Formation from the WCM. It is more restricted in extent than either the Hutton Sandstone or the WCM (Green 1997). The Eurombah Formation is considered an aquitard, consisting of siltstone, mudstone and fine to medium-grained poorly sorted sandstone, with almost no coal and consequently, little permeability (OGIA 2016a).

The Hutton Sandstone *Partial / Tight Aquifer*

The Hutton Sandstone was deposited in a non-marine environment by meandering streams on a broad floodplain (Exon 1976b) and consists mainly of sandstone with interbedded siltstone, shale, minor mudstone, and coal. The sandstone is white to light grey, fine to medium-grained, well sorted, generally quartz rich, partly porous with some pebble bands, shale, and siltstone clasts in the lower part. Siltstones and shales are light to dark grey, micaceous, carbonaceous and commonly interlaminated with very fine-grained sandstone (Green 1997). It is highly heterogeneous, with sand bodies limited in vertical and lateral extent.

The Evergreen Formation *Tight Aquitard*

The Evergreen Formation conformably overlies the Precipice Sandstone and separates the Precipice Sandstone from the Hutton Sandstone. The upper and lower Evergreen Formations are considered aquitards and generally consists of mudstones laminated with fine-grained sandstone, siltstone and shale (Green 1997).

The Precipice Sandstone *Regional Aquifer*

The Precipice Sandstone is the basal unit of the Surat Basin, which overlies the Moolayember Formation and sedimentary sequences of the Bowen Basin. Lower and upper sub-units are recognised, often separated by a siltstone or shale unit. The layers with the coarsest grain sizes were deposited by transverse bars in a braided stream system and the sediment layers with finer grain sizes were deposited in a lower energy fluviatile meandering system (Martin 1981). The lower subunit, also known as the Precipice Braided Stream Facies (or Precipice BSF), consists of white, fine to very coarse-grained, in part pebbly, thin to very thickly bedded, porous, quartz rich sandstone with a white clay matrix (Exon 1976b).

7.2 Local Hydrogeology

Quaternary-age alluvium (Qa) is mapped to the west and within the Project Area. Cenozoic sediments comprising Quaternary-Tertiary aged residual / colluvium is present in the east of the Project Area while the underlying Doncaster Member of the Wallumbilla Formation outcrops in the centre and to the northwest of the Project Area.

Alluvium and Tertiary Deposits

Alluvium in the vicinity of the Project Area is associated with Wallumbilla Creek, Washpool Creek and Middle Creek and associated tributaries. As discussed in Section7.1.3, no bores within the Project Area are screened within the alluvium or Tertiary age deposits, thus a thickness for these units cannot be verified.

Surat Basin Units

The Doncaster Member of the Wallumbilla Formation outcrops within the Project Area and underlies the Quaternary-Tertiary aged sediments, while the Coreena Member, also of the Wallumbilla Formation, is mapped as outcropping southwest and south of the Project Area. The Bungil Formation underlies the upper Cretaceous units and outcrops to the north of the Project Area. Successively older geological units outcrop in a northerly direction, with distance from the Project Area.

Two cross-sections, orientated north-south and west-east through the Project Area are presented in Figure 7.4. The location of the cross-sections is shown on Figure 7.2. These sections have been prepared using the OGIA groundwater model geometry (OGIA 2021b).

The north-south section indicates that the WCM dips in a southerly direction and occurs between 350 m and 650 m beneath the surface; and, has a mean thickness of 243 m.

Table 7.2 presents the mean thickness for each of the underlying hydrostratigraphic units within the Project Area. Isopachs for the key hydrostratigraphic units are presented in Figure 7.5, with the top of the unit elevation presented in Figure 7.6.

Both cross-sections indicate the thickness of the Quaternary / Tertiary aged sediments and underlying Wallumbilla Formation to be limited across the Project Area; with the Wallumbilla Formation shown in Table 7.2 to have a mean thickness of 2.8 m in the Project Area. These surficial units are separated from the WCM by the tight aquitards of the Orallo and Westbourne Formations, while the Durabilla and Evergreen Formations underlie the WCM. The abovementioned aquitards are observed to be laterally and vertically extensive within and beyond the Project Area, with mean thicknesses of 51 m and 198 m, respectively.

There are no major geological structures (e.g., faults) identified within the Project Area. Five 2D seismic lines are available across the Project Area, with a selection of representative seismic survey results presented in Figure 7.7. Seismic sections extend to include the WCM and the deeper-seated Bandanna Formation.

Table 7.2 Aquifer / Aquitard Thicknesses within the Project Area (OGIA 2021g)

Hydrostratigraphic Unit	Aquifer / Aquitard	Mean Thickness (m)
Wallumbilla Formation (Doncaster Member)	Tight Aquitard	2.8
Bungil Formation	Partial Aquifer	120.3
Mooga Sandstone	Regional Aquifer	90.2
Orallo Formation	Tight Aquitard	198.3
Gubberamunda Sandstone	Regional Aquifer	61.9
Westbourne Formation	Tight Aquitard	63.0
Springbok Sandstone	Tight Aquifer	112.9
Walloon Coal Measures	Productive Coal Seams	243.6
Eurombah / Durabilla Formation	Tight Aquitard	51.6
Hutton Sandstone	Partial / Tight Aquifer	243.6
Evergreen Formation	Tight Aquitard	161.2

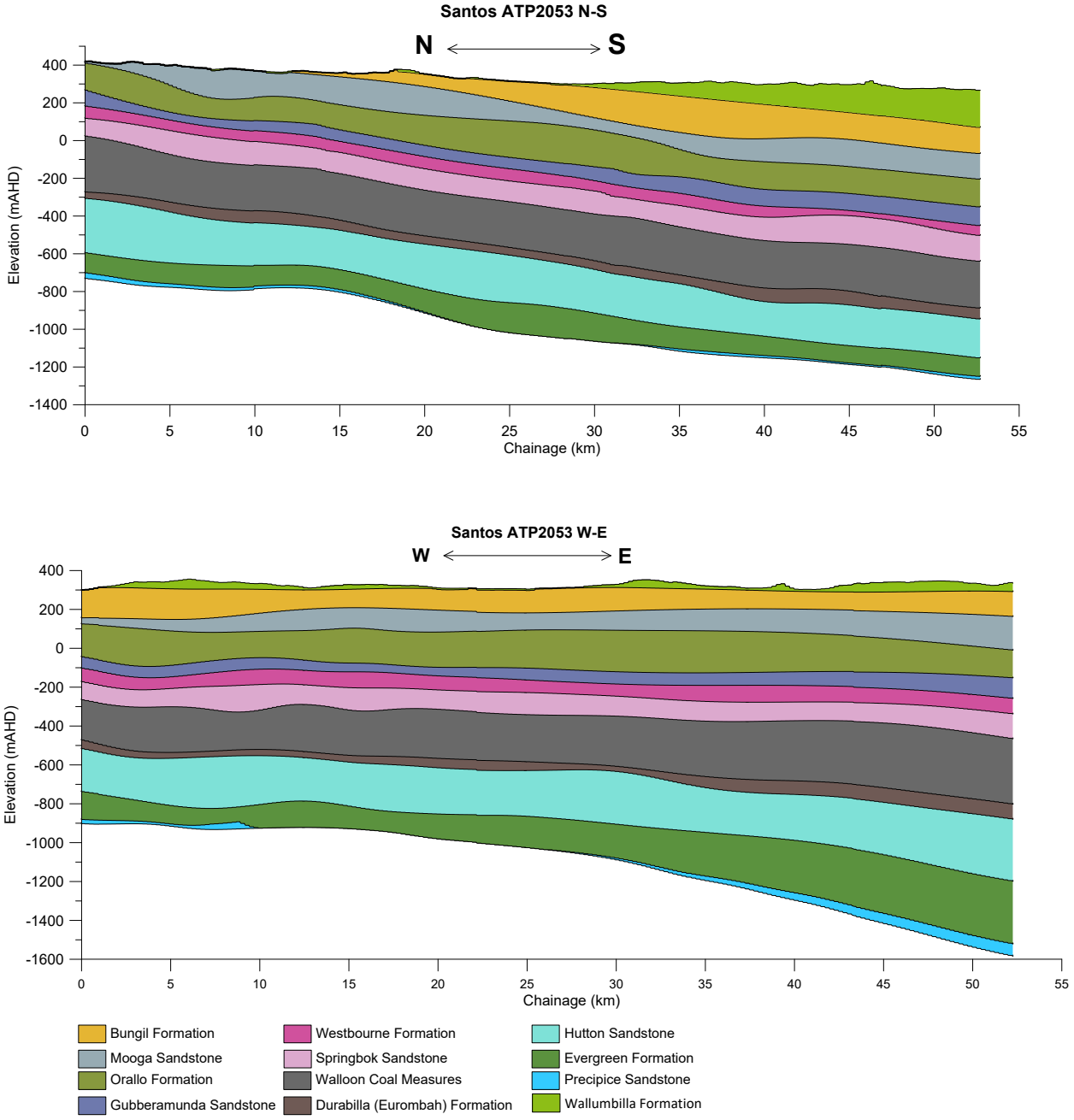


Figure 7.4 N-S and E-W Orientated Geological Cross-Sections of the Project Area

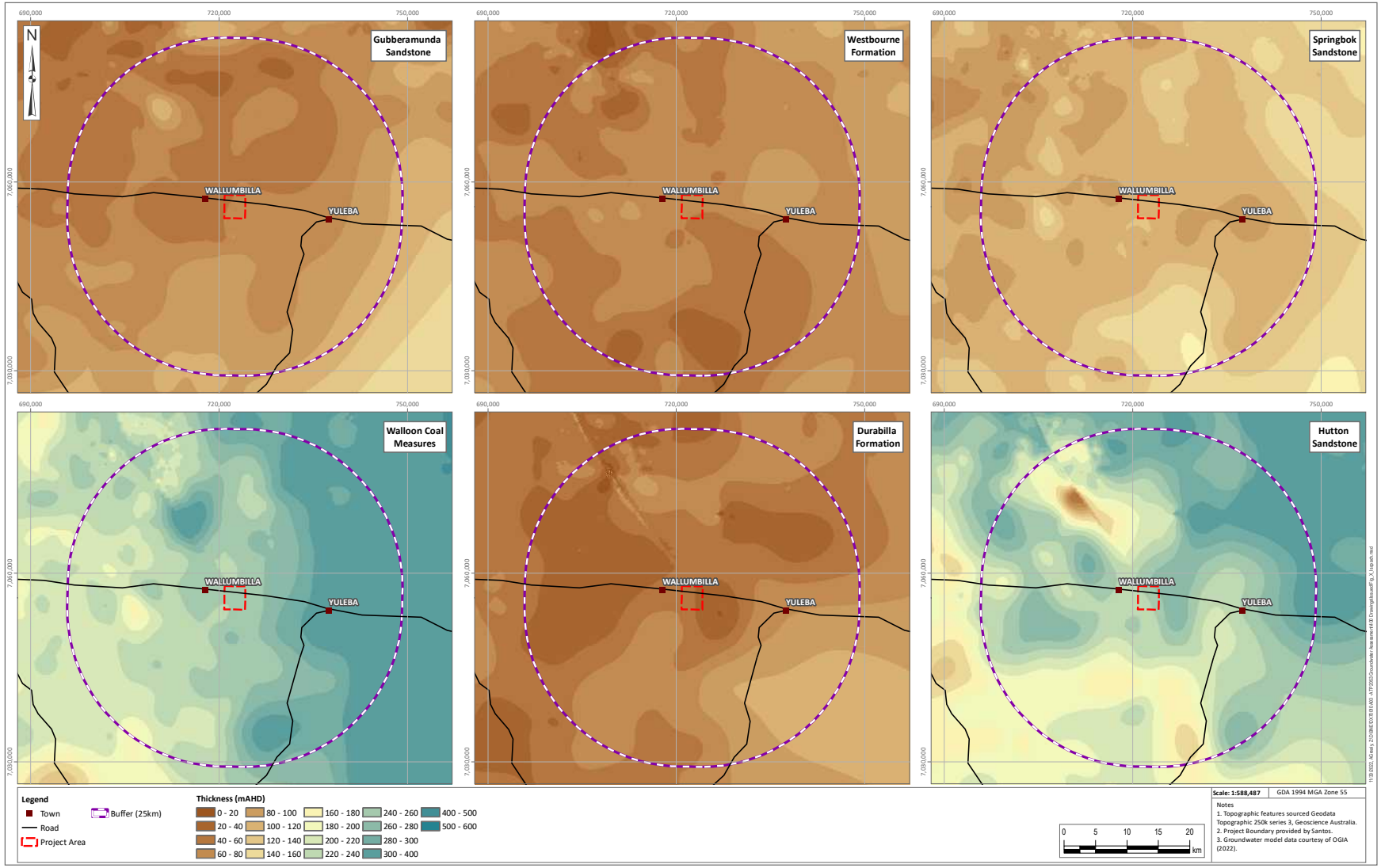


Figure 7.5 Formation Isopachs for Relevant Surat Basin Units (OGIA 2021g)

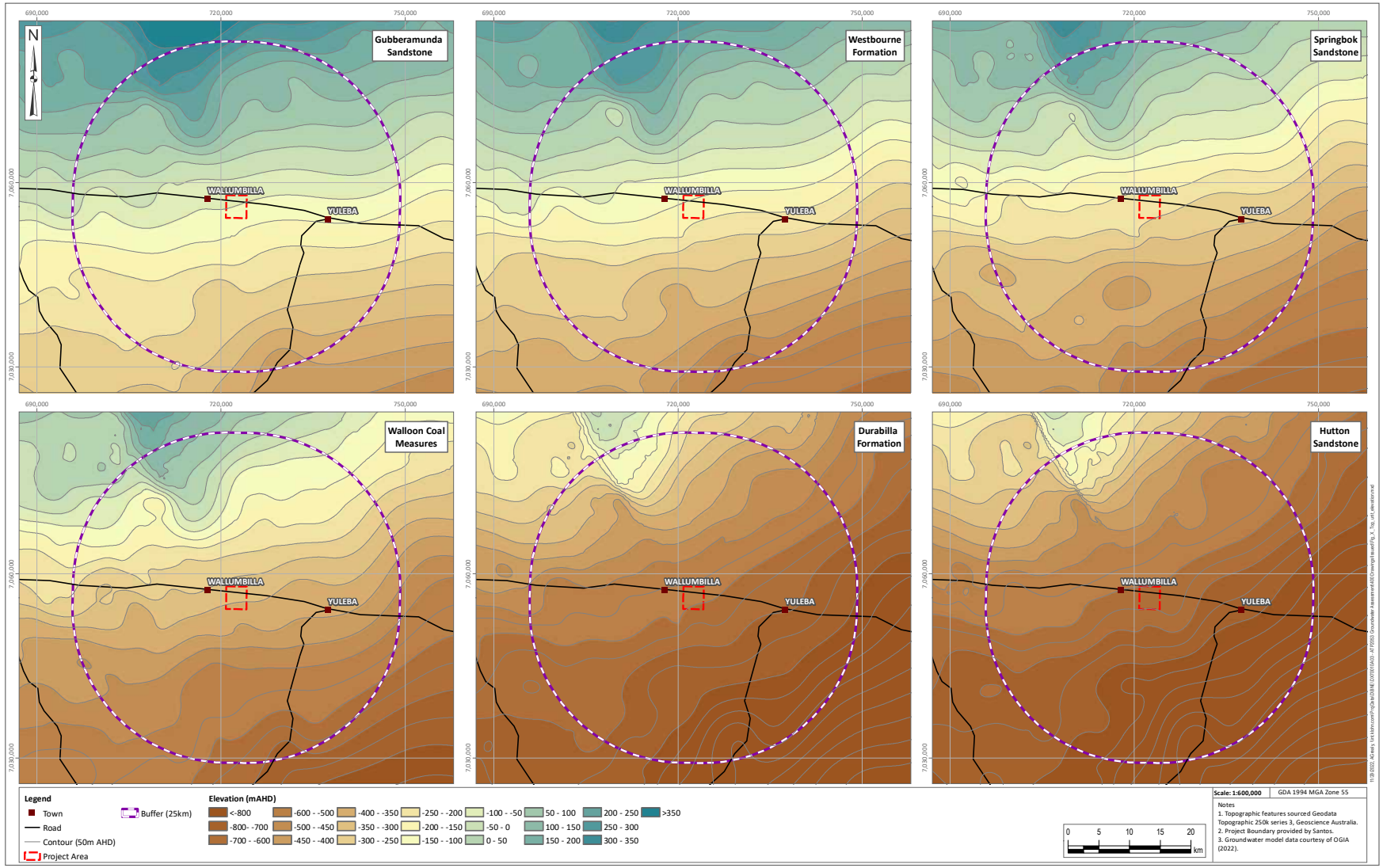


Figure 7.6 Top of Unit Elevation for Relevant Surat Basin Units (OGIA 2021g)

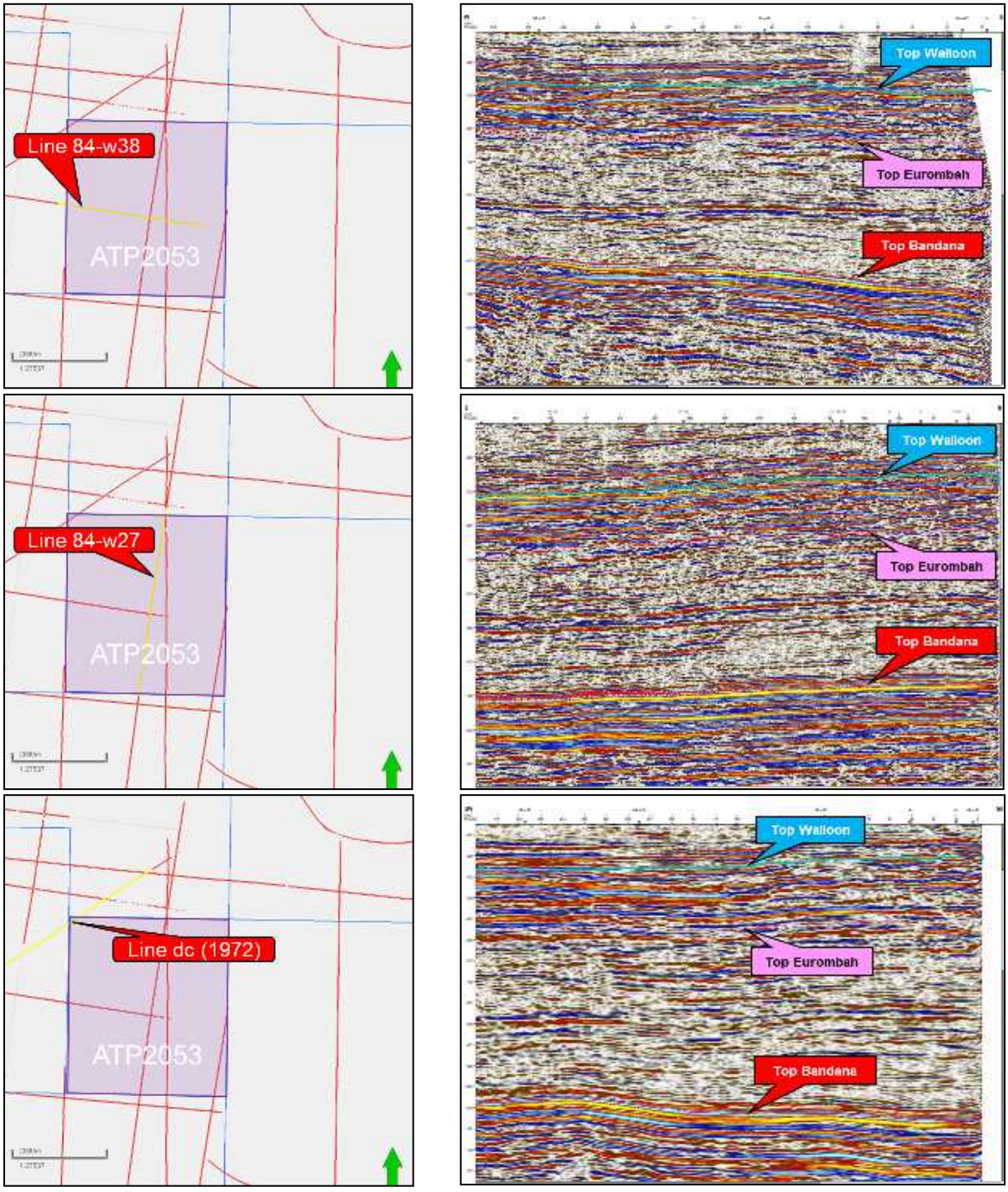


Figure 7.7 Selected Seismic Surveys and Interpretations Across the Project Area

7.3 Aquifer / Aquitard Hydraulic Properties

A number of hydraulic tests, to determine hydraulic properties of the hydrosratigraphic units, have been conducted across the Surat Basin on formations overlying and underlying the WCM. Site-specific data was not available at the time of reporting.

OGIA (OGIA 2019a) present a range of hydraulic conductivities, which have been estimated from core, drill stem tests (DSTs) and pumping tests within the Surat CMA.

The data was compiled as part of the 2016 UWIR (OGIA 2016b) from a range of sources including the GWDB, Queensland Petroleum Exploration Database (QPED), GAB Water Resource Assessment (Smerdon et al. 2012) and public domain sourced investigations undertaken by other CSG proponents.

Figure 7.8 presents the measured hydraulic conductivities presented in the 2019 OGIA UWIR(OGIA 2019d). The figure also presents the pre- and post-calibrated groundwater model ranges for each formation.

The hydraulic properties presented in the 2019 UWIR, are discussed further in the Hydrogeological Conceptualisation Report for the Surat CMA (OGIA 2016b); which includes the location and value of the hydraulic property data points for each of the hydrostratigraphic units of the Surat CMA. Ranges of horizontal hydraulic conductivities from these tests, together with model calibrated values indicate that the Gubberamunda and Precipice Sandstones are the most permeable consolidated formations in the Surat CMA Figure 7.8.

A summary of the information collated and presented in (OGIA 2019d)(OGIA 2019a) is provided in Table 7.3.

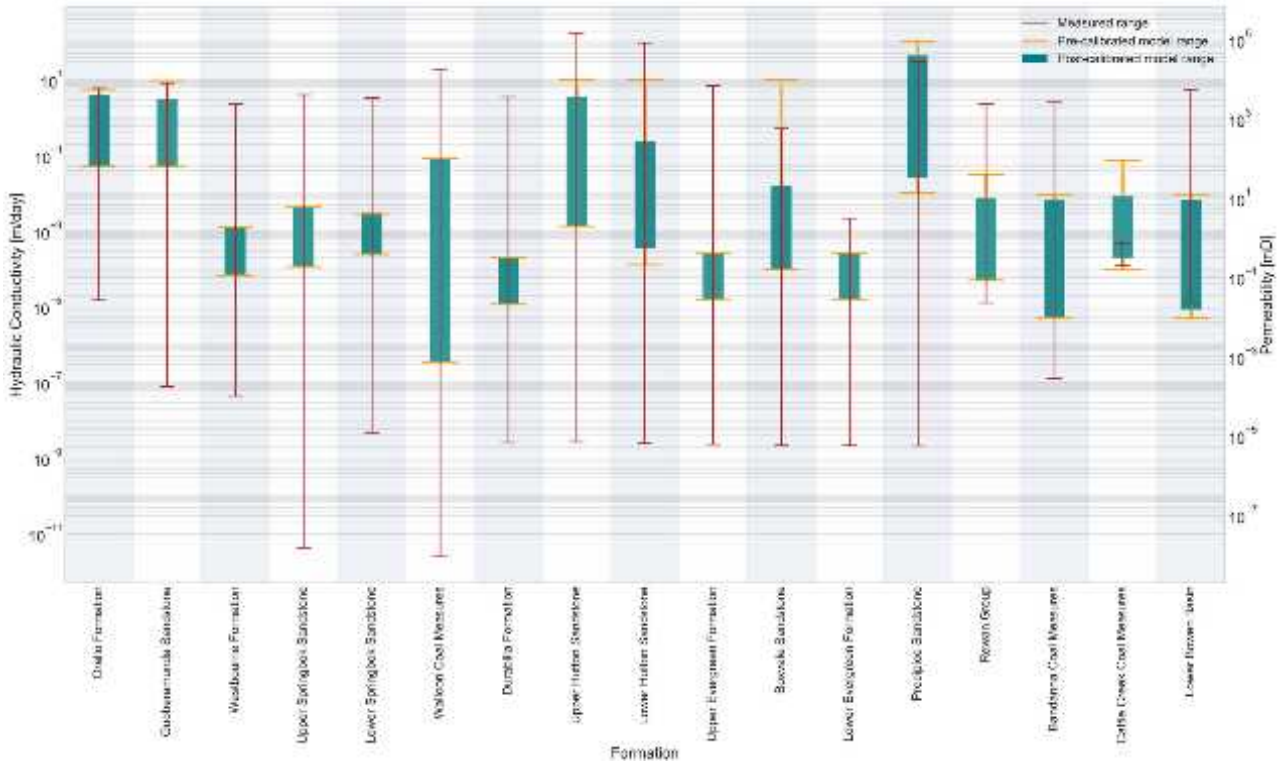


Figure 7.8 UWIR Hydraulic Conductivity Estimations (OGIA 2019a)

Table 7.3 Summary of Hydraulic Properties for Hydrostratigraphic Units in the Surat CMA (OGIA 2016b; 2019a)

Unit	Summary
Alluvium	Hydraulic conductivity of alluvial aquifers ranges between 2 and 116 m/day (10^{th} and 90^{th} percentiles), with a median value of 16 m/day.
Wallumbilla Formation	Horizontal hydraulic conductivity is reported between 8.00 x 10^{-5} and 1.25 m/day (core, DST and pumping test data), with median values reported between 3.31 x 10^{-4} and 4.72 x 10^{-2} m/day.
Bungil Formation	Hydraulic conductivity values are reported between 6.18 x10^{-5} and 1.52 m/day (core, DST and pumping tests). Median values range between 5.80 x 10^{-3} and 6.37 x 10^{-2} m/day.
Mooga Sandstone	Hydraulic conductivity values are reported between 3.59 x 10^{-3} and 2.86 m/day (core, DST and pumping test data). Median values range between 7.37 x 10^{-2} and 1.20 x10^{-1} m/day.
Orallo Formation	Hydraulic conductivity values are reported between 3.34 x 10^{-4} and 1.85 m/day (core and pumping test data). Median values appear high for the unit and may be due to miss-attribution of the formation.
Gubbermunda Sandstone	Median horizontal hydraulic conductivity values are reported between 1.28 x 10^{-1} and 7.76 x 10^{-1} m/day (core and pumping test data). Median vertical hydraulic conductivity is reported between 5.13 x 10^{-2} to 3.30 x 10^{-1} m/day (core and pumping test data).
Westbourne Formation	Median horizontal hydraulic conductivity values are reported between 8.0 x 10^{-4} and 1.37 x 10^{-1} m/day (core, DST and pumping test data). Median vertical hydraulic conductivity is reported between 1.83 x 10^{-4} to 2.41 x 10^{-2} m/day.
Springbok Sandstone	Separated into the Upper and Lower Springbok Sandstone permeability varies between the lower and upper units. The upper Springbok Sandstone hydraulic conductivity values are reported between 6.35 x 10^{-6} to 2.17 m/day, with a median of 1.02 x10^{-3} to 8.89 x10^{-3} m/day (core, DST, petrophysical and pumping test data). The Lower Springbok Sandstone hydraulic conductivity values are reported between 2.49 x 10^{-5} and 4.01 x 10^{-1} m/day (core, DST, petrophysical and pumping test data).
Walloon Coal Measures	Two distinct permeability groups: the low permeability interburden and the more variable coal. The interburden permeability is reported to be between 1x10^{-7} to 1x10^{-3} m/day (core tests). The coal ranges between 1x10^{-3} and 1.0 m/day (DST and core tests). A permeability-depth relationship also exists within the WCM with lower permeability associated with greater depth. Spatial variability associated with high fracture density shows a strong correlation to higher permeability zones.

7.4 Aquifer Inter-Connectivity

The Surat Basin comprises layers of aquifers and aquitards of varying hydraulic properties. The formations predominantly comprise fluvial sedimentary deposits that have formed stratifications of sand, silt and clay within and across hydrostratigraphic formations (OGIA 2016b). Groundwater flow within the Surat Basin hydrostratigraphic units is predominantly horizontal, as vertical flow is restricted by the spatial extent and continuity of aquitards, and by lower permeability horizons within the aquifers (OGIA 2016b).

Across the Project Area, there is potential for interaction between the WCM, and the aquifers present at depth, and specifically those immediately above and below the WCM, such as the overlying Springbok Sandstone and underlying Hutton Sandstone (separated from the WCM by the Durabilla Formation). The Durabilla / Eurombah Formation is classed as a tight aquitard and is laterally extensive across the Project Area, with a mean thickness of 51 m (Table 7.2). This provides a significant vertical barrier between the WCM and underlying Hutton Sandstone.

An upper WCM aquitard has been mapped by OGIA (the WCM non-productive zone, OGIA 2021f) as being up to 25 m thick across the Project Area, separating the WCM coal seams from the overlying Springbok Sandstone (which is also classed as a tight aquifer due to its low horizontal permeability and significant proportions of siltstone and mudstone).

As mentioned in Section 7.2, surficial Quaternary and Tertiary units mapped across the extent of the Project Area, are separated from the WCM by the outcropping / sub-cropping Doncaster Member (a tight aquitard part of the Wallumbilla Formation), and deeper tight aquitard units such as the Orallo Formation and Westbourne Formation. The thickness of these aquitards is presented in Table 7.2 and visually represented in Figure 7.4. The deeper-seated aquitards are observed to be laterally and vertically extensive within and beyond the Project Area, with mean thicknesses of 63 m and 198 m, respectively.

Aquitards present above and below the WCM in the vicinity of the Project Area provide a significant vertical barrier between the WCM and overlying / underlying partial and regional aquifers, as well as the surficial Quaternary and Tertiary mapped units. Isopachs for Westbourne and Durabilla / Eurombah Formation aquitards as well as the Springbok Formation and WCM are presented in Figure 7.5, with the top of the unit elevation presented in Figure 7.6.

7.5 Groundwater Recharge

Recharge processes within the Surat CMA are summarised in the 2021 UWIR (OGIA 2021g). Dominant recharge occurs along the zones of increased permeability in outcrop areas through fractures and permeable beds. Key processes of recharge include localised recharge, preferential pathway flow and diffuse recharge:

- Localised recharge occurs beneath drainage features including rivers, and free-draining unconsolidated sedimentary cover, such as alluvium.
- Preferential pathway flow arises from changes in permeability within aquifers and in overlying regolith, providing conduits for water to infiltrate. Zones of higher permeability may include fissures, faults, joints, tree roots and high-permeability beds within individual formations and along bedding planes (Kellett et al. 2003; Sucklow et al. 2016). This mechanism is considered the dominant recharge process in the GAB (Kellett et al. 2003).
- Diffuse recharge is the process by which high-intensity rainfall events and high-volume infiltrate and sufficiently saturate surficial sediments.

Recharge in the vicinity of the Project Area is expected to occur mainly as diffuse recharge with rainfall infiltration occurring at outcropping hydrostratigraphic units within, and surrounding, the Project Area. Quaternary and Tertiary aged systems are also likely to be replenished during prolonged wet periods when the ephemeral creek system is flowing (where sufficient saturation and hydraulic head allows water to infiltrate into surficial aquifers).

Estimates of long-term mean recharge rates for the Surat CMA have been made by OGIA as part of the 2016 UWIR (OGIA 2016b) using the chloride mass balance recharge estimation method. From this work, OGIA estimates the majority of surficial recharge to flow towards watercourses and discharge locally to streams and rivers such that only 10% of their recharge reaches the deeper confined aquifer.

For the units outcropping within the vicinity of the Project Area, the following regional recharge rates were estimated by OGIA (2019):

- Wallumbilla Formation[3] – 2.4 mm/yr.
- Bungil Formation (outcrops to northwest) – 1.3 mm/yr.
- Mooga Sandstone (outcrops to the north) – 2.7 mm/yr.
- Orallo Formation (outcrops to the north) – 4.3 mm/yr.
- Gubberamunda Sandstone (outcrops to the north) – 4.6 mm/yr.
- Westbourne Formation (outcrops to the north) – 2.1 mm/yr.
- Springbok Sandstone (outcrops to the north) – 1.3 mm/yr.

7.6 Groundwater Levels and Flow

7.6.1 Regional Groundwater Flow

At a regional scale, groundwater flow within the Surat Basin is typically north to south, from the outcrop areas located to the north (OGIA 2021c).

Groundwater movement is slow in the GAB with flow velocities estimated to be 1 to 5 m/year (Habermehl 1980). Generally, groundwater flow and movement occurs as sub-horizontal flow, with limited vertical leakage across formations, where pressure differences may exist (OGIA 2016c). Vertical flow generally only occurs downward in outcropping areas where recharge occurs. Local groundwater flow conditions may be different from regional flow conditions with potential steeper gradients and increased velocities in response to hydraulic stresses such as groundwater abstraction.

7.6.2 Groundwater Elevation and Monitoring Bores

Groundwater levels in the vicinity of the Project Area have been considered using available records from the GWDB (State of Queensland 2022b). A number of groundwater monitoring bores exist within the proximity of the Project Area as displayed in Figure 7.9, however transient groundwater level records are limited. Figure 7.10 displays the location of bores in the vicinity of the Project Area for which temporal groundwater elevation data is available (as presented in this section). The majority of these bores are installed as part of the UWIR and other programs such as CSG monitoring program or CSG Net Program which are coordinated by the Queensland Government.

The following section provides a summary of the available groundwater monitoring data from the GWDB, for all monitoring bores (existing, abandoned and usable, and abandoned and destroyed) as shown in Figure 7.9. Individual maps for each formation are also provided in the following sections.

[3] The Coreena Member of the Wallumbilla Formation is classed as a 'partial aquifer' while the Doncaster Member is classed as a 'tight aquitard'. The closest outcrop of the Coreena Member is 7 km to the south of the Project. Recharge associated with the Doncaster Member of the Wallumbilla Formation in the vicinity of the Project may therefore be expected to be less than the number presented; limited diffuse recharge is expected in outcropping areas.

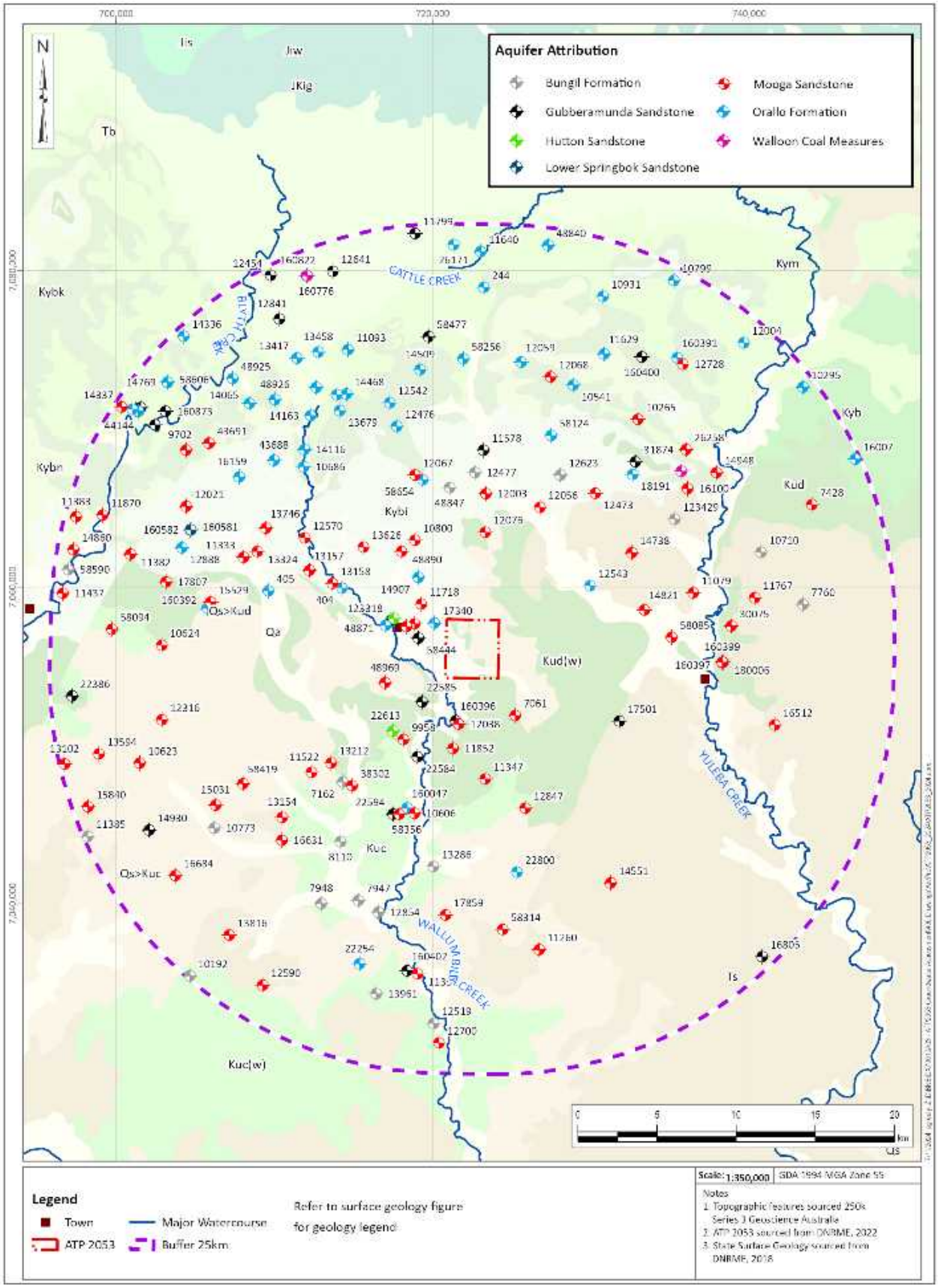


Figure 7.9 Location of Registered Water Level Monitoring Bores in the Vicinity of the Project Area (State of Queensland 2022b)

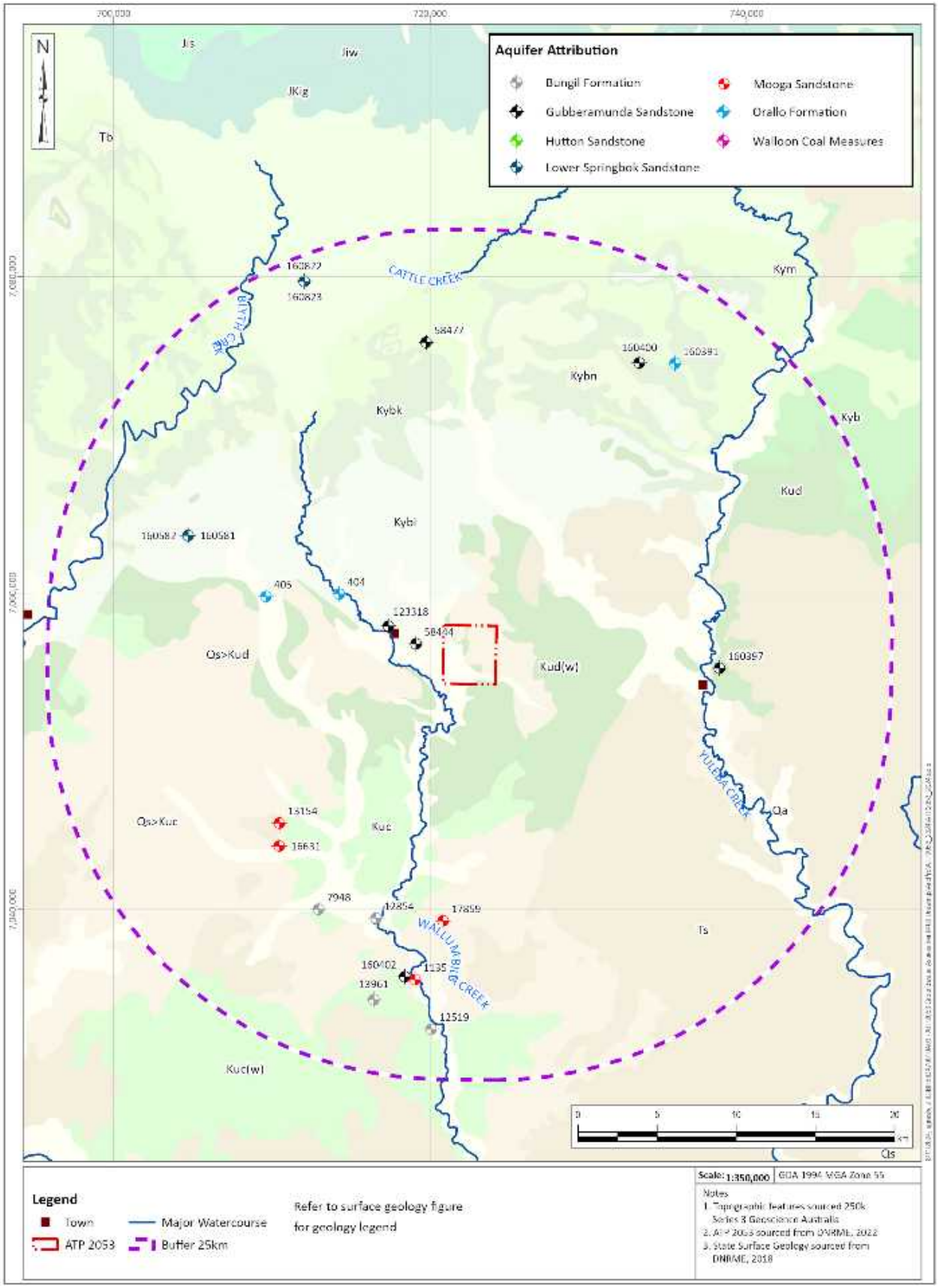


Figure 7.10 Bores with Temporal Water Level Monitoring Data in the Vicinity of the Project Area

Alluvium Monitoring Bores

There are no monitoring bores located in the alluvium. The lack of groundwater level monitoring records from alluvium associated with Wallumbilla Creek (and its tributaries including Washpool Creek and Middle Creek) in and around the Project Area, as well as the lack of third-party groundwater users sourcing groundwater from these alluvial deposits (refer to Section 7.11) highlights the limited water resource the alluvium represents in this region.

Wallumbilla Formation Monitoring Bores

Limited monitoring data is available for bores located in the Wallumbilla Formation with only six measurements recorded between 1937 and 1962. Water levels at five of the six bores were only recorded once. These historical measurements indicate water levels within the Wallumbilla Formation to range between 0 metres below ground level (mbGL) and 22 mbGL. One of the bores that recorded water at 0 mbGL is situated immediately adjacent to a farm water dam while the other bore is attributed to more than one aquifer and extends to the Mooga Sandstone, which is under artesian conditions.

Bungil Formation Monitoring Bores

The groundwater levels for bores monitoring the Bungil Formation are available within the vicinity of the Project Area, with the temporal trends of five bores with recent data presented in Figure 7.11. The location of these bores is shown in Figure 7.12 with the most recent recorded groundwater elevations also presented.

Observations from the available data include:

- Groundwater elevations from the available data (February 2012 to November 2019) range between 333.5 mAHD and 283.4 mAHD. Most of the bores presented are controlled flow artesian water supply bores.
- Earlier water level data is available for RN12519, RN12854, RN7948 and RN13961, (December 1969 to July 1988) however no data was collected between 1988 and 2012. The early data shows a decline between the 1970s and 2012 / 2013, which correlates to the rainfall excess / deficit trend (CRD).
- A slight correlation between groundwater elevation and CRD trend may be interpreted at RN12519 and RN123429.
- A review of the available groundwater levels at individual monitoring locations for the Bungil Formation was undertaken for bores within the vicinity of the Project Area. Several historical records were available (the most recent water level measurement was used) located to the northeast and southwest of the Project Area, as shown in Figure 7.9. These results indicate that the groundwater level elevations have ranged from 263 mAHD to 342 mAHD, with lower groundwater level elevations occurring at lower surface elevations.
- Monitoring data infers groundwater flow within the Bungil Formation in this area to be in a southwesterly direction, with the highest groundwater elevations located towards the northeast of the Project Area.

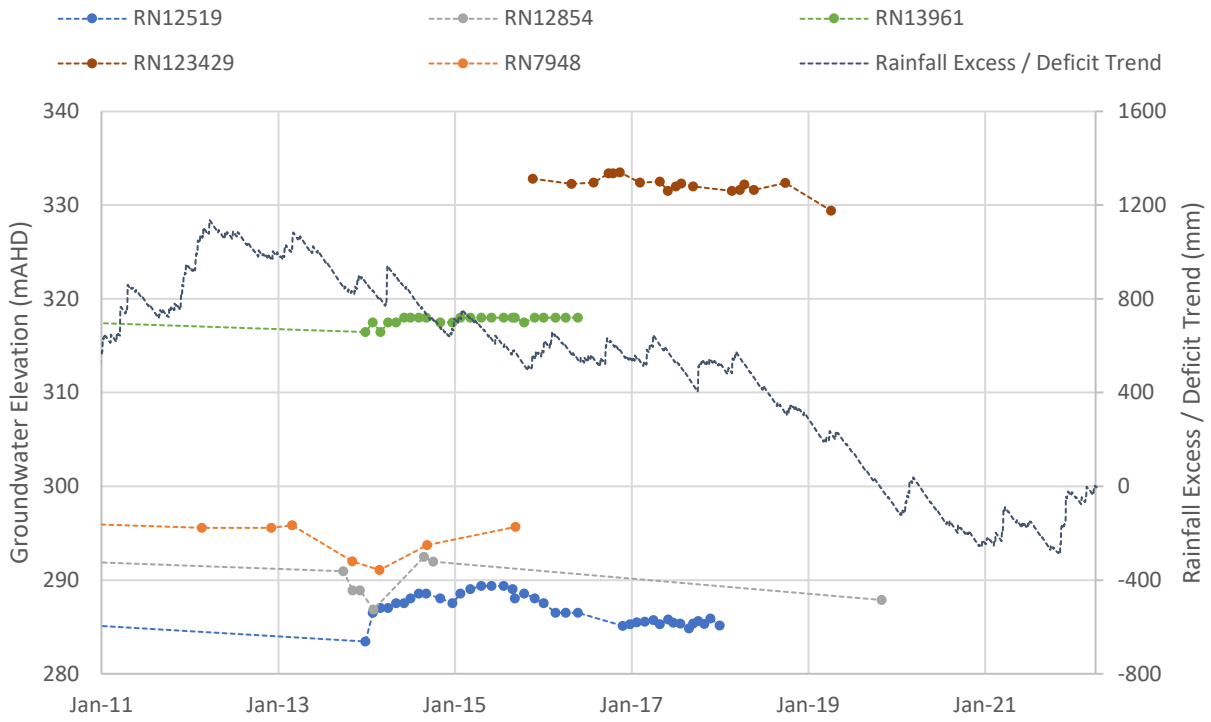


Figure 7.11 Bungil Formation Groundwater Elevation Hydrographs

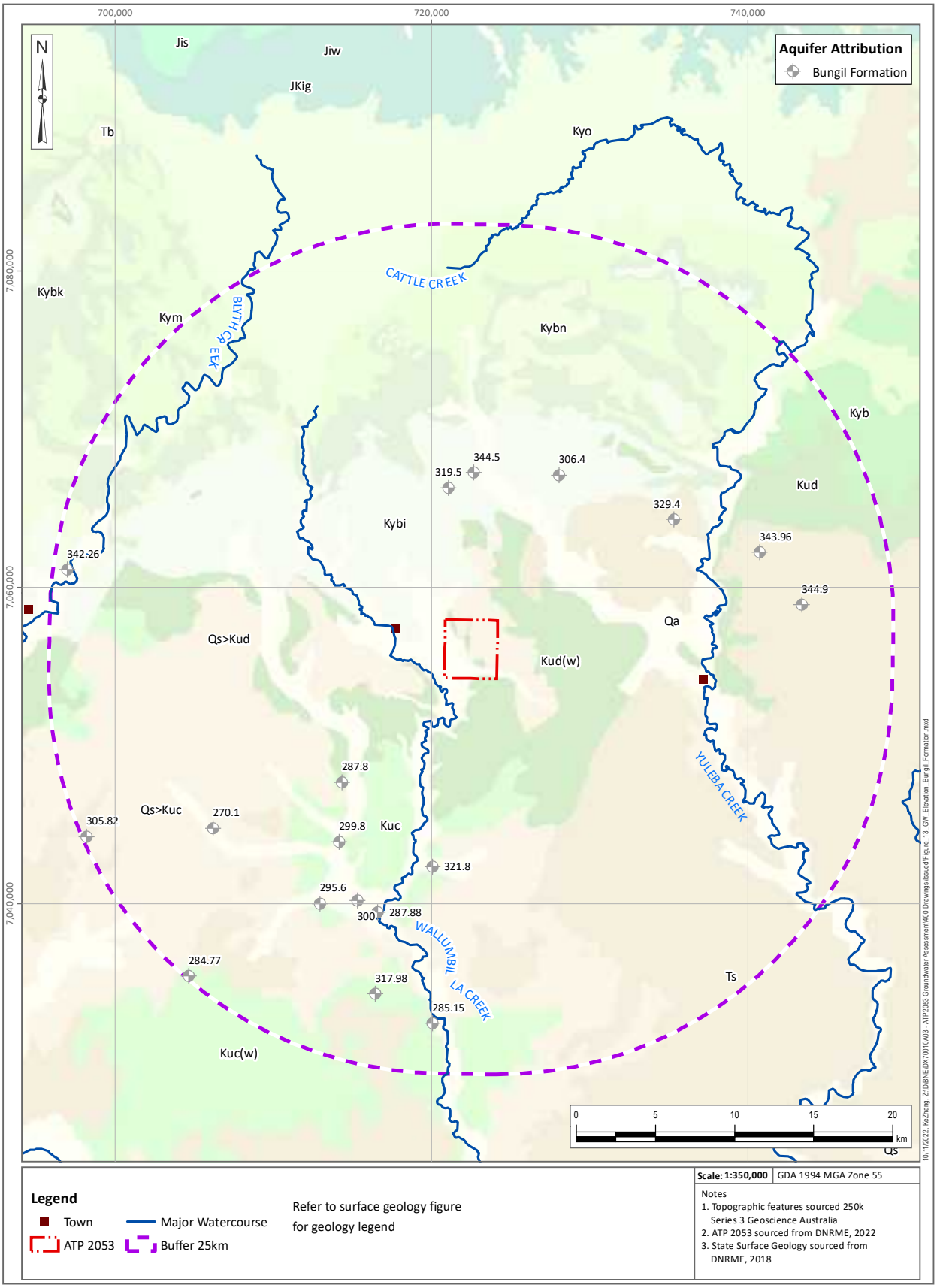


Figure 7.12 Location of Bungil Formation Monitoring Bores and Most Recent Groundwater Elevation in the Vicinity of the Project Area (State of Queensland 2022b)

Mooga Sandstone Monitoring Bores

The groundwater levels for five monitoring bores with recent temporal records in the Mooga Sandstone within the vicinity of the Project Area, is presented in Figure 7.13. The location of these bores and groundwater elevations are shown in Figure 7.14.

Observations from the available data include:

- Groundwater elevations from the available data (August 2012 to April 2022) range between 306.4 and 284.2 mAHD. Most of the bores for which data is available are controlled flow artesian water supply bores. A few artesian bores that have ceased to flow are also present. The exception is RN160399, which displays sub-artesian characteristics, was installed to facilitate monitoring as part of the Surat CMA UWIR.
- Limited data is available for RN17859, RN11351, RN13154 and RN16631 (between July 1957 and March 1987). Available data indicates that groundwater levels at these locations declined over time by around 15 – 20 m before consistent monitoring was resumed in 2012-2014, presumably due to pumping / dewatering.
- A declining trend in groundwater elevation in line with the CRD is observed in available data since 2012-2014.
- RN160399 displays multiple sudden decreases in groundwater elevation in July 2014, July 2017 and June / June 2019. These can likely be attributed to biannual groundwater sampling events.
- A review of the available groundwater levels at individual monitoring locations for the Mooga Sandstone was undertaken for bores within the vicinity of the Project Area. Several historical records were available (the most recent water level measurement was used) located evenly around the Project Area, as shown in Figure 7.12. These results indicate that the groundwater level elevations have ranged from 268 mAHD to 342 mAHD.

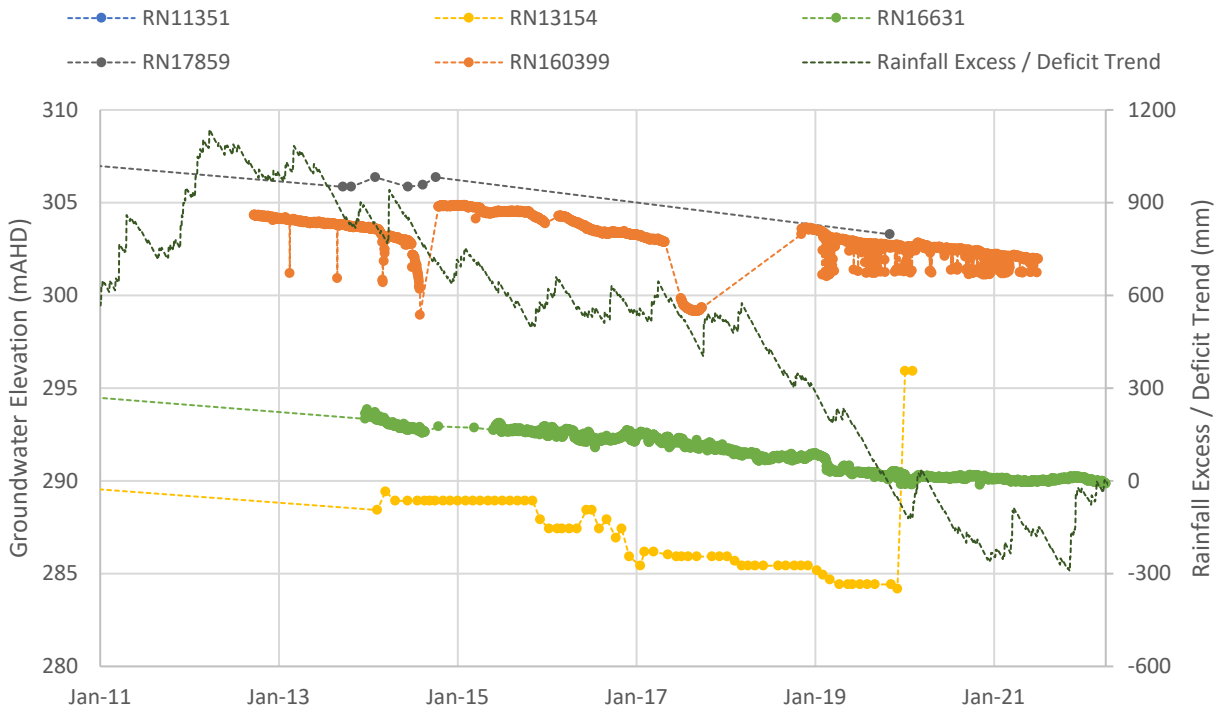


Figure 7.13 Mooga Sandstone Groundwater Elevation Hydrographs in the Vicinity of the Project Area

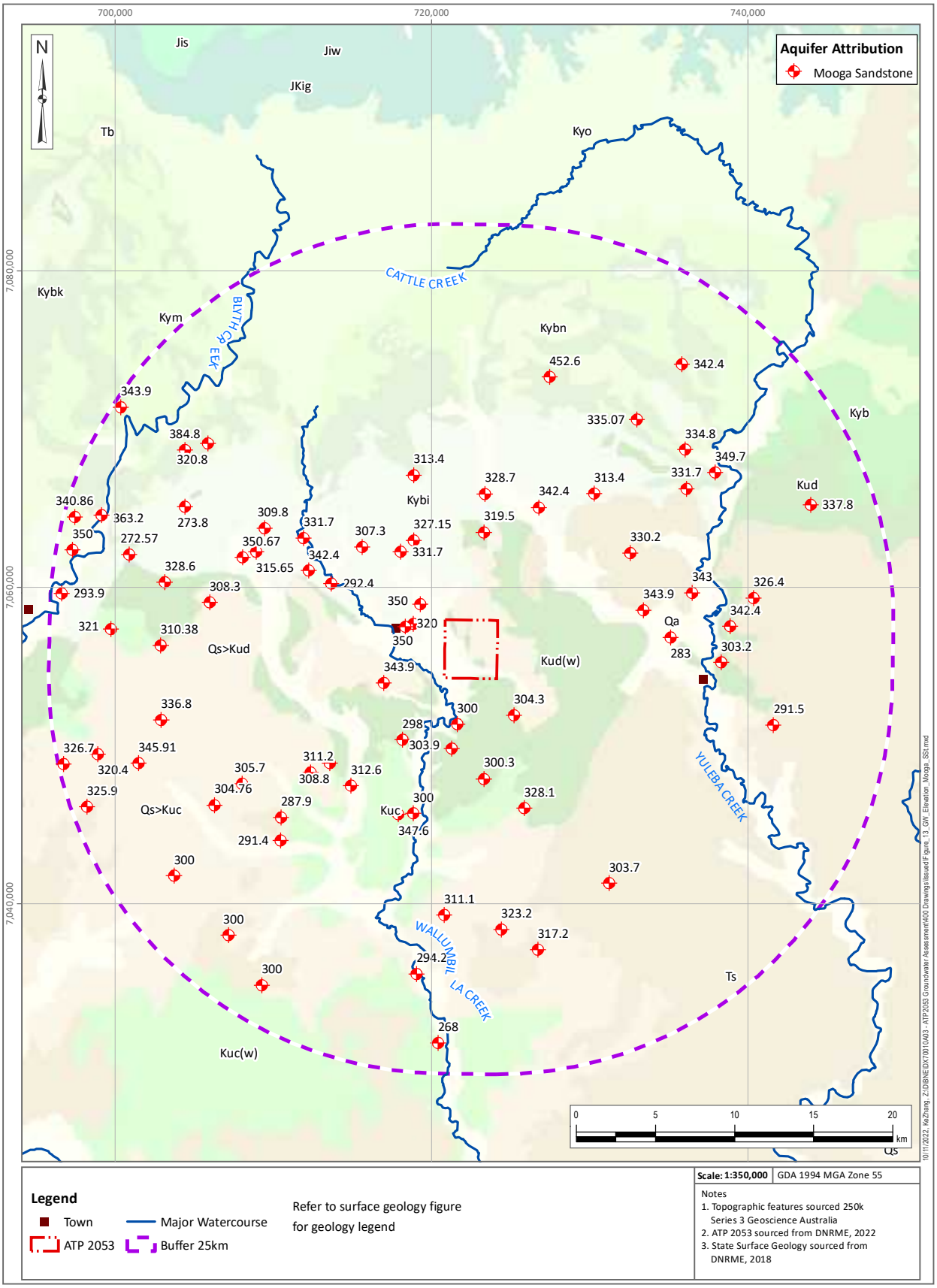


Figure 7.14 Location of Mooga Sandstone Monitoring Bores and Most Recent Groundwater Elevation in the Vicinity of the Project Area (State of Queensland 2022b)

Orallo Formation Monitoring Bores

The groundwater levels of three bores (RN404, RN405 and RN160391) with recent temporal records monitoring the Orallo Formation, within the vicinity of the Project Area are presented in Figure 7.15. The location of these bores and groundwater elevations are shown in Figure 7.16.

Observations from the available data include:

- Groundwater elevations from the available data (February 1964 to July 2021) range between 316.6 and 290.2 mAHD. Most of the bores for which data is available are sub-artesian bores and not used for water supply.
- Earlier data is available for RN404 and RN405, from May 1949 and February 1959, respectively; however, there is a 15-year gap between these and the following monitoring records.
- RN404 and RN405 show a declining trend between 1963 and 1997, however the data points are too far apart to show a correlation with the CRD. The reason for the declining trends is not well understood, it is however unlikely to be attributed to CSG activities.
- RN1600391, installed as part of the Surat CMA UWIR, displayed multiple sharp decreases in groundwater elevations (July 2014, July 2017, June / June 2019). These may be attributed to biannual groundwater sampling events.
- RN160391 shows a decline from 2012 to 2019, with small increases correlating to the CRD trend. Between August 2019 and November 2019, the groundwater elevation increases by 0.4 m, when the trend is still declining. This may be related to leakage from the Gubbermunda Sandstone (underlying lithology), which is the target formation for Santos' reinjection scheme at the Roma gas field (OGIA 2021g).
- A review of the available groundwater levels at individual monitoring locations for the Orallo Formation was undertaken for bores within the vicinity of the Project Area. The majority of historical records available (the most recent water level measurement was used) for the Orallo Formation are located to the north of the Project Area, as shown in Figure 7.16.
- These results indicate that the groundwater level elevations have ranged from 228 mAHD to 385 mAHD.

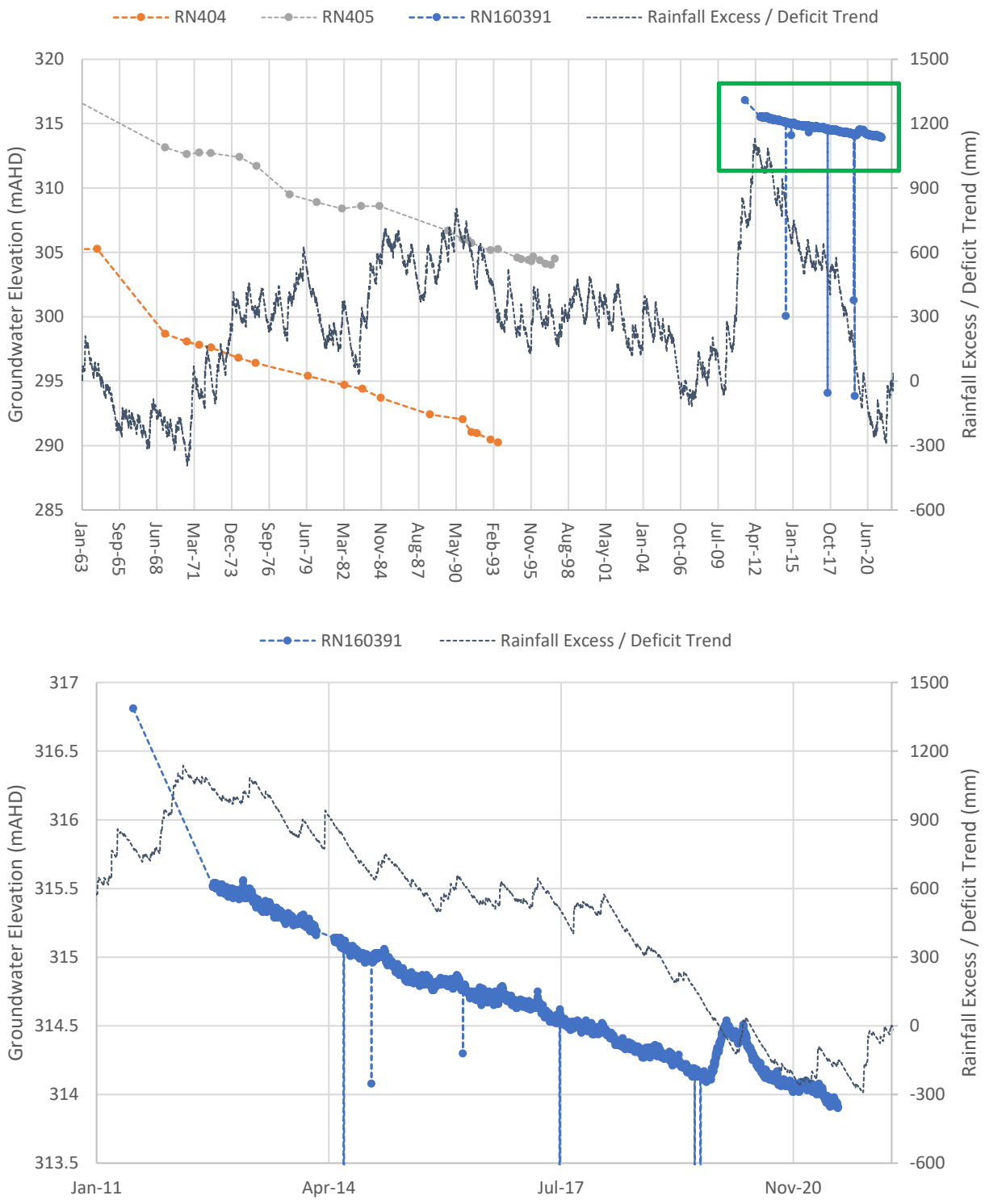


Figure 7.15 Orallo Formation Groundwater Elevation Hydrographs

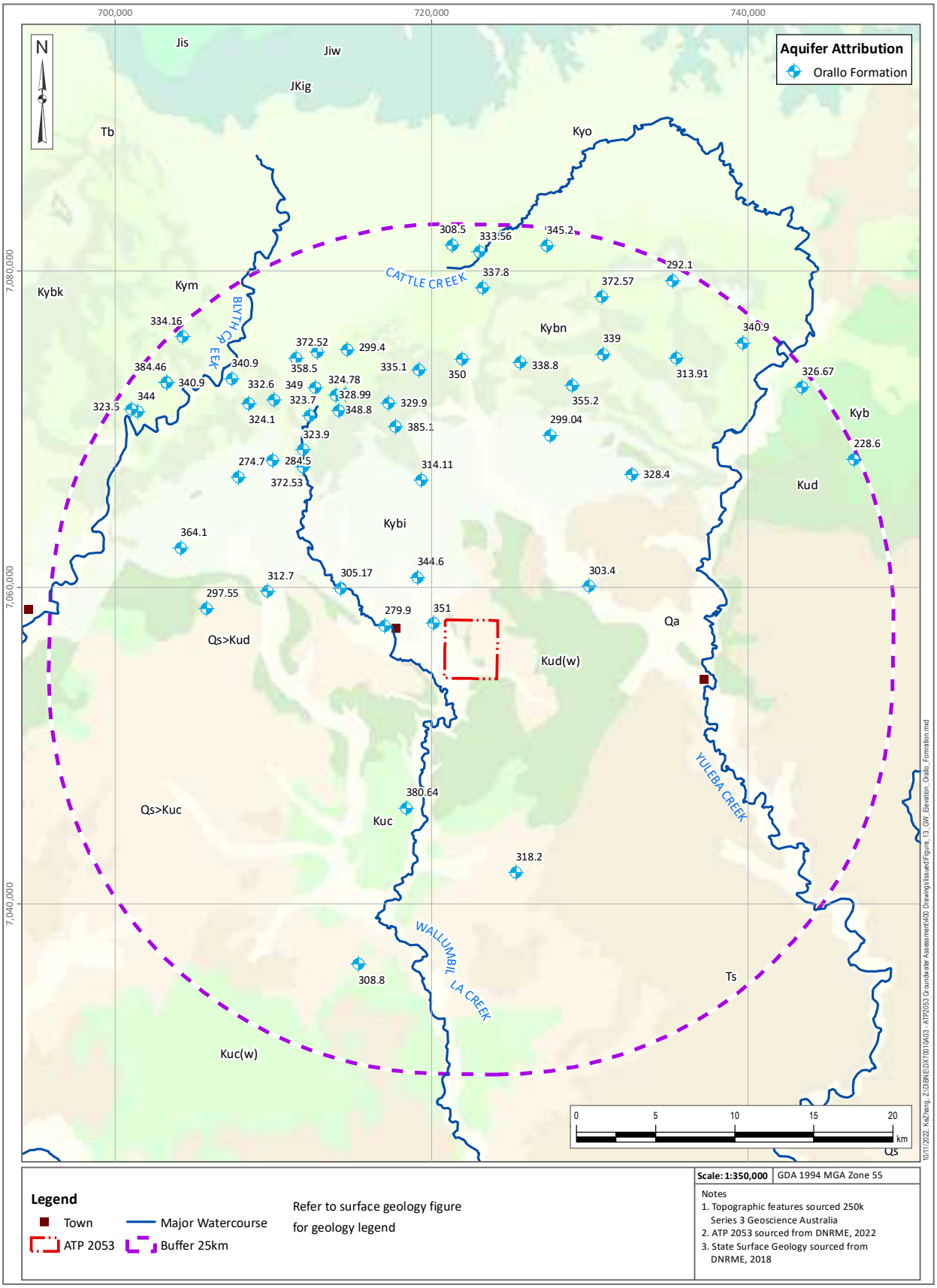


Figure 7.16 Location of Orallo Formation Monitoring Bores and Recent Groundwater Elevation in the Vicinity of the Project Area (State of Queensland 2022b)

Gubberamunda Sandstone Monitoring Bores

The groundwater levels of nine bores with recent temporal records monitoring the Gubberamunda Sandstone within the vicinity of the Project Area are presented in Figure 7.17. The location of these bores is shown in Figure 7.18, with most recent recorded groundwater elevations also presented.

Observations from the available data include:

- Groundwater elevations from the available data (January 2011 to April 2022) range between 330 mAHD and 260 mAHD. These bores are all sub-artesian bores. Bores RN17501, RN58444, RN58477, RN123318 and RN160394 are water supply bores.
- Single data points are available for RN17501, RN58477 and RN58447 between 1967 and 1991, however transient data was not collected again until 2011 or later, thus historical data is not shown on Figure 7.17.
- Groundwater elevations at most bores show no correlation to the CRD and remain relatively static.
- A review of the GWDB for additional groundwater levels was undertaken for bores within the vicinity of the Project Area.
- A review of historically available groundwater levels at individual monitoring locations for the Gubberamunda Sandstone was undertaken for bores within the vicinity of the Project Area. Several historical records were available (the most recent water level measurement was used) for the Gubberamunda Sandstone, located to the north and south of the Project Area, as shown in Figure 7.18. These results indicate that the groundwater level elevations have ranged from 259 mAHD to 378 mAHD.
- Monitoring data infers groundwater flow within the Gubberamunda Sandstone in this area to be generally southward, with the highest groundwater elevations located towards the north.

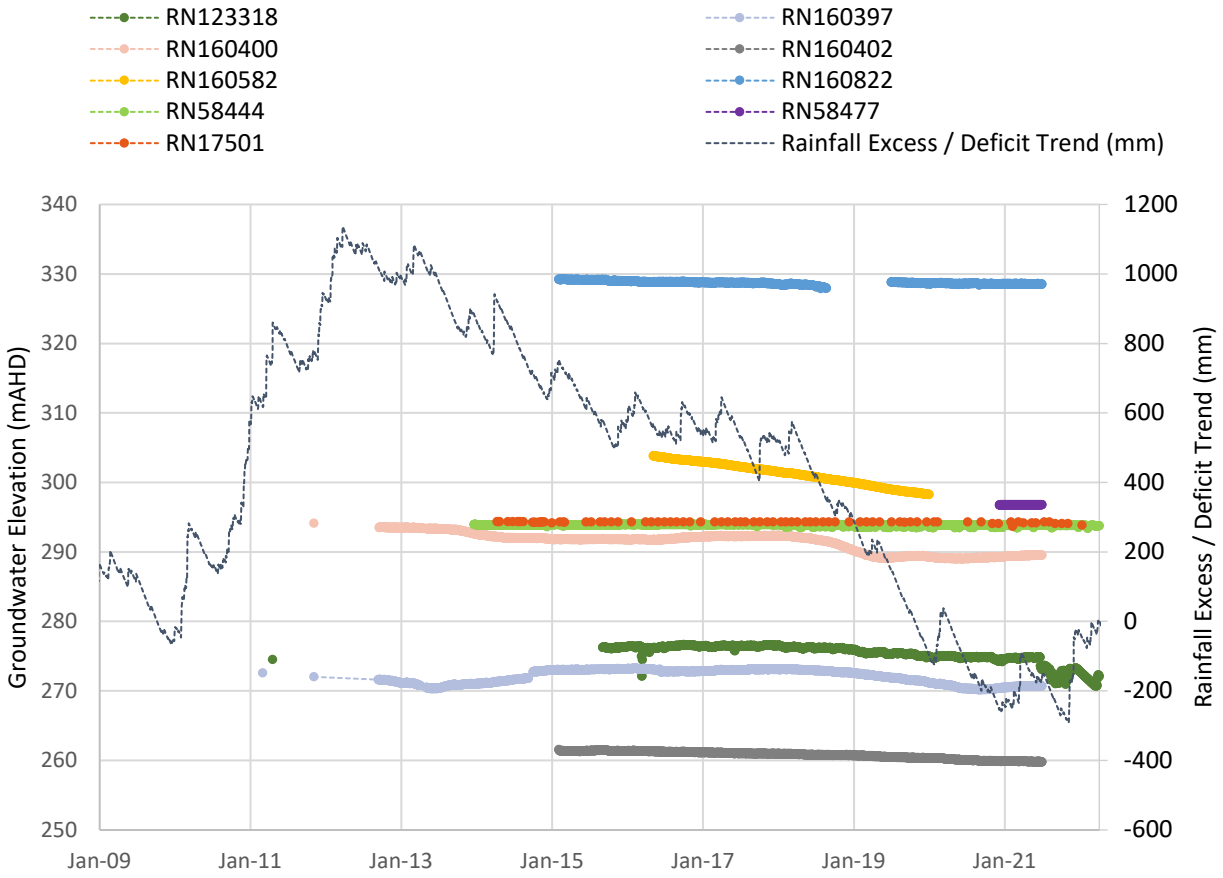


Figure 7.17 Gubberamunda Sandstone Groundwater Elevation Hydrographs

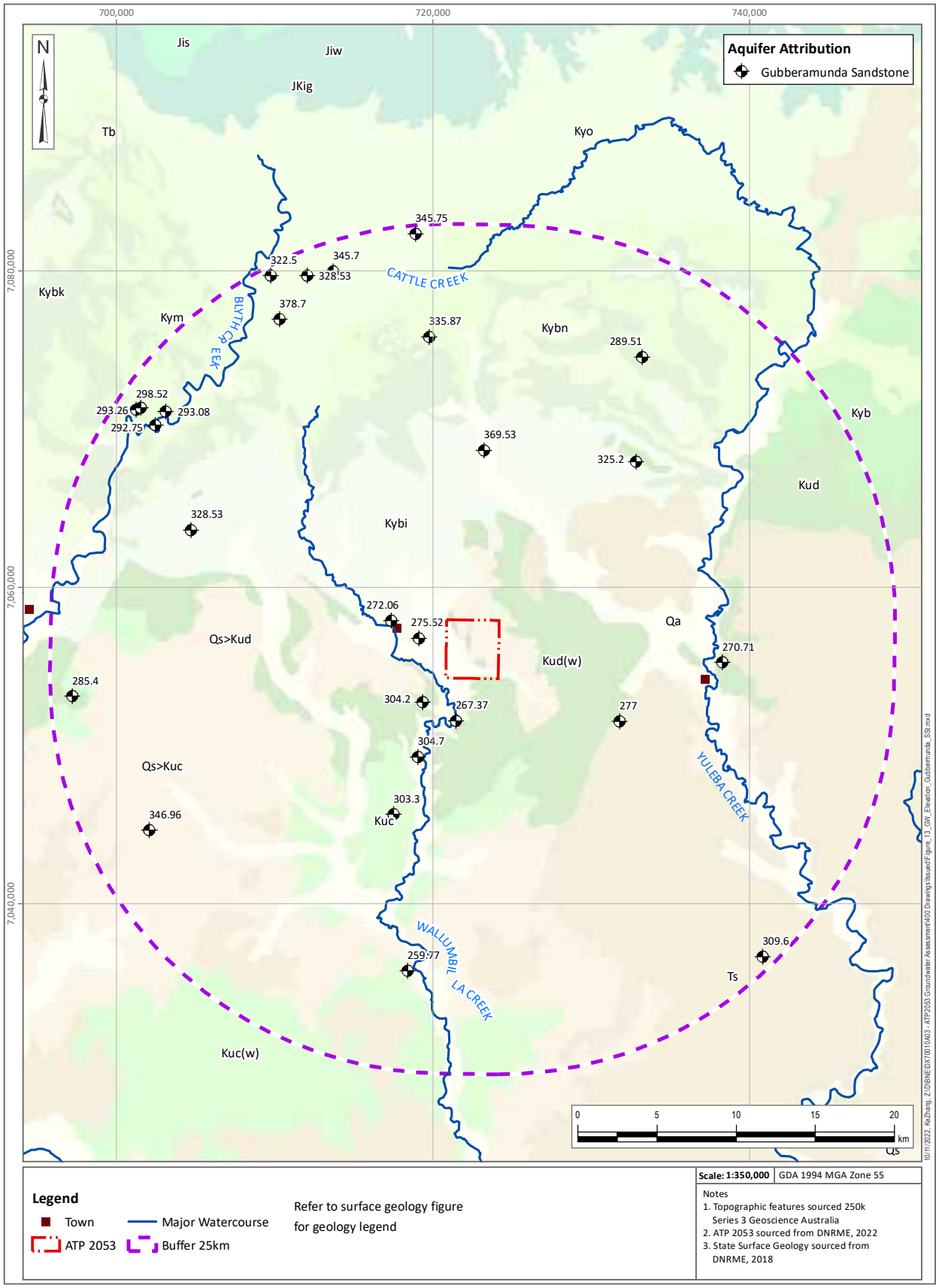


Figure 7.18 Location of Gubberamunda Sandstone Monitoring Bores and Groundwater Elevations in the Vicinity of the Project Area (State of Queensland 2022b)

Springbok Sandstone Monitoring Bores

Groundwater levels for the only two bores monitoring the Lower Springbok Sandstone within the vicinity of the Project Area are presented in Figure 7.19. The location of these bores is shown in Figure 7.20, with most recent groundwater elevations also presented.

Observations from the available data include:

- Groundwater elevations data presented between November 2011 to June 2021 for the Lower Springbok Sandstone range between 290 mAHD and 325 mAHD. The bores for which data is available are sub-artesian bores and are not used for water supply.
- Recorded groundwater levels remain relatively static and do not correlate with the CRD.
- RN160581E show a decline of 20 m, between 2016 and 2018, which may be associated with CSG production.
- RN160823A shows responses to pumping events and associated recovery. This response is common within the Springbok Sandstone. The slow and frequently incomplete recovery provides indication of the highly variable nature of the Springbok Sandstone and the very low permeability observed at many locations (OGIA 2016c).
- Based on the available data for the Springbok Sandstone, it is difficult to distinguish the groundwater flow directions within the vicinity of the Project Area, due to the lack of data points. Regionally, the groundwater system is multi-directional, and a groundwater divide occurs to the north of Roma and Miles, therefore it is likely that groundwater flow occurs northwest to southwest (OGIA 2021g).

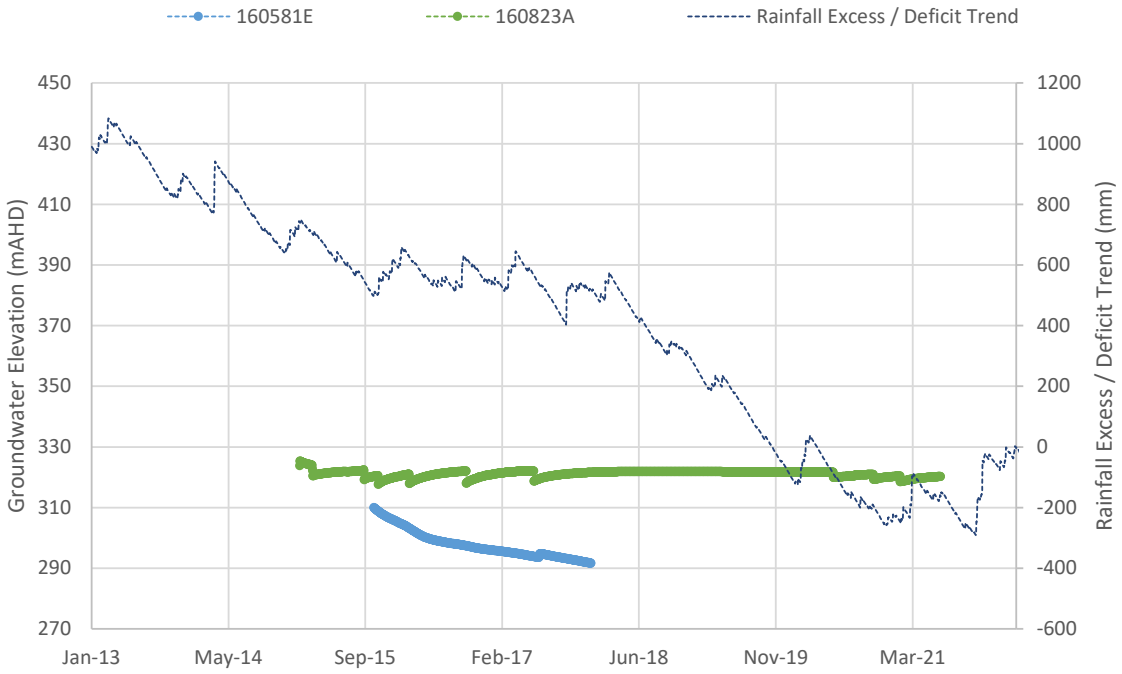


Figure 7.19 Lower Springbok Sandstone Groundwater Elevation Hydrograph

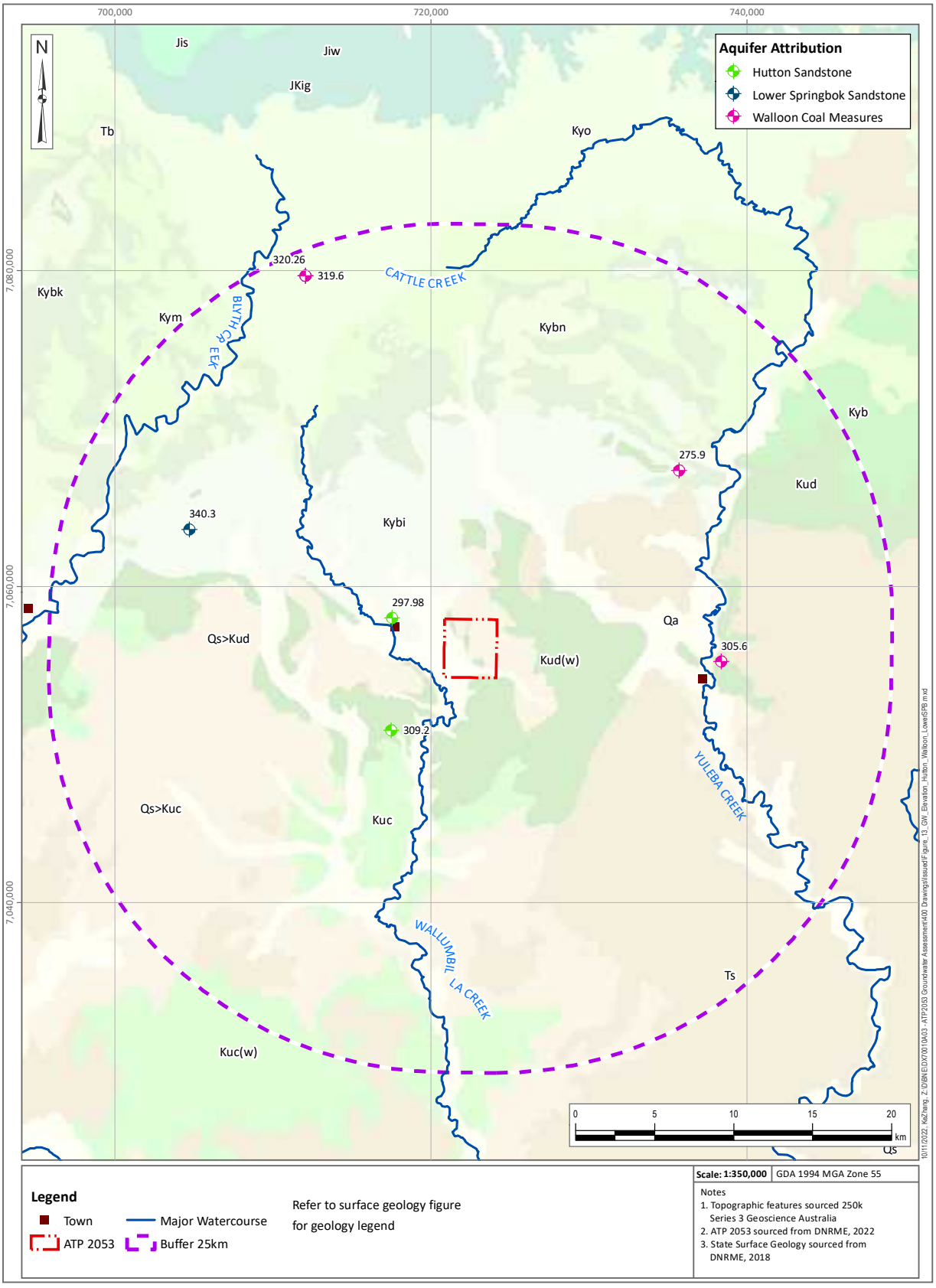


Figure 7.20 Location of Springbok Sandstone, Hutton Sandstone and Walloon Coal Measures Monitoring Bores and Recent Groundwater Elevation in the Vicinity of the Project Area

Walloon and Taroom Coal Measures Monitoring Bores

The groundwater levels for the three GWDB bores monitoring the WCM within the vicinity of the Project Area are presented in Figure 7.20 and Figure 7.21. The bores are screened within the following units:

- RN180006 – Upper Juandah.
- RN160776 – Lower Juandah.
- RN160646 – Taroom Coal Measures.

The location of these bores is shown in Figure 7.20, with groundwater elevations also presented.

Observations from the available data include:

- Groundwater elevations recorded between August 2010 to June 2021 range between approximately 340 and 260 mAHD. Available monitoring data are sourced from bores which are sub-artesian and are not used for water supply, with the exception of RN180006 which is identified as a potential water supply well.
- Groundwater levels remain relatively static in RN180006A, with a decline observed since January 2021 which may be attributed to groundwater abstraction.
- Groundwater elevation changes observed in other bores attributed to the WCM and Taroom Coal Measures are likely caused by CSG production activities.

Based on the available data for the WCM, the groundwater flow directions within the vicinity of the Project Area, is inferred to be towards the south, which aligns with the regional groundwater flow direction towards the southeast caused by radially convergent drawdown patterns observed due to CSG development (OGIA 2021c).

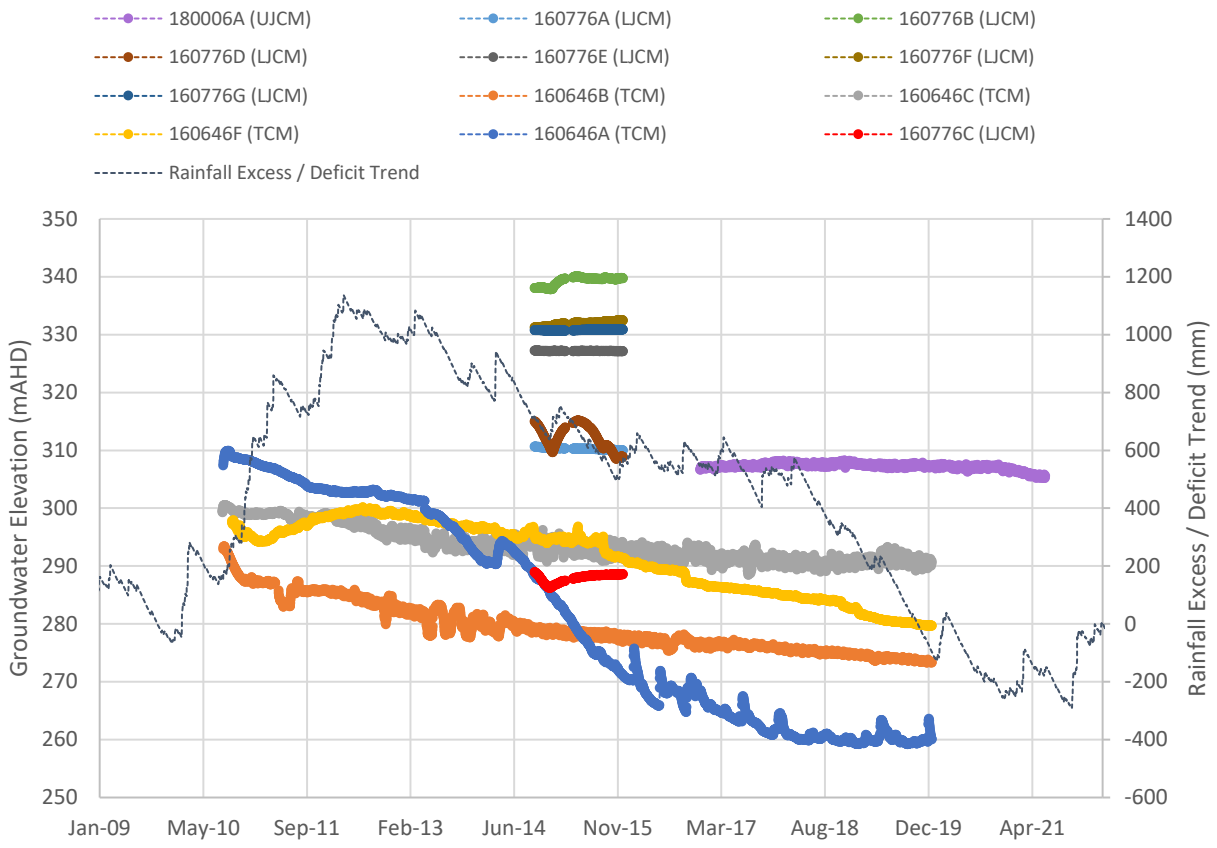


Figure 7.21 Walloon Subgroup Groundwater Elevation Hydrograph (RN180006, RN160776 and RN160646)

Upper Hutton Sandstone Monitoring Bores

The groundwater levels for the Upper Hutton Sandstone are available for three bores within the vicinity of the Project Area. The location of these bores is presented in Figure 7.20 and Figure 7.9. The groundwater elevations from the available data (June 1934 to November 1990) range between 315.3 mAHD and 297.0 mAHD.

Bore RN406 is identified as 'abandoned and destroyed' in the GWDB. Only four historical records were collected from this bore between 1934 and 1990. RN22613 has one data point (November 1975) and is identified as existing, however no recent data has been collected. Bore RN160581A is attributed to the Upper Hutton and a hydrograph indicating a stable trend is presented in Figure 7.22.

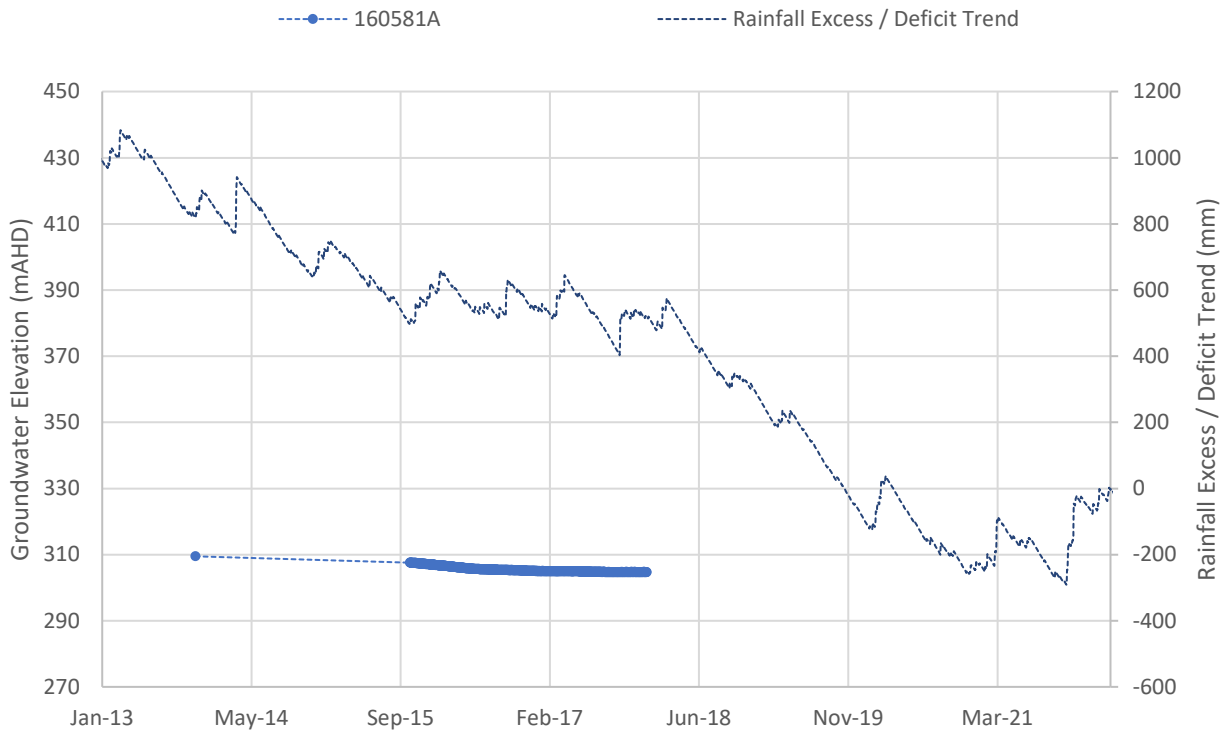


Figure 7.22 Upper Hutton Groundwater Elevation Hydrograph (RN160581A)

7.7 Groundwater Chemistry

Groundwater chemistry of the hydrostratigraphic units present at the Project Area has been considered using information reported in the UWIR 2021(OGIA 2021f), UWIR 2019 (OGIA 2019a) and data sourced from the GWDB. The primary factors influencing groundwater quality are formation mineralogy, proximity to areas where the formation is recharged, and groundwater flow dynamics within the formation. Table 7.4 presents water chemistry results for formations present within the Project Area as sourced from UWIR 2021 and UWIR 2019.

Table 7.4 Surat CMA Groundwater Chemistry (formations present within the Project Area) (sourced from OGIA 2019a Table D-2 and OGIA 2021f)

Analyte	Percentile	Alluvium	Cenozoic	Wallumbilla Formation	Bungil Formation	Mooga Sandstone	Orallo Formation	Gubberamunda Sandstone	Springbok Sandstone	Walloon Coal Measures		
										UJCM	LJCM	TCM
Ca	25th	30	15	3	2	2	2	2	11	29	29	36
	50th	46	44	11	4	3	3	3				
	75th	77	107	503	28	8	12	8				
Mg	25th	22	16	1	0	0	0	1	20	33	25	89
	50th	40	54	6	2	1	1	1				
	75th	80	176	364	7	3	4	3				
Na	25th	100	398	435	440	396	320	274	1100	1840	605	798
	50th	205	563	500	527	462	435	350				
	75th	500	1504	3452	805	567	535	424				
K	25th	0	0	0	0	0	0	1	4	7	4	3
	50th	1	4	2	2	1	1	1				
	75th	3	10	16	3	2	2	3				
Alkalinity	25th	308	276	229	348	460	339	350	431	397	432	401
	50th	403	470	486	715	700	598	527				
	75th	512	641	855	930	888	885	664				
Cl	25th	84	370	160	141	140	110	104	1600	3070	820	1270
	50th	250	630	376	303	210	164	150				
	75th	780	2320	6736	1047	457	423	257				
SO_4	25th	5	9	1	0	0	1	1	21	2	19	156
	50th	15	38	26	2	2	6	3				
	75th	70	135	613	12	48	51	22				
TDS	25th	649	1406	1447	1468	1273	1080	895	1727	2442	1952	1380
	50th	1064	1901	1664	1757	1558	1388	1126				
	75th	2016	5018	12408	2328	1857	1792	1320				
pH	25th	7.6	7.6	7.2	8.1	8.1	8.1	7.9	8.0	8.1	8.0	7.8
	50th	7.9	8.0	8.0	8.2	8.4	8.4	8.4				
	75th	8.2	8.2	8.5	8.5	8.6	8.5	8.7				

Note: - Median values from Surat CMA target formation for Springbok Sandstone and Walloon Coal Measures, as presented in UWIR 2021.
- UJCM = Upper Juandah Coal Measures, LJCM = Lower Juandah Coal Measures, TCM = Taroom Coal Measures; TDS: Total Dissolved Solids

Further groundwater chemistry data has been sourced from the GWDB for bores within a 25 km radius of the Project Area. The location of the bores with groundwater chemistry and OGIA aquifer attribution (OGIA 2022a) is shown in Figure 7.23.

The GWDB chemistry records are generally limited to analysis of the major cations and anions, with few samples analysed for metals.

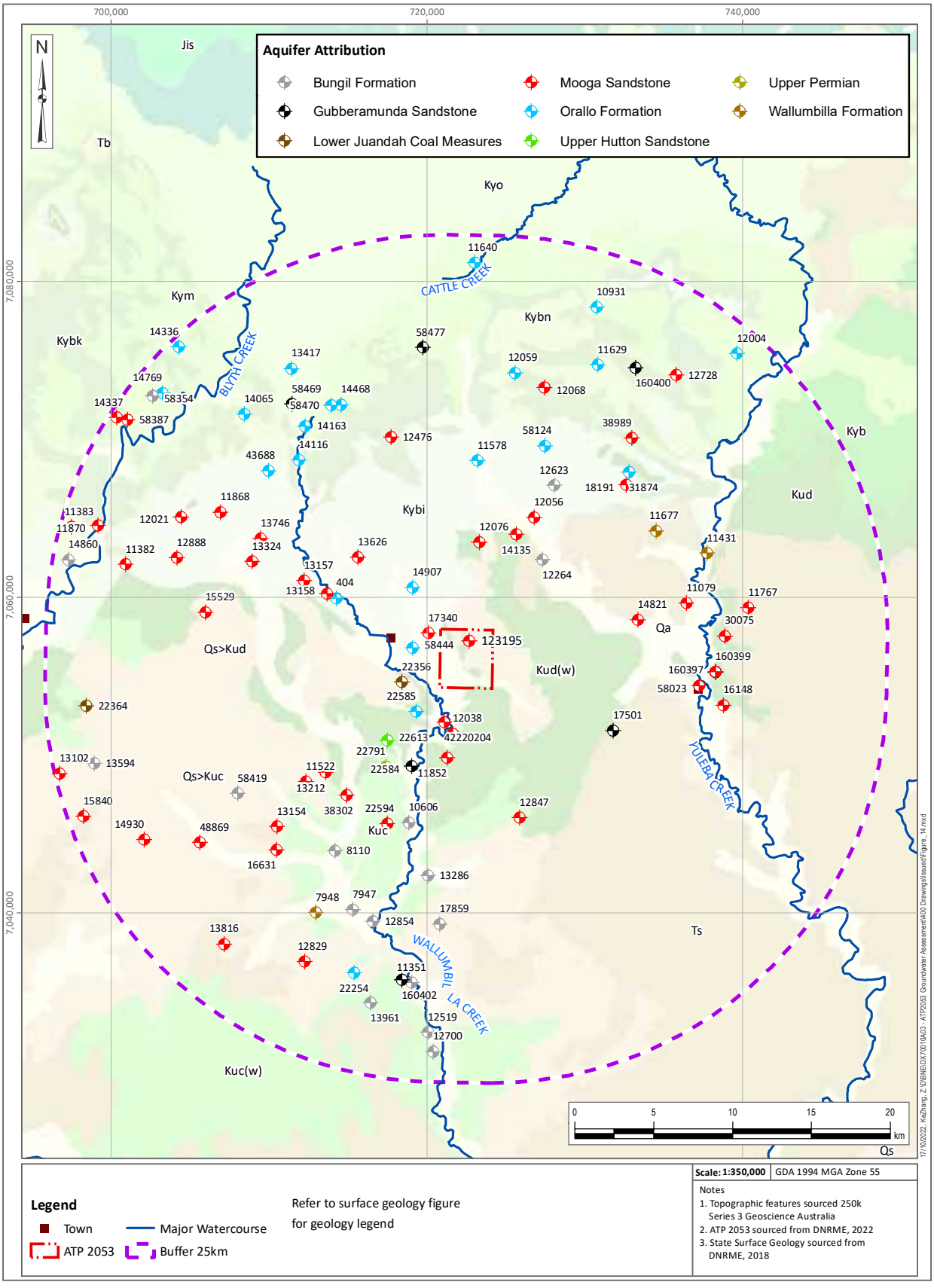


Figure 7.23 GWDB Bores with Chemistry Data in the Vicinity of the Project Area (State of Queensland 2022b)

Figure 7.24 presents a Piper diagram for each relevant hydrostratigraphic unit from the GWDB records, with a Durov diagram shown in Figure 7.25. The following observations can be made for the local hydrochemistry:

- The majority of the samples (regardless of formation) display a sodium bicarbonate to sodium-chloride water type.
- The majority of formations have TDS concentrations <2000 mg/L.

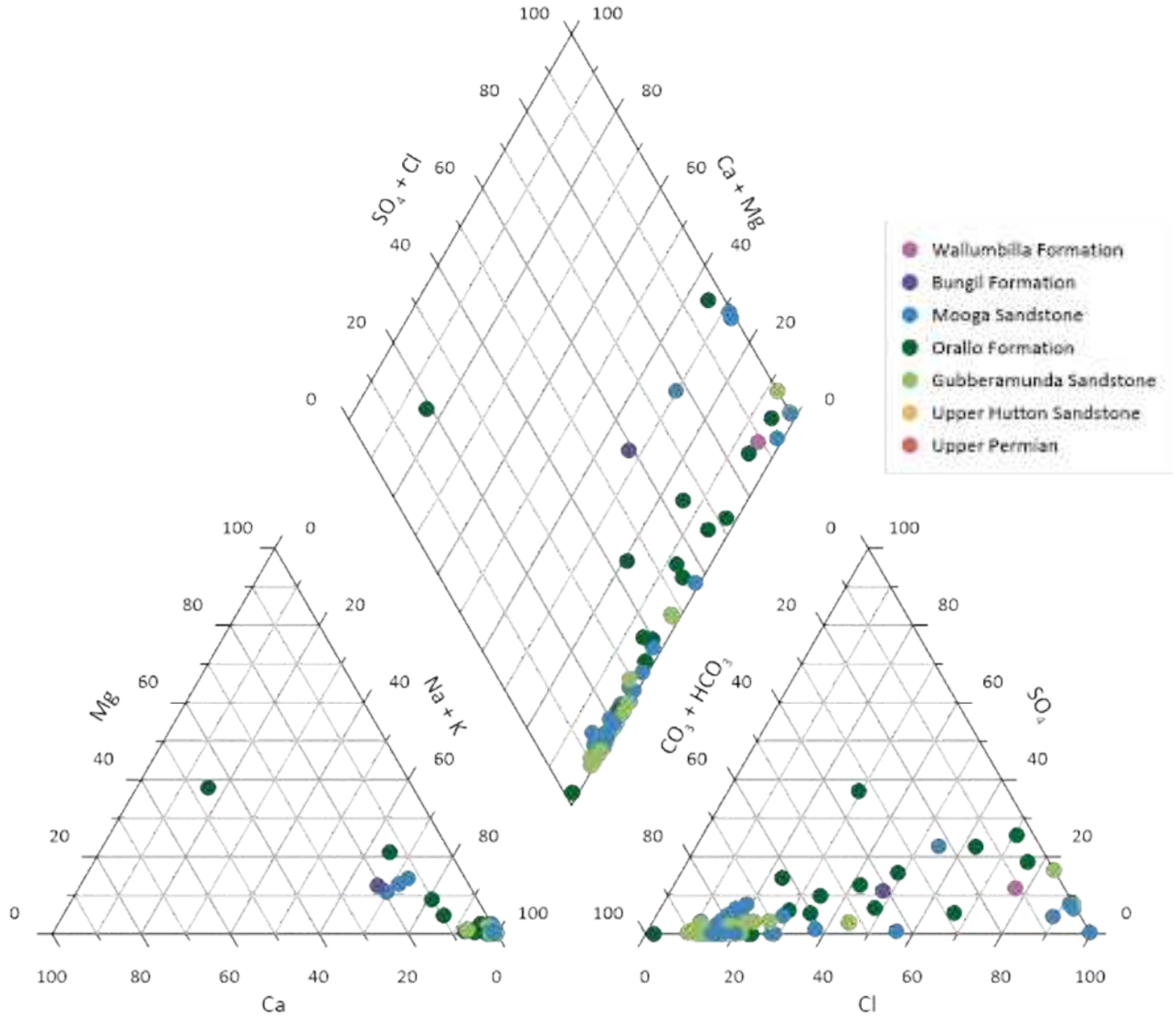


Figure 7.24 Piper Diagram from GWDB Chemistry Records from Bores within a 25 km Radius of the Project Area (State of Queensland 2022b)

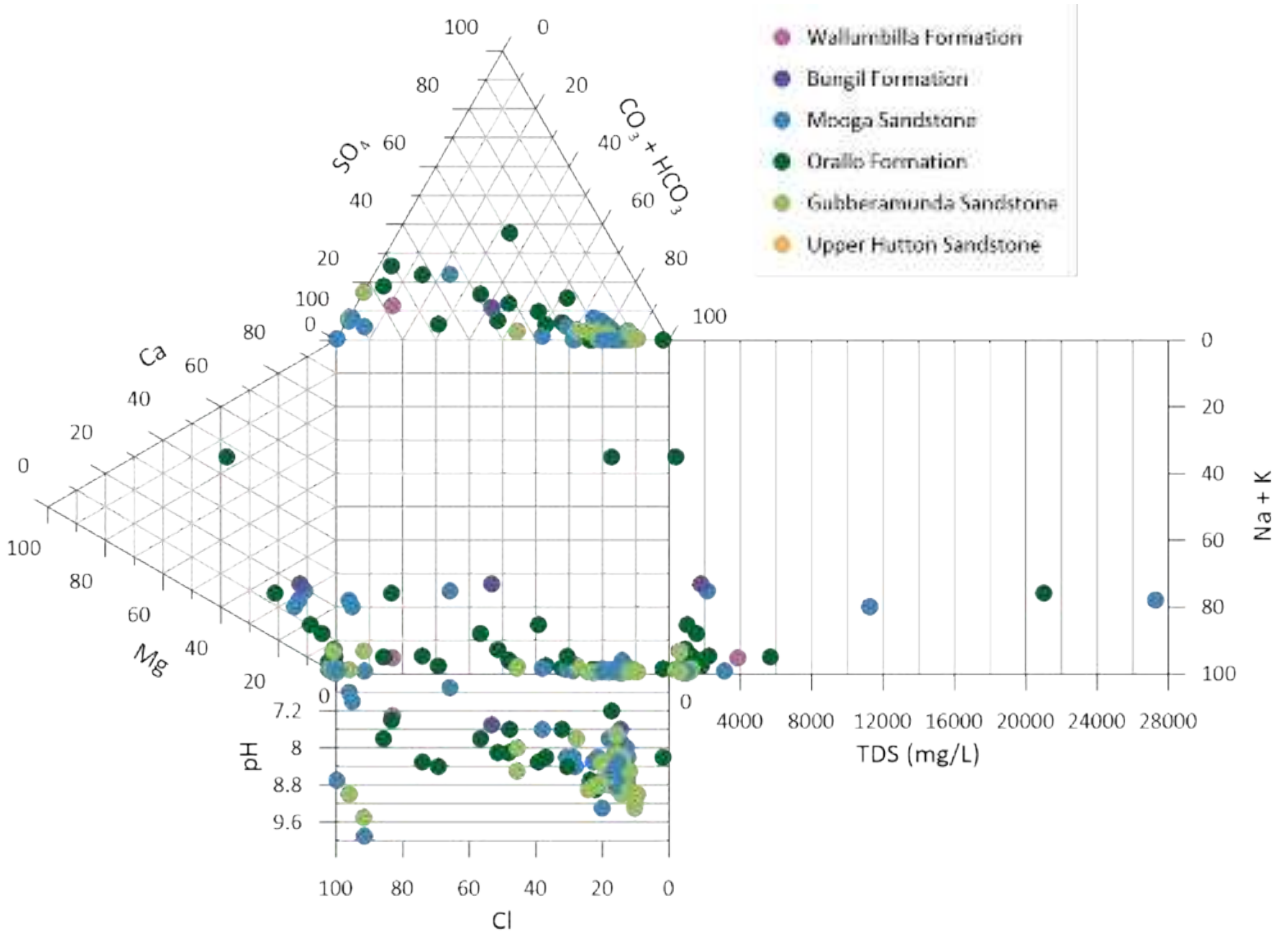


Figure 7.25 Durov Diagram from GWDB Chemistry Records from Bores within a 25 km Radius of the Project Area (State of Queensland 2022b)

7.8 Groundwater-Surface Water Interactions

Groundwater-surface water interaction in the vicinity of the Project Area may occur as a result of two key processes:

- Discharge of groundwater to watercourses as baseflow; and
- Recharge of aquifers from leakage from watercourses.

Quaternary-age alluvium (Qa) is mapped in the west within, and to the west of the Project Area along larger creeks. Cenozoic sediments comprising Quaternary-Tertiary aged residual / colluvium are present in the east of the Project Area while the underlying Doncaster Member of the Wallumbilla Formation outcrops in the centre and to the northwest of the Project Area.

There are no monitoring or groundwater supply bores located in the Quaternary or Tertiary aged deposits within 25 km of the Project Area indicating the limited potential of these units as a water resource. The Doncaster Member of the Wallumbilla Formation is a mudstone dominated unit. Very little monitoring data is available for this unit, no monitoring records more recent than 1962. The Doncaster Member of the Wallumbilla Formation is conceptualised as a tight aquitard by OGIA (OGIA 2019e).

The watercourses in the vicinity of the Project Area are highly ephemeral, and streamflow only occurs following material rainfall events (refer to Section 6.4). Recharge to groundwater systems from watercourses may occur at the Project Area, however this only occurs when there are conditions of sufficient saturation and hydraulic head to allow water to infiltrate into surrounding aquifers (e.g. alluvium). Temporary perched groundwater conditions may result due to percolation of infiltrated rainwater along streamlines and collection of rainwater in low lying areas underlain by material with low permeability.

In summary, available information infers that limited to no groundwater contribution from the regional system to watercourses as baseflow is likely at the Project Area.

7.9 Current Groundwater Stressors

The Surat CMA UWIR provides for the assessment and management of cumulative groundwater impacts resulting from the incidental extraction of groundwater by resource development activities – i.e. CSG, conventional oil and gas, and coal mining (OGIA 2021e).

The UWIR reports CSG to be the dominant, and expanding, resource development activity in the Surat Basin with five major operators – QGC, Santos, Origin Energy, Arrow Energy and Senex Energy. The existing and planned CSG production area has increased by 8% since 2019, with current projection of about 22,000 CSG wells – of which about 8,600 are already in place. Current associated water extraction by the CSG operators is around 54,000 ML per year and is likely to average around the same over the life of the industry. There are approximately 8,000 water supply bores, half of which are in the GAB, within and in the immediate proximity of the CSG production areas, extracting 59,000 ML of groundwater per year for consumptive use.

Groundwater modelling predicts 450 m of drawdown or less in the CSG and coal target formations in the Surat, and 80 m in the Springbok Sandstone. Minor impacts of less than 12 m are predicted in the Hutton Sandstone and Precipice Sandstone.

Predicted drawdown in aquifers of interest in the vicinity of the Project Area are shown in Figure 7.26. The Project Area is located in an existing CSG area, with notable additional CSG operations planned. Drawdown due to approved projects at the time of UWIR compilation (2021) in excess of 200 m was predicted in the WCM to the north of the Project Area. Notable drawdown in the Springbok Sandstone (> 100 m) was also predicted, while the drawdown in the Hutton and Precipice Sandstones is generally less than 1 m. These impacts exclude the current Project.

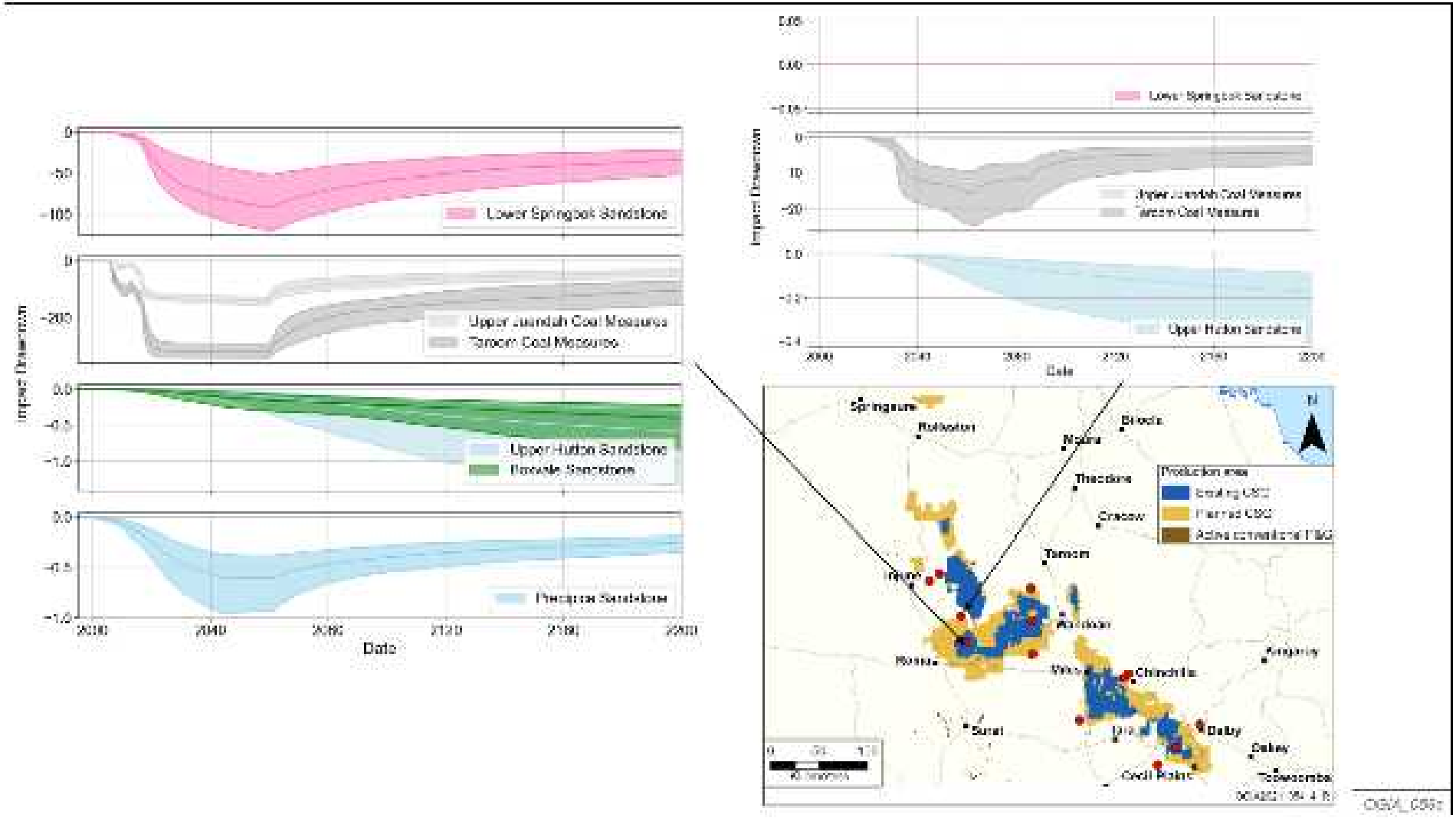


Figure 7.26 Predicted Drawdown Time Series, CSG Development Area North-East of Roma (OGIA 2021e)

7.10 Groundwater Dependent Ecosystems

Potential GDEs have been mapped within the vicinity of the Project Area (State of Queensland 2018d). GDEs are defined in water-related responses to CSG extraction and coal mining (DoEE 2015) as:

> *"Natural ecosystems which require access to groundwater on a permanent or intermittent basis to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services (Richardson et al. 2011). The broad types of GDE are (Eamus et al. 2006):*
>
> - *Ecosystems dependent on surface expression of groundwater;*
> - *Ecosystems dependent on subsurface presence of groundwater; and*
> - *Subterranean ecosystems."*

OGIA (2019a) provides further terminology relating to surface expression GDE's, which include spring vents / complexes:

- Spring vents are described as a single location in the landscape where groundwater discharges at the surface. A spring vent can be mounded or flat and can also present as wetland vegetation, with no visible water at the location of the spring.
- A spring complex is a group of spring vents located close to each other. The spring vents are located in the same surface geology and share the same source aquifer and landscape position. No adjacent pair of spring vents in the complex is more than 10 km apart.
- A watercourse spring is a section of a watercourse where groundwater from an aquifer enters the stream through the streambed. This includes waterholes and flowing sections of streams dependent on groundwater. This type of spring is also referred to as a baseflow-fed section of a watercourse.
- Spring group, a collection of complexes and / or watercourse springs, which share the same source aquifer and are in the same geographic area.

Potential Terrestrial GDEs (TGDEs) are mapped as present in the vicinity of the Project Area and are discussed in the following sections.

7.10.1 Potential TGDEs

The Project Area is located in the Brigalow Belt bioregion. The distribution of potential mapped TGDEs (State of Queensland 2018d), in the vicinity of the Project Area is presented in Figure 7.27. Potential TGDEs in this area are indicated to intermittently connect to aquifers with brackish salinity and alkaline pH in unconsolidated Quaternary alluvial.

Small patches of low confidence 01 – 80% derived TGDEs are mapped within the Project Area, south, southeast north and northwest of the Project Area. Limited potential TGDEs are indicated surrounding the Project Area. Low to moderate confidence potential TGDEs (81 – 100%) are mapped to the east of the Project Area. Potential high confidence TGDEs mapped to the west of the Project Area correspond with riverine areas such as the Wallumbilla and Middle Creeks (1 – 80% derived TGDEs).

Queensland Government mapped potential TGDEs agree with potential TGDEs mapped using the GDE mapping rule sets as defined by the Queensland Government (2017) in Groundwater dependent ecosystem mapping rule sets for the Eastern Murray-Darling Basin. The rule sets occurring in the vicinity of the Project Area include:

- *eMDB RS 01D* – Ecosystems intermittently connected to aquifers with brackish salinity and alkaline pH in unconsolidated Quaternary alluvium. Potential surface GDEs dependent on these alluvial aquifers include lacustrine and palustrine wetlands, riverine water bodies and channels identified through prior research and deep-rooted REs including ecosystems dominated by Eucalyptus camaldulensis, Eucalyptus intertexta, Corymbia tessellaris, and / or Eucalyptus coolabah.
- *eMDB RS 04D* (located to the east of the Project Area) – Ecosystems intermittently connected to aquifers with brackish salinity and alkaline pH in unconsolidated inland sand ridges. Potential TGDEs dependent on these inland sand ridge aquifers include regional ecosystem 11.3.19 and 6.3.17.

No remnant vegetation is mapped within the Project Area.

7.10.2 Springs and Potential Surface Expression GDEs

There are no spring vents or complexes within the 25 km buffer of the Project Area. The closest watercourse springs are located along the Blyth and Yuleba Creeks (associated with the Mooga Sandstone) more than 20 km to the northeast and northwest of the Project Area, respectively.

The watercourses in the vicinity of the Project Area are expected to be highly ephemeral, with streamflow only occurring following rainfall events. This is likely a consequence of the catchments being in the uppermost reaches with limited runoff area. Limited to no groundwater contribution from the regional groundwater system to watercourses as baseflow is anticipated in the vicinity of the Project Area.

Surface expression GDEs are not indicated to be present in the Project Area. Small patches of low confidence surface expression GDEs associated with the Wallumbilla Creek are mapped to the west of the Project Area.

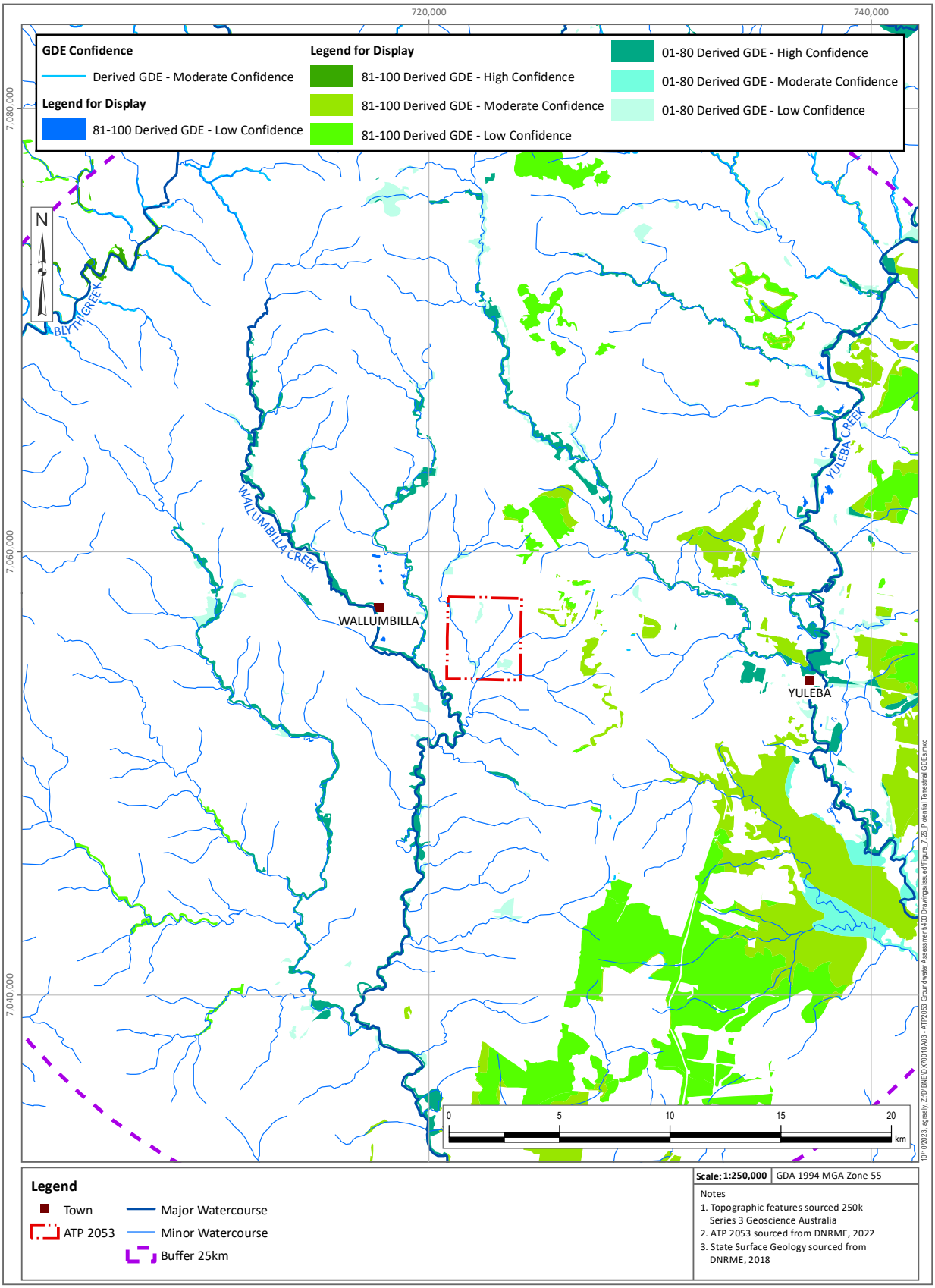


Figure 7.27 Location of Mapped Potential TGDEs in the Vicinity of the Project Area (State of Queensland 2018d)

7.10.3 RE Verification

Much of the Project Area has been largely cleared of native vegetation to form a non-remnant derived grassland dominated by introduced pastoral grasses, with occasional native trees and shrubs (Boobook 2024b).

Ground-truthed vegetation surveys undertaken by Boobook (2024) identified five RE types within the Project Area. Vegetation in the southern part of the Project Area is on land zone 3 (Quaternary alluvium) associated with streamlines and alluvial plains. Vegetation in the northern part of the Project Area includes areas on land zone 9 (fine-grained sediments). Ground-truthed areas of regrowth native vegetation is identified to occur as irregular, discontinuous corridors along streamlines, road easements and fence line corridors or as small, isolated fragments. Regrowth vegetation comprises Poplar Box (*Eucalyptus populnea*) woodland in riparian corridors, on narrow floodplains and on gently undulating terrain.

River Red Gum (*Eucalyptus camaldulensis*) dominates riparian woodland along the banks of larger streams, while Poplar Box (*E. populnea*) dominates floodplain woodlands. Brigalow (*Acacia harpophylla*) and / or Belah (*Casuarina cristata*) are prominent in areas of heavy soil and patches of Weeping Myall (*A. pendula)* occur on floodplains. Some low-lying areas have groundcover dominated by characteristic wetland fringe plants including sedges, Nardoo (*Marsilea spp.),* forbs and grasses. These floodplain wetlands include areas of non-remnant vegetation and modified drainage structures such as channels and overflow areas around dams (Boobook 2024b).

Boobook assessed vegetation conditions using the BioCondition methodology which indicates significant disturbance and consequent loss of ecosystem integrity relative to intact areas of each RE. The scores also reflect landscape level fragmentation of native vegetation, which is in small patch size, low connectivity and a low proportion of remnant and regrowth vegetation in the surrounding landscape.

The location and extent of ground-truthed REs from field surveys is displayed in Figure 7.28 and summarised in Table 7.5.

7.10.4 Site-Specific Ecological Assessment

Ecological assessment for the Project as detailed in the ERA identifies that no Significant Impact to MNES or MSES is expected as a result of the proposed development (Boobook 2024b). This is due to the existing severe fragmentation, generally poor habitat quality and the very small and localised disturbance area relative to surrounding habitat patches as well as citing of infrastructure to largely avoid disturbance to vegetation. Cumulative impacts resulting from the Project are assessed to be negligible. The conclusions included in the ERA are summarized in this section. Conservation status of REs are indicated in Figure 7.28 and MNES and MSES species potentially present in the Project area are listed per RE in Table 7.5.

Matters of National Environmental Significance

- **Threatened Ecological Communities (TEC):** Two TEC were identified to be present within the Project Area; Poplar Box grassy woodland on alluvial plains, and Weeping Myall woodlands.

- **MNES Flora:** No EPBC Act-listed threatened flora species were detected within the Project Area and no suitable habitat is present for species identified within desktop searches.
- **MNES Fauna:** No EPBC Act-listed threatened fauna species were detected within the Project Area. Potential habitat for eight EPBC Act-listed threatened fauna species is present within the Project Area. Potential habitat for multiple species of EPBC Act-listed migratory fauna species is present within the Project Area. These are all widespread and mobile species occurring in habitats that are common in the landscape surrounding the Project Area. These species do not depend on specific resources within the Project Area.
- **Weeds of National Significance:** Four species of WoNS were detected within the Project Area.

Matters of State Environmental Significance

- **Regional Ecosystems:** Two endangered REs are present within the Project Area and three Of Concern REs. BioCondition scores for regrowth and remnant vegetation within the Project Area varied from 0.47 to 0.60 indicating significant disturbance and loss of ecological integrity relative to benchmark sites.
- **MSES Flora:** No Queensland *Nature Conservation Act 1992* (State of Queensland 2024i)(NC Act) - listed threatened flora species were detected within the Project Area and no suitable habitat is present for these species.
- **MSES Fauna:** No NC Act-listed threatened fauna species were detected within the Project Area. Potentially suitable habitat is present for multiple NC Act-listed threatened fauna species. The Project Area includes scarce potential fauna breeding and/ or shelter places.
- **Biosecurity:** Four *Biosecurity Act 2014* (State of Queensland 2024a) Category 3 Restricted Matter invasive plants were present within the Project Area.

7.10.5 Groundwater Dependence

A summary of the characteristics of ground-truthed REs identified within the Project Area is presented in Table 7.5. REs 11.3.25 and 11.3.2 have the potential to include both ephemeral and permanent wetlands.

As discussed, limited to no groundwater contribution from the regional groundwater system to watercourses as baseflow is anticipated within the Project Area. No groundwater level information is available for the Quaternary or Tertiary aged deposits, and only very limited data for the Wallumbilla Formation. No water level information is available for the Bungil Formation in the vicinity of the Project Area.

A review of available literature on tree rooting depth for the dominant species (based on available desktop information) in each of the ground-truthed REs has been completed to understand how dependent these species may be on groundwater.

The average rooting depth for species of Eucalyptus present in the dominant remnant / mature regrowth REs in the Project Area is known, based on literature reviews, to range from 9 m to 22.6 m, depending on the species and the interactions between geomorphology and plant physiological traits.

Eucalypts (including Forest Red Gums, *E. tereticornis*) have two rooting systems (known as a dimorphic rooting system), with the ability to access deep groundwater during periods of time where shallower soil moisture is limited, they have shown physiological responses allowing them to adapt to water stress (CDM Smith 2021).

Groundwater dependence of ground-truthed vegetation was inferred using GDE assessment guidelines (Serov, Kuginis, and Williams 2012). Partial reliance on groundwater is considered possible along creek lines where Tertiary sediment and alluvial systems are replenished during prolonged wet periods (when ephemeral creek systems are flowing).

Potential TGDEs may also be associated with percolation of infiltrated rainwater along streamlines and collection of rainwater in low lying areas underlain by material with low permeability which may result in temporary / seasonally perched groundwater conditions. If GDEs are present, a high resilience in the vegetation and aquatic communities may be expected due to the ephemeral nature of the creek systems.

OGIA completed a regional scale desktop risk assessment of TGDEs that may potentially be impacted by CSG and coal mining activities as part of the Surat CMA UWIR (OGIA 2021g). The assessment was conservative because it was applied to vegetation that has been classified, mostly through desktop studies, by the Queensland Herbarium as a potential TGDE (therefore, it included vegetation that may not be dependent on groundwater). No potential TGDE areas in the vicinity of the Project Area were identified as being at risk.

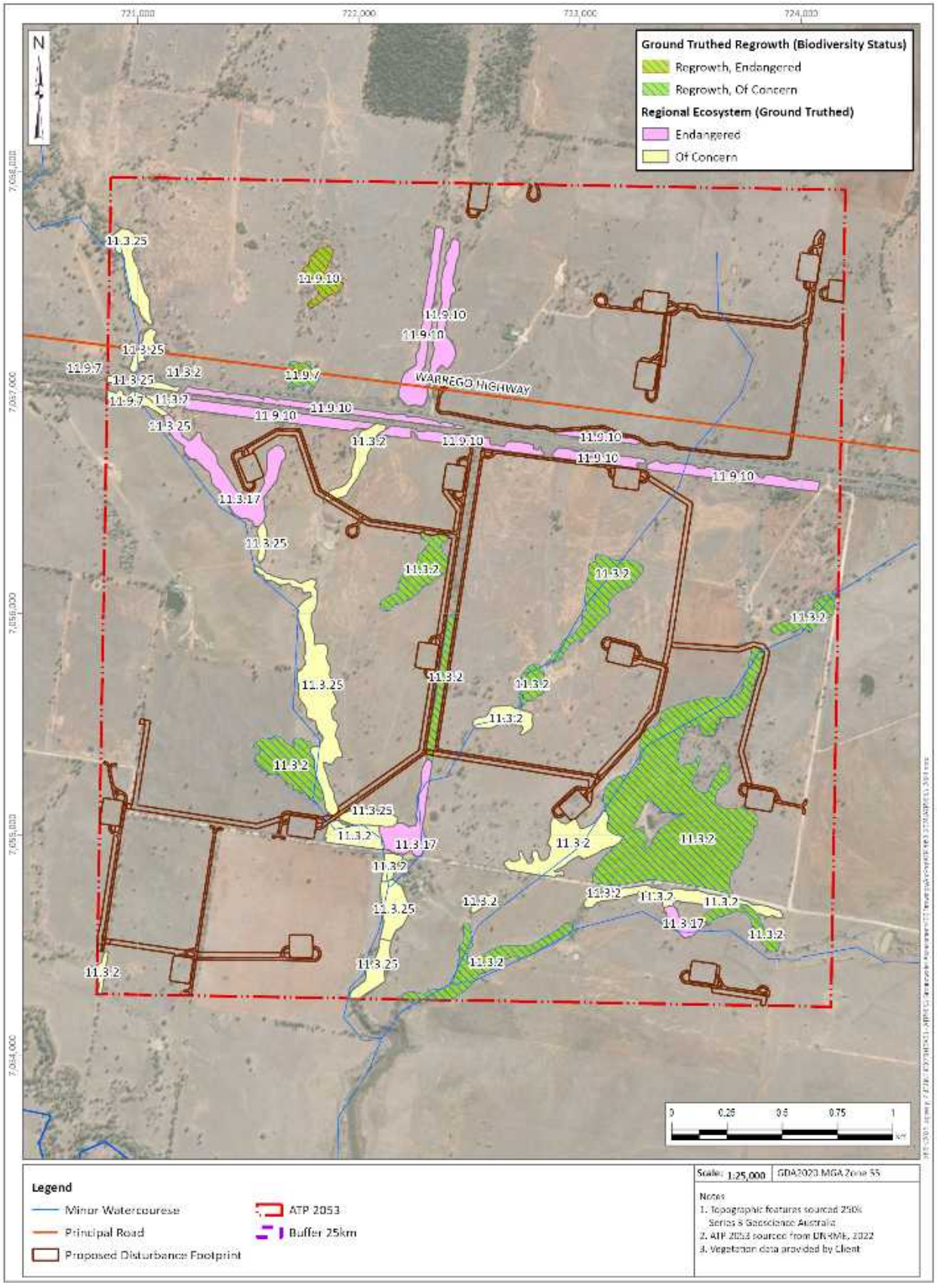


Figure 7.28 Ground-Truthed Regional Ecosystems and Wetlands in the Project Area (Boobook 2024b)

Table 7.5 Ground-Truthed Regional Ecosystems in the Project Area

Regional Ecosystem	Land Zone	Biodiversity Status	VM Act Class	Short Description	Available Rooting Depths	Potential for Groundwater Dependance	Extent in the Project Area (ha)	EPBC Act-Listed Threatened Species Potentially Present	NC Act-listed Endangered and Vulnerable Species Potentially Present
11.3.2	Alluvium (river and creek flats)	Of concern - dominant	Of concern	*Eucalyptus populnea* woodland on alluvial plains; may contain Palustrine wetlands	12.6 - 22.6 m *for E. populnea* / Poplar Box	Potential for groundwater / partial dependence	19.41	Glossy Black-Cockatoo, White-throated Needletail, Koala, Yakka Skink, Grey Snake, Sharp-tailed Sandpiper, Latham's Snipe, Australian Painted Snipe	Glossy Black-Cockatoo, White-throated Needletail, Australian Painted Snipe, Koala, Yakka Skink, Grey Snake
11.3.17	Alluvium (river and creek flats)	Endangered - dominant	Of concern	*Eucalyptus populnea* woodland with *Acacia harpophylla* and/or *Casuarina cristata* on alluvial plains; not a wetland	*E. populnea* / - 12.6 - 22.6m (Kath, et al., 2014)	Potential for groundwater / partial dependence	10.81	Glossy Black-Cockatoo, White-throated Needletail, Koala Yakka Skink, Grey Snake, Sharp-tailed Sandpiper Latham's Snipe, Australian Painted Snipe	Glossy Black-Cockatoo, White-throated Needletail, Australian Painted Snipe, Koala, Yakka Skink, Grey Snake
11.3.25	Alluvium (river and creek flats)	Of concern - dominant	Least concern	*Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage	At least 9m and assumed to reach groundwater reservoirs (*E. tereticornis* / Forest Red	Potential for groundwater / partial dependence	20.94	White-throated Needletail, Koala Grey Snake, Sharp-tailed Sandpiper Latham's Snipe,	White-throated Needletail, Australian Painted Snipe, Koala, Grey Snake

Regional Ecosystem	Land Zone	Biodiversity Status	VM Act Class	Short Description	Available Rooting Depths	Potential for Groundwater Dependance	Extent in the Project Area (ha)	EPBC Act-Listed Threatened Species Potentially Present	NC Act-listed Endangered and Vulnerable Species Potentially Present
				lines; riverine wetland	Gum) 12.1 - 22.6 m (*E. camaldulensis*)			Australian Painted Snipe	
11.9.7	Hills and lowlands on metamorphic rocks	Of concern	Of concern	*Eucalyptus populnea, Eremophila mitchellii* shrubby woodland on fine-grained sedimentary rocks; not a wetland	No information	Unlikely groundwater dependent	0.61	Glossy Black-Cockatoo, White-throated Needletail, Koala, Sharp-tailed Sandpiper Latham's Snipe, Australian Painted Snipe	Glossy Black-Cockatoo, White-throated Needletail, Australian Painted Snipe, Koala
11.9.10	Undulating country on fine-grained sedimentary rocks	Endangered - dominant	Of concern	*Eucalyptus populnea* open forest with a secondary tree layer of *Acacia harpophylla* and sometimes *Casuarina cristata* on fine-grained sedimentary rocks; not a wetland	*E. populnea* / - 12.6 - 22.6m (Kath, et al., 2014)	Unlikely groundwater dependent	23.96	Glossy Black-Cockatoo, White-throated Needletail, Koala Yakka Skink, Sharp-tailed Sandpiper, Latham's Snipe, Australian Painted Snipe	Glossy Black-Cockatoo, White-throated Needletail, Australian Painted Snipe, Koala, Yakka Skink

7.10.6 Subterranean Fauna

Stygofauna are predominantly crustaceans that are between 0.3 mm and 15 mm in length (Humphreys 2006). They are predominantly found in aquifers with large (mm or greater) pore spaces, especially alluvial, karstic and some fractured rock aquifers (Hose et al. 2015). The size of the pore spaces is a key determinant of the suitability of an aquifer as *stygofauna* habitat.

Stygofauna have been recorded occasionally in coal seam aquifers, particularly where those aquifers are hydrologically connected to a shallow alluvial aquifer (Hose et al. 2015). Hose et al. (2015) indicates the following related to the presence of *stygofauna*:

- The abundance and diversity of *stygofauna* typically decreases with depth below ground. Fauna are rarely found more than 100 mbGL.
- *Stygofauna* are found across a range of water quality conditions (from fresh to saline), but most common in fresh and brackish water (EC less than 5,000 µS/cm).
- *Stygofauna* are rarely found in hypoxic groundwater (< 0.3 mg O_2/L); and
- *Stygofauna* are more abundant in areas of surface water-groundwater exchange, compared to deeper areas or those further along the groundwater flow path remote from areas of exchange or recharge.

In the context of the Project Area, it is unlikely that *stygofauna* will be present within the target coal seams, or in the formations surrounding the coal seams due to the depth below ground level.

Saturated conditions (and therefore suitable habitat for *stygofauna*) within the surficial Tertiary and Quaternary sediments are expected to be variable and dependant on rainfall and ephemeral creek flow.

7.11 Existing Groundwater Users

7.11.1 Registered Groundwater Bores

There are 427 registered groundwater bores located within a 25 km buffer of the Project Area. Of these bores, 376 are existing bores (which include water supply and monitoring bores), with the remainder either abandoned and destroyed, abandoned but usable or proposed. A summary of registered bores is presented in Table 7.6 and displayed in Figure 7.29. (OGIA 2022b; State of Queensland 2024j).

Table 7.6 GWDB Registered Bore Statistics for the Project Area and a 25 km Buffer

Type		Abandoned and Destroyed (AD)	Abandoned but Usable (AU)	Proposed (PR)	Existing (EX)	Total
Artesian	Condition Unknown (AB)	1	1	0	16	18
	Ceased to flow (AC)	5	0	0	25	30
	Controlled Flow (AF)	17	1	0	71	89
	Uncontrolled Flow (AU)	0	0	0	1	1
Sub-Artesian (SF)		23	1	2	263	289
Total		46	3	2	376	427

AB: artesian condition unknown; AC: artesian bores, which have ceased to flow; AF: bores that are under artesian pressure and capped to control free flow; AU: artesian bores, which are uncontrolled; SF: bores which do not flow under any condition and where active pumping is required to abstract water.

Groundwater bores not registered in the GWDB may be present in the vicinity of the Project Area (e.g. this may include bores installed prior to the requirement to register water bores with the State of Queensland). It is not known how many unregistered bores may exist; however, these bores may be identified during future baseline assessments. The data from baseline assessments is provided to OGIA and the State of Queensland for incorporation into future updates to the GWDB.

7.11.2 Groundwater Use and Purpose

Groundwater is used for a number of purposes in the Surat CMA, including stock and domestic; agriculture, including general agriculture, irrigation and stock intensive; town water supplies; and industrial / mining purposes. Groundwater abstraction for stock and domestic purposes is likely to be the dominant water use within the vicinity of the Project Area, with 368 existing, abandoned but usable and potential water supply bores identified within 25 km of the Project Area (Table 7.7).

OGIA completed an assessment to estimate groundwater use within the Surat CMA as part of the UWIR (OGIA 2021f). This estimate forms part of the non-CSG water component within the regional groundwater flow model which predicts impacts associated with CSG (Section 8.2).

As part of the UWIR, OGIA also completed an assessment to assign an aquifer to each bore within the Surat CMA. Their approach sourced data from the GWDB, tenure holder bore assessments, research projects, State of Queensland datasets, previous aquifer attribution for the 2012 and 2016 UWIR (QWC 2012; OGIA 2016b) and the 2018 Surat CMA geological model (OGIA 2019a). The approach used a hierarchical approach to estimate the source aquifer, with the hierarchy taking into account the confidence level of the data source. OGIA have provided this dataset to Santos to use as part of this assessment of existing groundwater users within the vicinity of the Project Area (OGIA 2022b). Updated registered bore data were also sourced from the GWDB (State of Queensland 2024j). Bore logs were assessed and attribution assigned for bores where OGIA attribution was not available.

A summary of aquifer attribution for water supply bores (potential, existing and abandoned but usable) within a 25 km buffer of the Project Area is provided in Table 7.7, with the bore purpose presented in Figure 7.30. The majority of water use is attributed to the Mooga Sandstone and Orallo Formation, followed by the Gubberamunda Sandstone and Bungil Formation.

There are six bores located within 25 km of the Project Area that do not have an aquifer attribution assigned to them. Three (RN168013, RN168178 and RN208460) of the six are water supply bores. For the purposes of this report and for conservatism, these two have been assigned to the Gubberamunda Sandstone as this is the closest aquifer above the WCM.

Table 7.7 Aquifer Attribution and Number of Water Supply Bores within a 25 km buffer of the Project Area

Aquifer Attribution	Number of Bores	% of total bore count
Wallumbilla Formation	8	2%
Bungil Formation	22	6%
Mooga Sandstone	118	32%
Orallo Formation	102	28%
Gubberamunda Sandstone	59	16%
Westbourne Formation	3	1%
Lower Springbok Sandstone	2	1%
Upper Juandah Coal Measures	1	1%
Lower Juandah Coal Measures	2	1%
Taroom Coal Measures	5	1%
Upper Hutton Sandstone	29	8%
Lower Hutton Sandstone	1	0%
Precipice Sandstone	6	2%
Moolayember Formation	2	1%
Upper Bandanna Formation	1	0%
Lower Bandanna Formation	1	0%
Upper Permian	1	0%
#N/A	5	1%
Total	**368**	

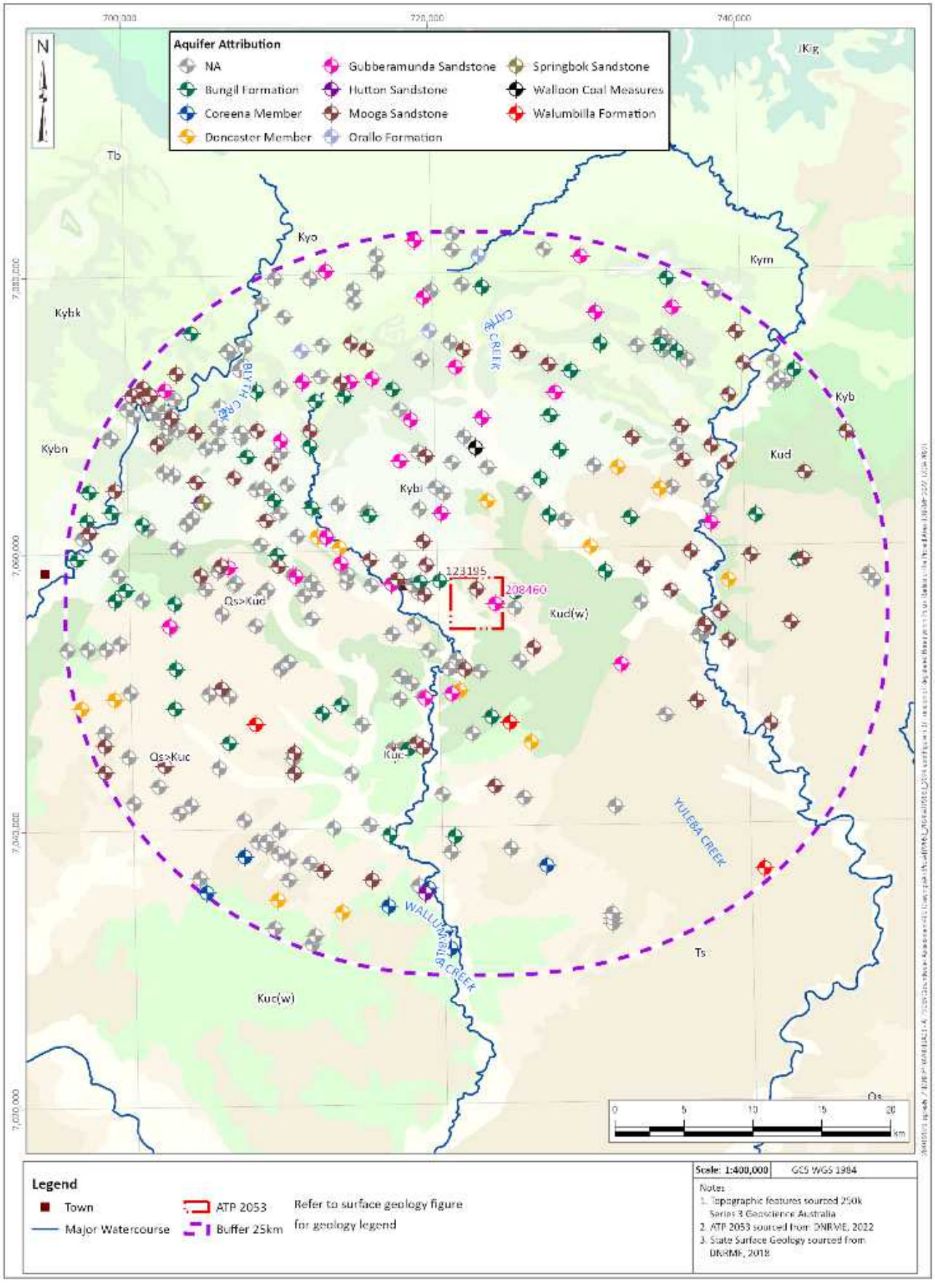


Figure 7.29 Location of Registered Bores within 25 km Radius of the Project Area

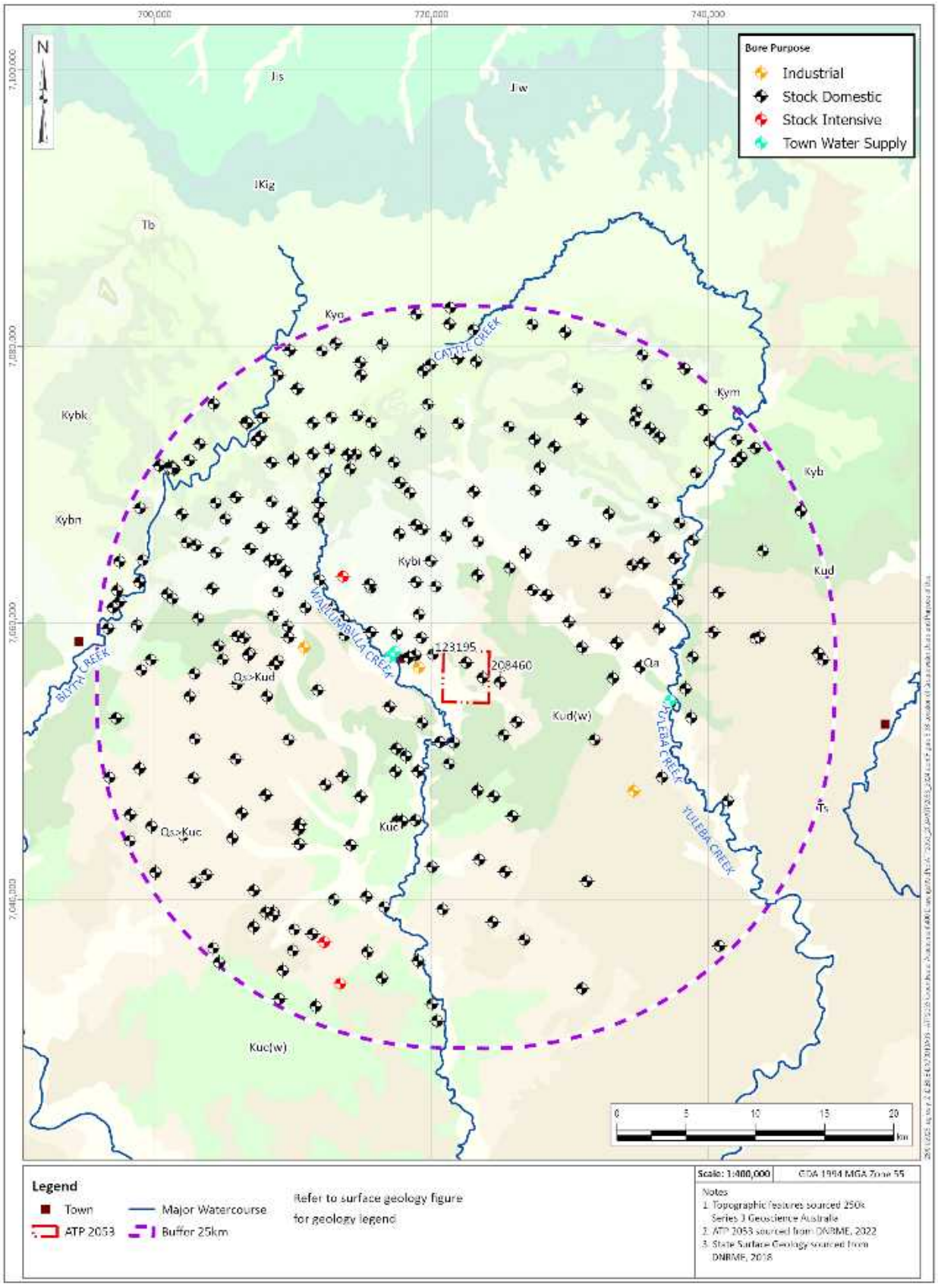


Figure 7.30 Location of Groundwater Users and Purpose within 25 km Radius of the Project Area

7.11.3 Bore Baseline Assessment

Under the Water Act 2000, CSG proponents are required to undertake baseline assessments of water bores located within their petroleum tenures prior to commencement of production. Baseline assessments are undertaken in accordance with the *Baseline Assessment Guideline* (DES 2017), to obtain information such as: bore status, type and purpose; information related to the construction of the bore, including depth installed, screen interval and source aquifer; groundwater level and quality and field gas measurement; and bore equipment including pump depth, pumping frequency and flow rate.

There is one operational water bore located within the Project Area attributed to the Mooga Sandstone, as shown in Figure 7.29. Baseline assessment was undertaken in 2009 for RN 123195. Another groundwater bore (RN208460) was drilled on the tenement in June 2024. This new bore is indicated as “no longer used”. Bore locations are shown in Figure 7.29. Santos are in the process of revising their Baseline Assessment Plan to consider the new bore, with baseline assessment planned to occur in 2025 (prior to commencement of the Project).

Table 7.8 Baseline Assessment Bore Details

Bore Registration Number (RN)	Bore Name	Property	Easting (GDA94)	Northing (GDA94)	Purpose	Date of Existing Baseline Assessment	Aquifer Attribution	Baseline Assessment Date
123195	House Bore	123WV468	722513	7057126	Domestic	4/11/2009	Mooga Sandstone	04/11/2009
208460	-	-	723709	7056052	Domestic / Stock	-	-	2025; prior to project commence-ment

7.11.4 Town Water Supply

Maranoa Regional Council operates reticulated water networks in several towns including Roma and Yuleba. The Surat's municipal water allocation is 350 ML per annum. This water allocation has been exceeded by more than 5% in 5 of the last 10 years (Maranoa Regional Council 2024).

Town water supply in the vicinity of the Project Area is sourced from the Gubberamunda Sandstone (township of Wallumbilla) and Orallo Formation (Yuleba), located >3 km and > 12 km from the Project Area boundary, respectively (refer to Table 7.9). In future, water may also be sourced from the Mooga Sandstone.

Table 7.9 Current / Historical Town Water Supply Bores

RN	Easting (GDA94)	Northing (GDA94)	Status	Aquifer Attribution	Location
58023	737254	7054389	Existing	Orallo Formation	Yuleba
48871	717033	7057579	Abandoned but usable	Orallo Formation	Wallumbilla
123318	717375	7057909	Existing	Gubberamunda Sandstone	Wallumbilla

7.12 Hydrogeological Conceptual Model Summary

This section summarises the information of the previous sections in terms of the conceptual models for the hydrological and hydrogeological systems and identifies the water-dependent assets for consideration in the impact assessment. A summary of the conceptual model is as follows:

- The surface geology within the vicinity of the Project Area comprises Quaternary-age alluvium associated with the watercourses (Wallumbilla Creek, Washpool Creek and Middle Creek), with Cenozoic aged residual / colluvium in the east of the Project Area. The Doncaster Member, a tight aquitard of the Wallumbilla Formation, outcrops with limited extent in the centre of the Project Area and underlies the Quaternary and Tertiary aged alluvium and residual / colluvium across the Project Area (larger outcropping areas are present to the east and south of the Project Area). The Wallumbilla Formation has a limited vertical extent in the Project Area with a mean thickness of 2.8 m. The Wallumbilla Formation appears to confine the underlying Bungil and Orallo Formation in some areas; the majority of bores in these formations are artesian.
- The Coreena Member, also of the Wallumbilla Formation, is a partial aquifer and outcrops to the south of the Project Area while other Cretaceous units outcrop to the north of the Project Area. The Wallumbilla Formation is underlain by the Bungil Formation, a partial aquifer of the Blythesdale Group.
- The southeasterly extent of the Hutton-Wallumbilla Fault is indicated to occur 4 km northwest of the Project Area. There are no major or observable local geological structures (e.g. faults) intersecting the Project Area.
- The watercourses within the Project Area are characteristically ephemeral and typically only flow during and immediately following significant rainfall events.
- Potential TGDEs associated with the watercourses, if partially groundwater, would likely be sourcing groundwater from the shallow unconsolidated sediments within and adjacent to watercourses within the Project Area (Washpool Creek). Quaternary and Tertiary deposits present across the Project Area are expected to be primarily recharged during prolonged wet periods due to rainfall infiltration and when the ephemeral creek systems are flowing. Limited water level monitoring data is available for the Quaternary and Tertiary aged units as well as the Doncaster Member and Bungil Formation, which highlights each of these units as having a limited potential to be a water resource. This does not facilitate robust conclusions regarding groundwater level depth and the potential for interaction with surface water systems; however, available information indicate that limited to no groundwater contribution from the regional system to watercourses as baseflow is likely at the Project Area, particularly considering the watercourses are ephemeral.
- There are no spring vents or complexes within the 25 km buffer of the Project Area. The closest watercourse springs are located along the Blyth and Yuleba Creeks (associated with the Mooga Sandstone) more than 20 km to the northeast and northwest of the Project Area, respectively.

- Groundwater use is predominately associated with the Mooga Sandstone (32% of the total groundwater use) and the Orallo Formation (28% of the total groundwater use), followed by the Gubberamunda Sandstone (16%). Most are used for stock and domestic purposes, with 368 water supply bores (existing, abandoned but usable and potential) identified within 25 km of the Project Area.
- The target for gas production is the WCM which occurs at 650 mbGL (vertical depth) at the Project Area.
- The WCM and Springbok Sandstone (a tight aquifer that directly overlies the coal measures) are over- and underlain by thick sequences of several tight aquitards (which limit propagation of drawdown into the overlying and underlying aquifers), including most notably the overlying Westbourne Formation (which has a mean thickness in the Project Area of 63 m) and the Orallo Formation (with a mean thickness of 198 m), as well as the underlying Eurombah / Durabilla Formation (which has a mean thickness of 52 m) and the Upper Evergreen Formation (with a mean thickness of 161 m).
- The WCM is also separated from the overlying Springbok Sandstone by the Upper WCM Non-Productive Layer; also, identified as an aquitard.

The conceptual model is summarised in Figure 7.31.

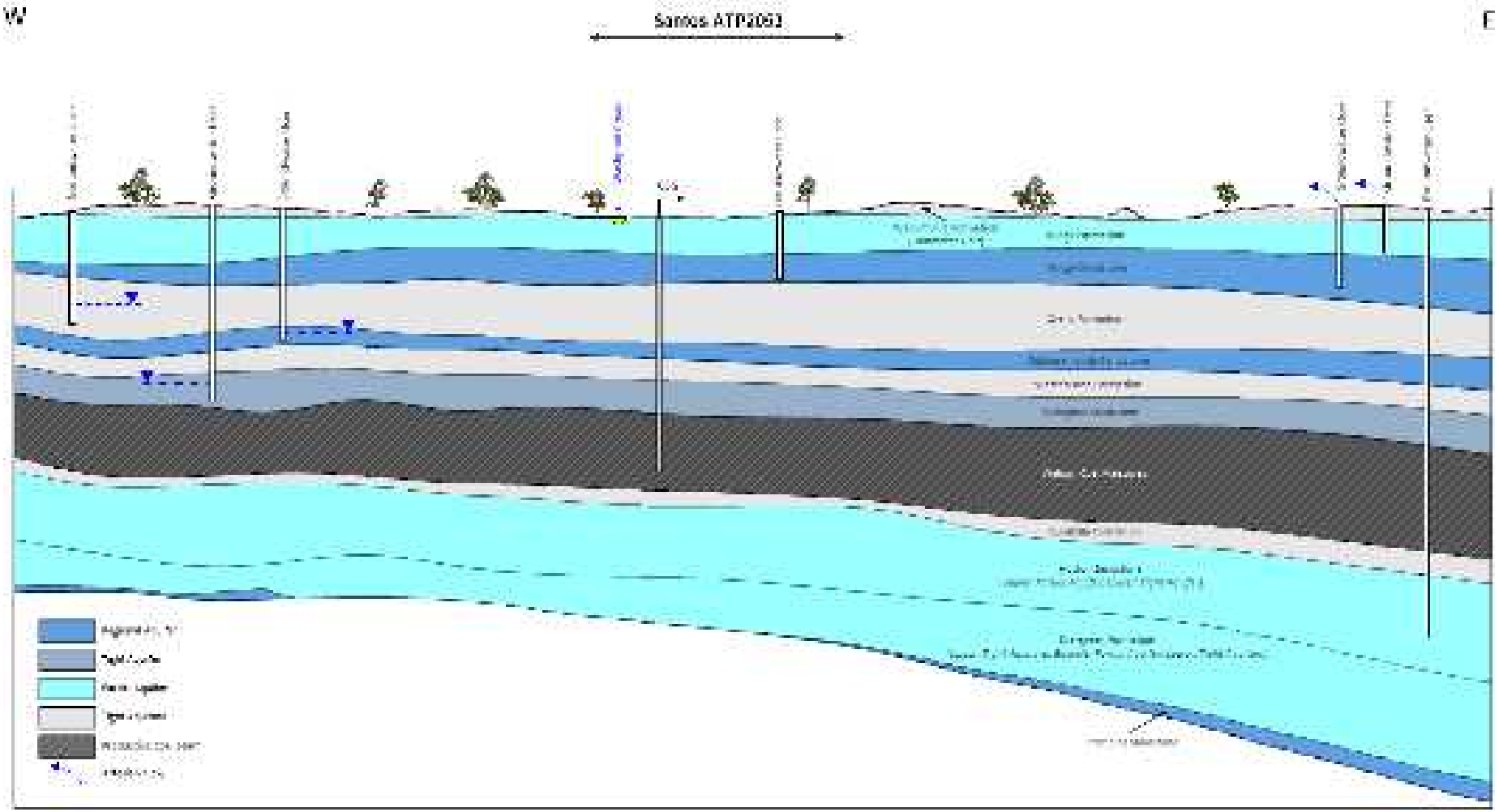


Figure 7.31 Conceptual Model of the Project Area

8 NUMERICAL GROUNDWATER MODELLING

8.1 Overview

As detailed in Section 3.1, the Project Area is located within the Surat CMA, which was declared under the Water Act 2000, as a result of concentrated development by multiple tenure holders.

The Project Area is located adjacent to other active and proposed CSG developments. As groundwater is removed via CSG production wells to depressurise the coal seams, there will be a degree of interaction between the individual tenure holders.

OGIA, established under the Water Act 2000, is responsible for predicting regional impacts on water pressures in the hydrostratigraphic units of the Surat CMA and identifying potentially impacted groundwater bores and springs as presented in the UWIR, which is updated and published every three years.

As part of the Surat CMA UWIR, OGIA developed a regional numerical groundwater flow model to predict cumulative groundwater pressure impacts due to activities from multiple P&G tenure holders. The model was first developed and utilised as part of the 2012 UWIR (QWC 2012b). An updated UWIR and updated numerical groundwater model was published by OGIA in September, 2016 (OGIA 2016c), July, 2019 (OGIA 2019a) and most recently May 2022 (OGIA 2021g). Since the previous UWIR in 2019, the most recent UWIR addresses a new legislative requirement to include coal impact in the assessment and to assimilate contemporary data and conceptualisation work.

The primary purpose of the model is to predict regional water pressure or water level changes in aquifers within the Surat CMA footprint in response to extraction of groundwater associated with CSG, coal mining and conventional oil and gas. In particular, the OGIA numerical groundwater model is used to assess potential impacts to landholder groundwater bores and springs relative to the Water Act 2000 trigger thresholds (State of Queensland 2024m).

The current OGIA groundwater model is the agreed basis for assessment for all Surat CMA CSG impacts, even at the scale of individual bores for make good investigation purposes, therefore, also appropriate to use at the GDE scale for this assessment where it applies to non-alluvial units.

The Surat CMA UWIR is updated periodically (every three years), therefore, the OGIA numerical groundwater model for the Surat CMA is also updated periodically to support the UWIR. Key updates to the model include recalibration of the model based on monitoring data provided by proponents operating within the CMA, extraction records, and the incorporation of newly approved CSG developments within the CMA. Therefore, each update to the OGIA model results in the additional incorporation of site data and an update of the predicted cumulative drawdown impacts across the CMA.

The model domain includes the extent of the Surat CMA, with hydrostratigraphic units from the Surat Basin as well as interconnected basins (Bowen Basin and Clarence-Moreton Basin). The model domain is shown in Figure 8.1. The model consists of 35 layers, with the additional layer in the WCM (Taroom Coal measures) as shown in Figure 8.2.

This additional layer, added since the UWIR 2019, improves representation of flow between units within the WCM and will assist in predicting drawdown impacts within this formation.

A summary of key aspects of the model is presented in Table 8.1.

Table 8.1 Summary of the OGIA Regional Groundwater Flow Model (after OGIA 2019a) and (OGIA 2021a)

Model Component	Description
Modelling Platform	MODFLOW-USG
Model Domain	Model covers the entire Surat CMA (Figure 8.1), including all coal seam formations and potentially connected aquifers in the Surat, southern Bowen and Clarence-Moreton Basins. The model domain is 460 x 650 km.
Model Layers	Model consists of 35 layers (Figure 8.2). Addition of Taroom Coal Measures (2021 UWIR)
Grid Spacing	Model grid spacing is 1.5 km x 1.5 km
Parameterisation	Initial parameters for use in the Surat CMA model were developed using an innovative workflow, developed by OGIA, centred around a suite of detailed numerical permeameters. This workflow was initially developed for use in the 2016 regional groundwater flow model and has been further enhanced for the current model. This approach extracts full value from the large geological and hydraulic parameter dataset available for the CMA. Outputs from this process include formation scale horizontal and vertical permeabilities that are then used as inputs to the regional groundwater flow model for further calibration against water level and other observed data.
Water Production Simulation	Simulated using the MODFLOW-USG 'drain' boundary condition. Multiple MODFLOW-USG drains are assigned to each well; these descend over time as pressures in the CSG well are reduced.
Calibration	Calibration was undertaken using the automated calibration software PEST_HP and PESTPP_IES. Calibration of the model was achieved using a three-stage simulation: 1. The first simulation was to replicate conditions that existed prior to the commencement (1947) of any groundwater extraction, for petroleum, gas or other purposes. 2. The second simulation was to replicate pre- P&G extraction conditions in 1995 to provide starting or initial conditions for the third and final stage. 3. The third stage was a transient simulation to replicate the period from January 1995 to December 2020, during which P&G production commenced initially from the Bandanna Formation and then from the WCM.

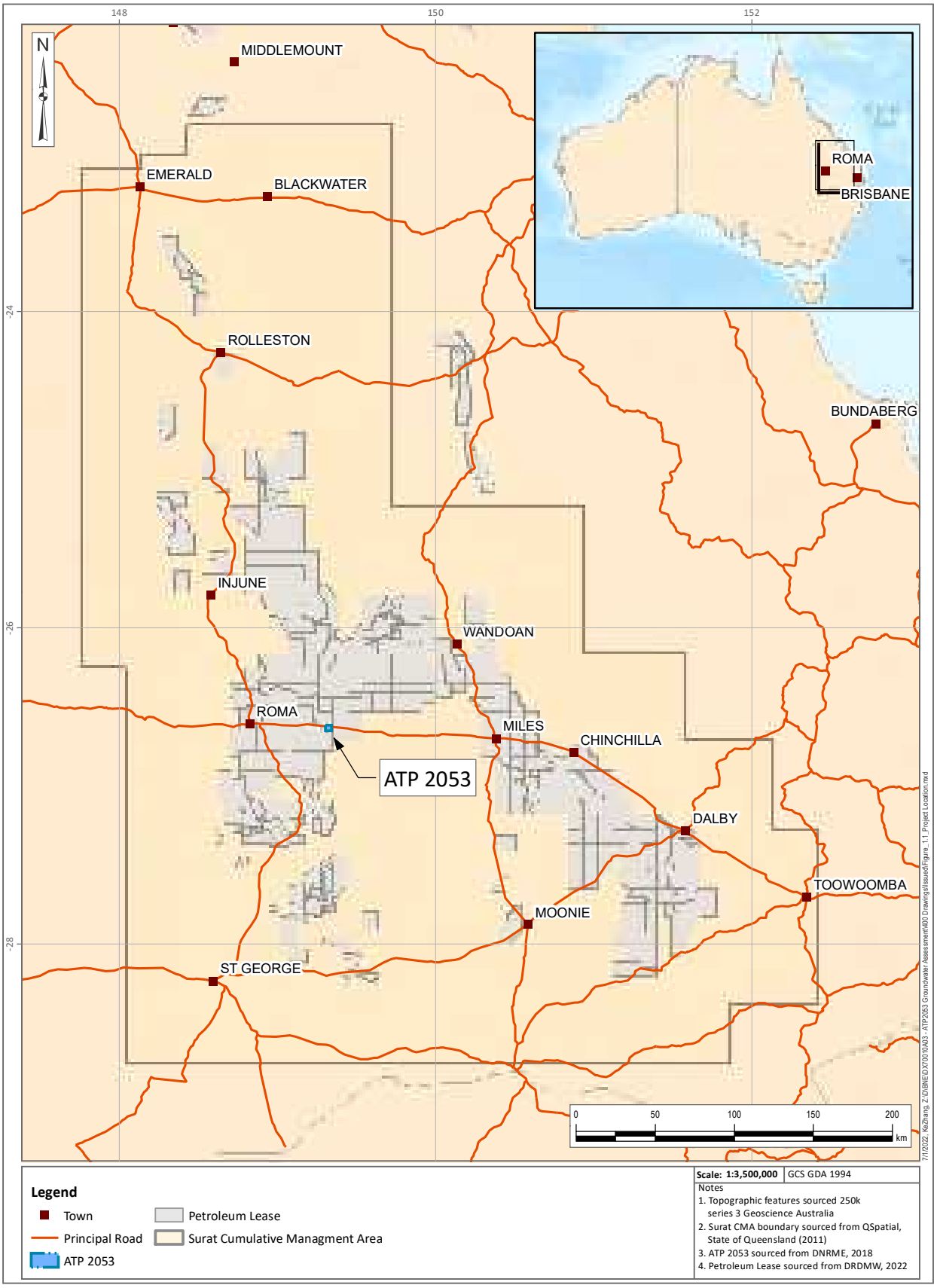


Figure 8.1 Location and Extent of the Surat CMA Regional Flow Model Domain and the Project Area

PROJECT CSG TARGET



Figure 8.2 Model Layers and Corresponding Units Represented in the OGIA Regional Groundwater Flow Model (OGIA 2021b)

8.2 Model Parameters, Boundary Conditions and Calibration

The information provided in the following sections has been summarised from the *Groundwater Modelling Report for the Surat Cumulative Management Area* (OGIA 2016c), *Underground Water Impact Report for the Surat CMA* (OGIA 2021i), and *modelling of cumulative groundwater impacts in the Surat CMA: approach and methods* (OGIA 2021b).

8.2.1 Model Parameters

OGIA improved their approach to assigning initial numerical groundwater model parameters as part of the update to the regional model for the 2016 UWIR and have continued to further refine the model for the 2021 UWIR.

The approach included three steps, as described in OGIA (OGIA 2019a):

- Initial values of hydraulic conductivity for each of six lithology types (clean sand, dirty sand, siltstone, mudstone, carbonaceous shale, and coal) from geophysical logs are derived from expert knowledge, literature, and analysis of geophysical logs.
- These initial values are then input to a stochastic permeability model and calibrated (or 'conditioned') through comparison with around 13,000 hydraulic test results at three different scales (i.e. pump tests, core test and geophysical measurement).
- Once calibrated, these values are then used to populate numerical permeameters – detailed 21 x 21 km numerical models of each stratigraphic unit, generated using lithological data for about 6,000 CSG wells and covering the full extent of the 12 stratigraphic units modelled. In total, more than 138,000 model runs were carried out during this part of the process.

OGIA model parameters (horizontal and vertical hydraulic conductivity) for the Project Area are displayed in Appendix I.

8.2.2 Groundwater Abstraction – Boundary Conditions

Optimal flow conditions for gas production are typically achieved when water pressures within the production well are equivalent to 25 to 80 m of water head (OGIA 2019a). To simulate water production, OGIA have used the MODFLOW-USG 'drain' boundary condition, with multiple drains assigned to each production well descending over time as pressures in the CSG production well reduce.

The simulation using the drain boundary condition, is based on the sequencing of development and production well spacing provided by tenure holders across the model domain. Water is removed from the model to achieve the optimal head conditions (25 to 80 m), rather than removing a volume predicted using a modelling tool (e.g. estimated abstraction volume in Section 3.4.1).

Groundwater abstraction for non-P&G purposes, such as stock and domestic, are simulated using the MODFLOW-USG 'well' boundary condition.

8.2.3 Model Calibration

Calibration of the 2021 model was achieved using a three-stage simulation (OGIA 2021b). The first was a pre-development (1947) simulation was to replicate conditions that existed prior to the commencement of any groundwater extraction, for petroleum, gas, or other purposes.

The second simulation was to replicate pre- P&G extraction conditions in 1995 to provide starting or initial conditions for the third and final stage.

The third stage was a transient simulation to replicate the period from January 1995 to December 2020, during which P&G production commenced initially from the Bandanna Formation and then from the WCM.

The calibration was undertaken using the automated calibration software PEST, with a range of qualitative and quantitative measures used to assess each calibration iteration, consistent with the *Australian Groundwater Modelling Guidelines* (Barnett et al. 2012).

8.3 Project Model Scenarios

Santos has recently planned to advance development of the Project, and as such the tenure has not been included in previous versions of the UWIR (including the recently published 2021 UWIR).

To assist Santos with approval applications, and to maintain consistency with the 2019 UWIR predictions, OGIA agreed to simulate the proposed CSG production for the Project within the UWIR model based on information provided by Santos. These outputs have been provided for use and processed as part of this assessment. All processing and analysis of model outputs were undertaken by KCB based on raw model outputs provided by OGIA.

Scenarios simulated by OGIA include:

- **Project only scenario** - includes future development at the Project only (24 wells, including two multi-wells comprising two wells each).
- **A cumulative CSG production model scenario** - includes all current and proposed non-P&G and P&G groundwater abstraction (original UWIR 2021 model) *plus* the Project *plus* reasonably foreseeable production at Santos ATP 1187 and ATP 2052.

Predicted drawdown of the Project only scenario and Cumulative scenarios are presented in Section 8.5.1 and Section 8.5.2, respectively.

8.4 Assumptions and Limitations

Assumptions and limitations of the regional groundwater model are provided in OGIA (2016a). Key assumptions and limitations of the model associated with its use for this assessment are provided as follows:

- Since the model is required to cover the full extent of the Surat CMA and all aquifers potentially impacted by P&G water extraction within the Surat CMA, groundwater numerical model cell sizes are relatively large in lateral extent (1.5 km × 1.5 km). One outcome of the large cell size is that shallow, unconfined groundwater systems, and the interaction of these systems with deeper systems, can be simulated only approximately.

- Model cell sizes are large in vertical extent. Other than the WCM, most stratigraphic layers in the Surat and Bowen Basins are represented by only one or two model layers. Vertical head gradients within these layers, and geological details which lead to variations of these gradients, are only an approximation for the entire stratigraphic thickness.

  (i.e. heterogeneity of the stratigraphic unit is not fully captured in the numerical model although considerable efforts were made to generate upscaled parameters and test that the model could replicate impact predictions made using highly detailed models with minimal upscaling).

- Depressurisation of coal measures leading to desorption of gas, and hence the resulting dual phase flow (gas and water), is simulated using a van Genuchten function in which water saturation is a function of pressure alone. This is a simplification of more complex processes that include desorption of gas and then flow of gas together with water towards extraction centres. Buoyant potential up-dip movement of gas, not captured in CSG production wells, is also not represented.
- The effect of local faulting, and abandoned and poorly constructed wells, on vertical propagation of drawdown to stratigraphic units adjacent to the WCM units is not considered. However, major regional fault systems are represented in both the model structure and parameterisation, and hence their effects on impact propagation are considered.
- Limited site-specific hydraulic parameter data is available for the Project Area. Therefore, the values utilised in the model in the vicinity of the Project Area have been inferred and calibrated through reference to data outside of the Project Area. This may increase / decrease the effects of CSG production, and associated groundwater abstraction, in the vicinity of the Project Area.
- CSG production is represented by drain boundary conditions with elevations set for optimal gas production. As a result, the produced volume of water from the drain cells may not necessarily represent actual CSG water production due to localised variability in aquifer hydraulic parameters. The model, however, has been calibrated to historic actual production data and is able to replicate production in most current fields to a high degree of accuracy.

8.5 Scenario Results

8.5.1 Project Only Scenario Results

Numerical model outputs provided by OGIA, for the scenarios detailed in the previous section, have been used by KCB to assess the extent and magnitude of drawdown related to CSG production from the Project.

Appendix II includes the predicted drawdown for the individually modelled hydrostratigraphic units where drawdown of more than 0.2 m is observed (as detailed in Figure 8.2). The figures in Appendix II presents the Project only scenario drawdown and recovery post-development.

Summary figures are presented in Figure 8.3 to Figure 8.5, which show the maximum predicted Project only scenario drawdown for the relevant hydrostratigraphic unit, irrespective of date. Figures were not generated for formations where predicted drawdown is less than 0.2 m.

Observations include:

- Drawdown exceeding the trigger levels are not predicted in the surficial unconsolidated Quaternary and Quaternary-Tertiary units (layer 1), or in Cretaceous-aged formations (layers 2 to 6), the Gubbermunda Sandstone (layer 7) and the Westbourne Formation (layer 8).
- There is no notable drawdown predicted in the Hutton Sandstone (layer 19) and in formations beneath the Hutton Sandstone.
- Drawdown greater than 0.2 m (spring trigger threshold) is predicted in model layer 9 (Lower Springbok Sandstone) to model layer 18 (Durabilla Formation).
- Drawdown greater than 5 m (consolidated bore trigger threshold) is only predicted in model layers 12 to 18 (WCM and the underlying Durabilla Formation); and
- The highest drawdown is predicted in model layers 13 to 17, which represent the WCM (target for CSG production).

Appendix II presents the predicted Project only scenario drawdown and recovery post-development where notable drawdown is observed. The post-development timesteps presented are for Project recovery year 0 (end of Project), 56, 176, 326, 526 and 726. These figures show rapid groundwater level drawdown within the WCM during Project implementation and slow recovery following Project completion. Drawdown impact is still evident in the WCM 700 years after Project completion.

Limited drawdown is predicted to propagate into the overlying / underlying layers (as described above) during Project development, and recovery is pronounced following Project cessation.

Drawdown within the Durabilla Formation is shown to decrease to below 5 m between 200 – 500 years following Project completion. The Upper and Lower Springbok Sandstone reflects complete recovery between 180 - 320 years following Project completion.

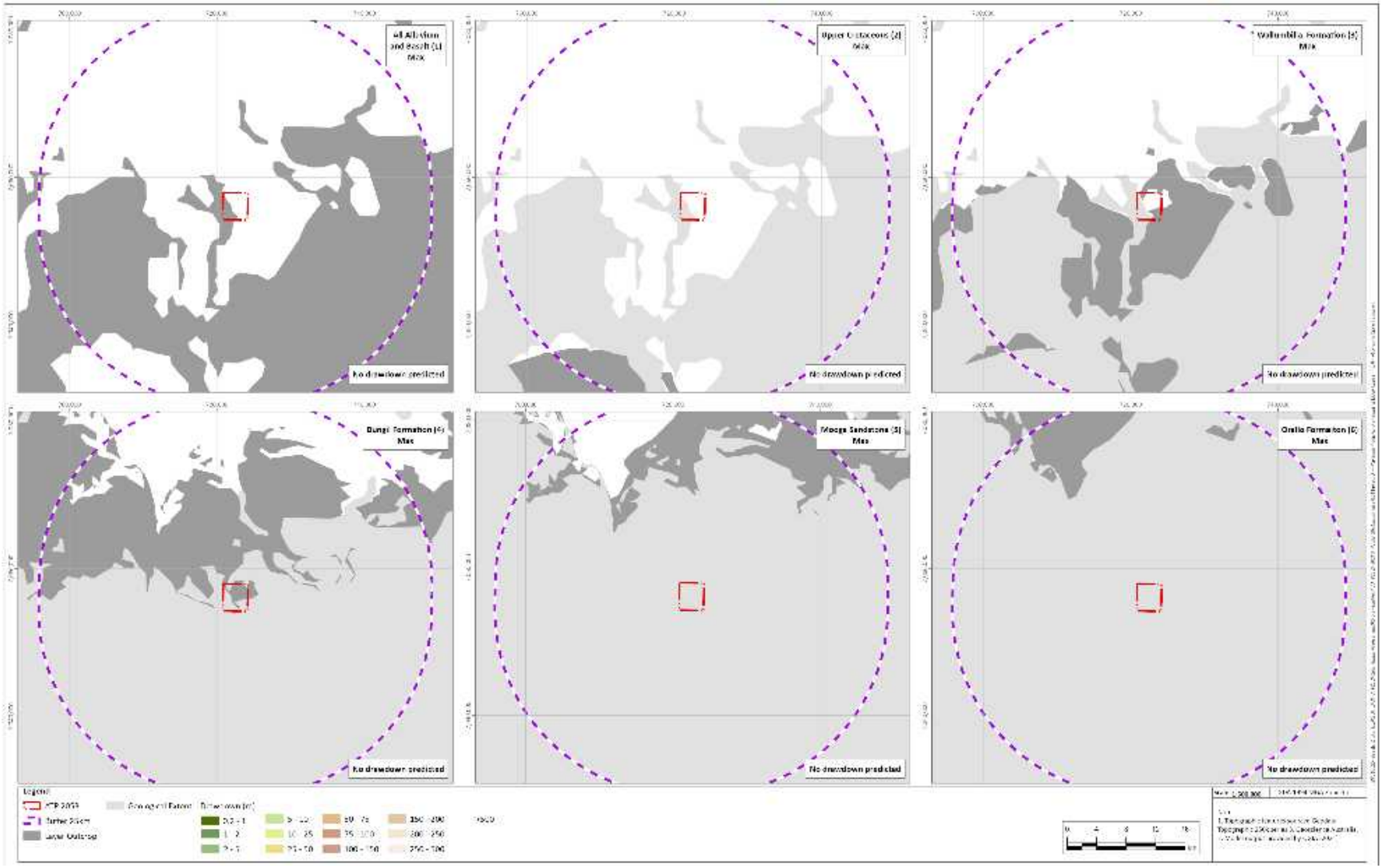


Figure 8.3 Project Only Scenario Maximum Drawdown Pattern for Model Layers, 1 to 6 – Upper Springbok to Upper Juandah Coal Measures

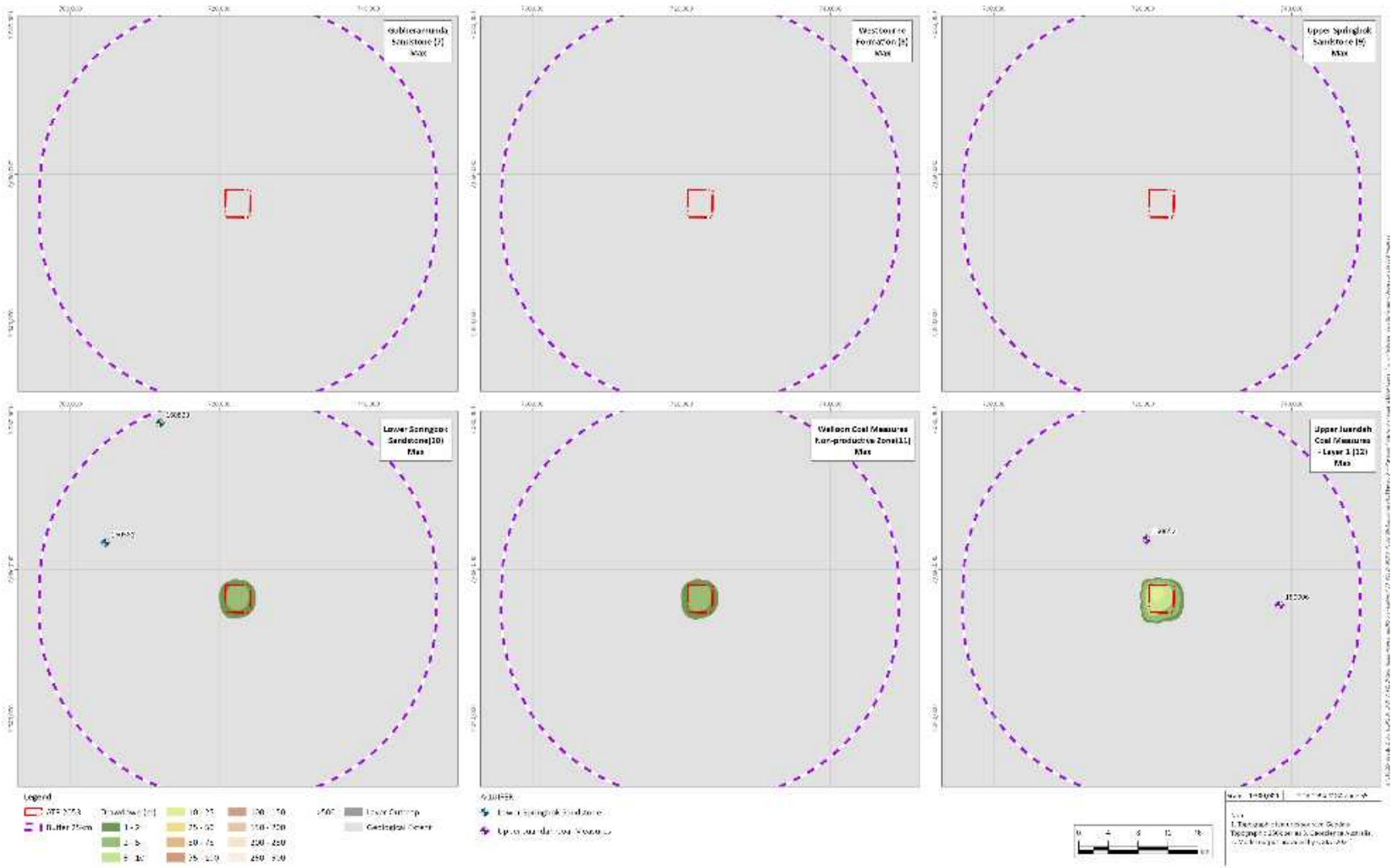


Figure 8.4 Project Only Scenario Maximum Drawdown Pattern for Model Layers, 7 to 12 – Upper Springbok to Upper Juandah Coal Measures

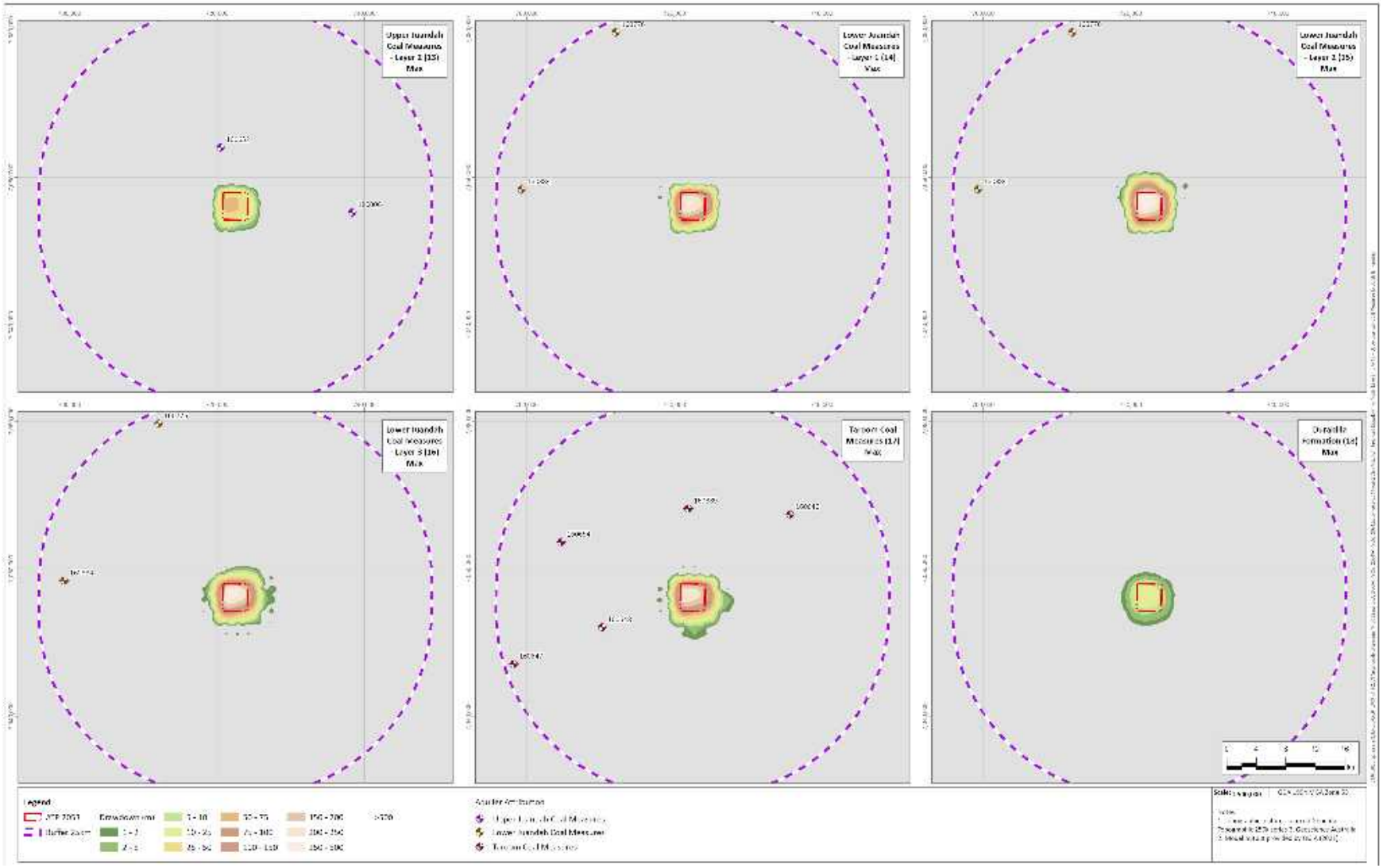


Figure 8.5 Project Only Scenario Maximum Drawdown Pattern for Model Layers, 13 to 18 – Lower Juandah Coal Measures to Durabilla Formation

8.5.2 Cumulative Scenario Results

The cumulative drawdown scenario includes includes all current and proposed non- P&G and P&G groundwater abstraction (as reported in the original UWIR 2021 model) *plus* the Project *plus* reasonably foreseeable production at Santos's neighbouring future development tenures - including ATPs 1187 and 2052.

Summary figures for the Cumulative scenario are presented in Figure 8.6 to Figure 8.8. These figures show the maximum predicted cumulative drawdown for the relevant hydrostratigraphic unit, irrespective of date.

Observations include:

- The cumulative drawdown results indicate that drawdown greater than 0.2 m is not predicted within the vicinity of the Project Area in surficial unconsolidated Quaternary and Quaternary-Tertiary units (layer 1), and in the upper Cretaceous and Wallumbilla formations (layers 1 to 3).
- Drawdown of between 0.2 – 1 m is predicted in the Bungil Formation, the Mooga Sandstone, the Orallo Formation and the Gubberamunda Sandstone (layers 4 – 7) >12 km to the north of the Project Area (in the vicinity of existing CSG operations), where drawdown greater than 5 m is predicted to extend from the Westbourne Formation to the Durabilla formation (layers 8 – 18). This drawdown is not associated with the proposed Project but is rather associated with the water production from neighbouring CSG developments operating on tenures located closer to these outcropping units.
- The largest drawdown in the Upper Juandah Coal Measures and Springbok Sandstone is also predicted to occur to the north of the Project Area, corresponding with neighbouring CSG developments. Drawdown also occurs to the south, where other CSG proponents are operating.
- Drawdown in the Lower Juandah Coal Measures and Taroom Coal Measures, as well as the Durabilla Formation is anticipated to be widespread.

Project Contribution to Cumulative Scenario in Outcropping Areas

The proportion of cumulative drawdown (in excess of 0.2 m) in outcropping formations within 25 km of the Project Area, and which can be attributed to the Project, has been quantified as follows:

- Bungil Formation: Project contribution to the predicted cumulative drawdown is 0 – 4%.
- Mooga Sandstone: Project contribution to the predicted cumulative drawdown is 0 - 2 %; and
- Orallo Formation: Project contribution to the predicted cumulative drawdown is 0 - 1 %.

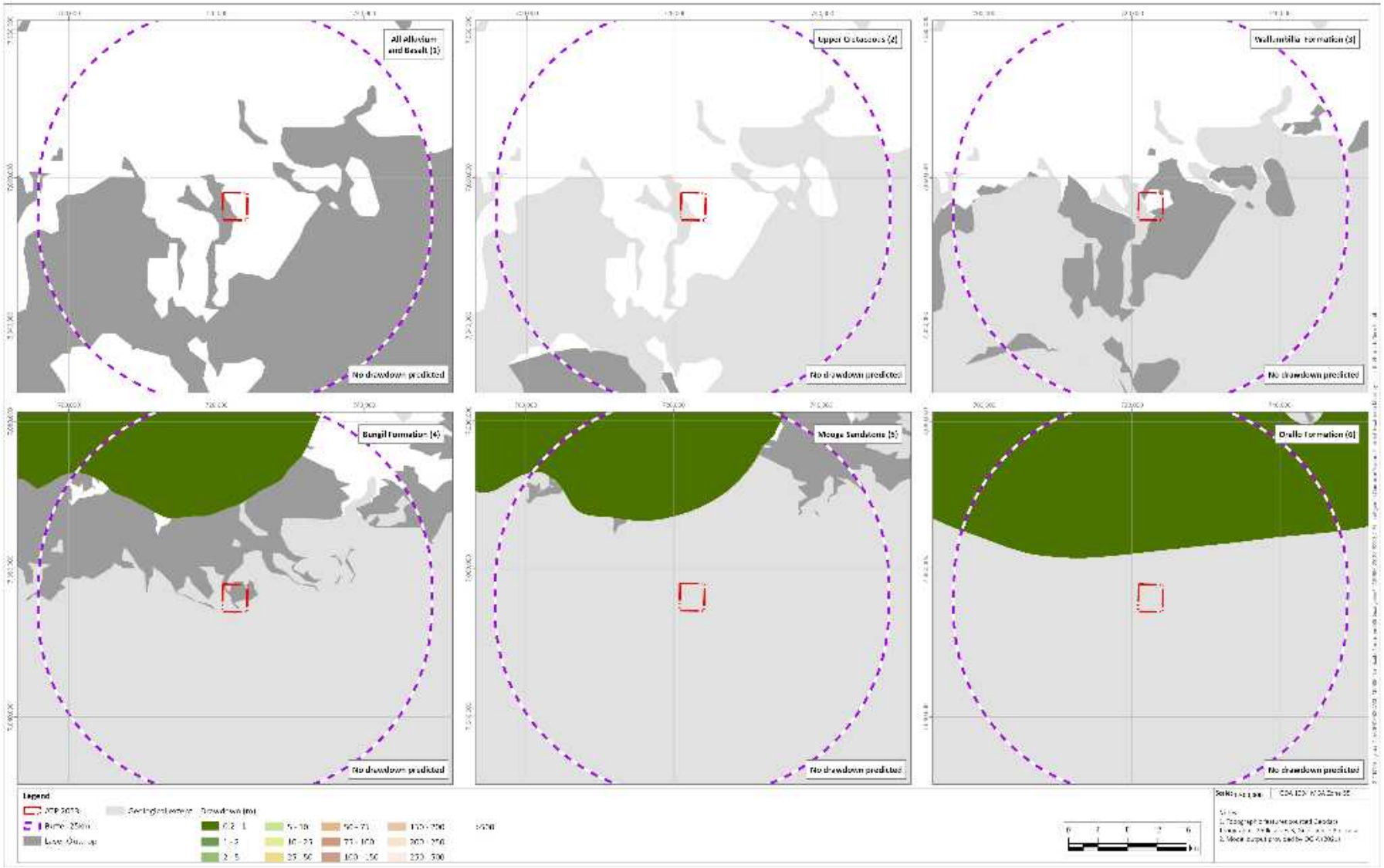


Figure 8.6 Cumulative Maximum Predicted Drawdown for Model Layers, 1 to 6 – Alluvium to Orallo Formation

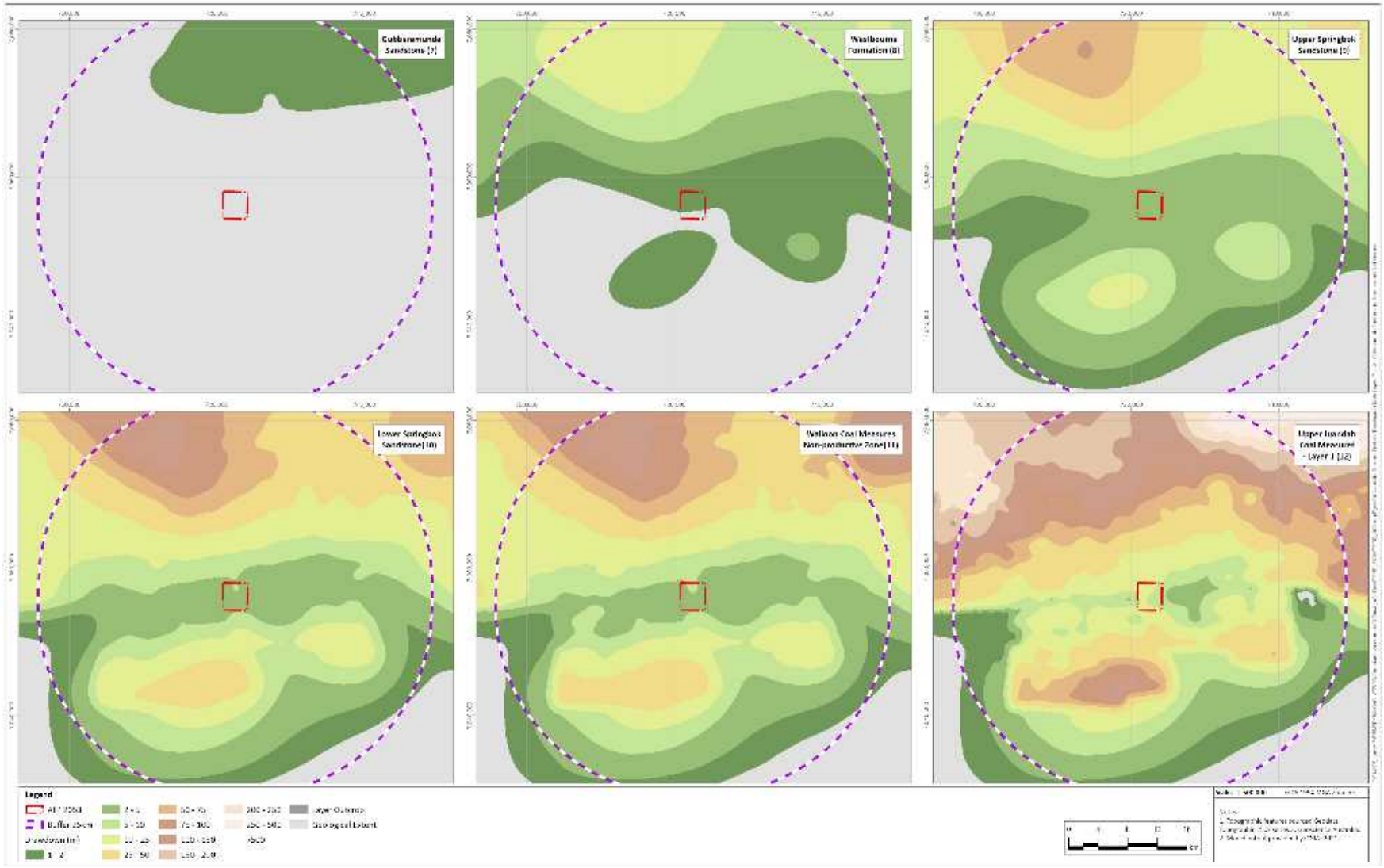


Figure 8.7 Cumulative Maximum Predicted Drawdown for Model Layers, 7 to 12 – Gubberamunda Sandstone to Upper Juandah Coal Measures

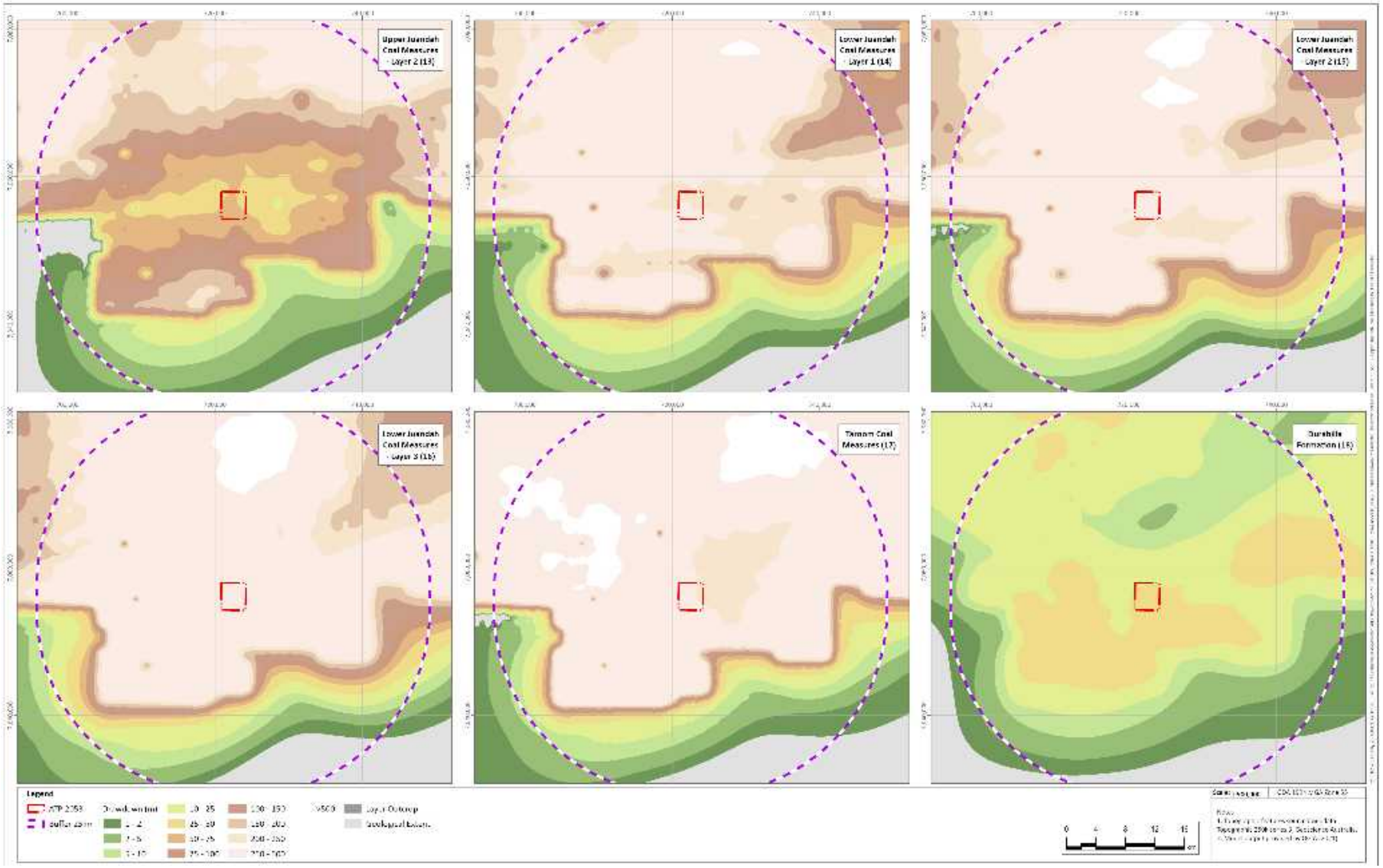


Figure 8.8 Cumulative Maximum Predicted Drawdown for Model Layers, 13 to 18 – Upper Juandah Coal Measures to Durabilla Formation

9 IMPACT ASSESSMENT

9.1 Potential Project Impacts

9.1.1 Groundwater

Water production occurs as part of the CSG production process. Groundwater is removed via CSG wells during the coal seam depressurisation process, which then liberates gas flow. This depressurisation and gas flow sustains groundwater flow from each CSG well to maintain the target gas producing operational pressure.

Santos intend to exercise their underground water rights under the P&G Act (Section 2.2.1) to produce CSG. Several other authorised petroleum lease holders are also exercising their underground water rights in the vicinity of the Project Area.

Potential impacts resulting from CSG related water production include:

- Decline in groundwater level / pressure at water bores, reducing water availability and potentially impacting groundwater EVs.
- Reduction in groundwater head resulting in a reduction of groundwater discharge at spring complexes, potentially causing degradation of GDEs; and
- Reduction of baseflow to watercourses, potentially resulting in degradation of GDEs and reduced water availability to potential users downstream.

These impacts have been quantitatively assessed in the following sections using modelling outputs from the UWIR 2021 numerical groundwater model. Potential impacts to water-dependent assets have been assessed based on the Water Act 2000 trigger threshold for springs (0.2 m drawdown) and bores (5 m drawdown in consolidated aquifer; 2 m drawdown in unconsolidated aquifer) using the predicted drawdown for both the Project only scenario and Cumulative scenarios.

Other potential impacts associated with groundwater are mitigated and managed by adopting the appropriate monitoring, management, and mitigation strategies. These impacts may include:

- Potential to introduce a connection between hydrostratigraphic units (which were previously isolated units) though drilling and construction of CSG production wells, resulting in the potential for alteration of flow regimes and quality; and
- Potential impacts such as an increased demand in groundwater use as a result of the Project (e.g. from the establishment of site camps) are not anticipated. Temporary camp facilities may be located within the Project Area, however the majority of the personnel for the operations will utilise existing accommodation at nearby Santos camp facilities.

Avoidance, mitigation, management and monitoring practices associated with the above activities are discussed further in Section 10.

Impacts relating to climate change (increase in median annual temperature, decrease in median annual rainfall and increase in median annual evaporation) will likely result in a reduction of groundwater recharge and slightly depressed groundwater levels over time, specifically in near-surface aquifers. It is not anticipated that climate change effects will result in exacerbation of

Project related impacts, since notable Project related drawdown does not extend to near-surface aquifers.

9.1.2 Surface Water

Impacts to surface water from the Project are anticipated to be minimal. The Project does not include any:

- Planned material discharge to / abstraction from natural surface water systems; or
- Watercourse diversions.

Potential impacts that may result from Project activities to surface water are summarised below. These potential impacts are associated with the general construction and day-to-day operations of CSG surface facilities rather than CSG production, and could comprise:

- Alteration of a watercourse character or changes to riparian buffers due to construction works and / or infrastructure; and
- Altered surface water runoff characteristics from construction / developed areas;

No material impacts to surface water environmental values are anticipated, including to aquatic ecosystems and cultural and spiritual values, due to development of the Project.

Regardless of the low potential for impact, avoidance, mitigation, management and monitoring plans will be implemented to address any risks that my develop during operations. Further discussion of these management plans is included in Section 10.

As discussed in Section 3.1, the Project Area is surrounded by other resource tenements, including PLs 315, 318, 1020, 281 and 282. Further, reasonably foreseeable nearby tenures for CSG development include ATPs 1187, 2052 and 2054. Due to the local and limited nature of potential surface water impacts associated with the Project, **the Project contribution to potential cumulative impacts (if present) is anticipated to be low.**

9.1.3 Chemical Contamination

As discussed in Section 4.2.3, Santos has developed the CRAF and CRAR for the Project to assess the full lifecycle of chemicals that are stored, transported, handled, used and / or disposed during or following drilling and completions, and hydraulic fracturing activities.

The CRAF / CRAR assessment process is designed to align with national guidance and other regulatory frameworks and assesses the full lifecycle of chemicals that are stored, transported, handled, used and / or disposed during or following drilling and hydraulic fracturing activities.

The CRAF includes the following:

- Consideration of potential risks and effects of chemicals used during CSG operations (defined as drilling and completions and hydraulic fracturing) and the potential risks and effects of geogenic (naturally occurring) constituents that may be present in recovered drilling fluids and produced waters during coal seam gas operations.

- It details the conceptual exposure model (CEM) that describes the chemical source(s), pathways of chemical migration through environmental media and the potential susceptible populations (both human and ecological) that may be exposed.

  In the development of the exposure pathways current environmental setting and land uses, environmental fate and transport mechanisms, and life cycle stages of usage of chemicals and relevant receptors were evaluated to determine which pathways are potentially complete and identify potential receptors for those pathways. A complete exposure pathway exists when a source, a migration pathway, a mechanism for exposure and a potential receptor are all present.
- Assessment of fate and transport of constituents in the subsurface, which indicates that conservative constituents (soluble and mobile) will sufficiently attenuate in the subsurface such that beyond 90 m there are no potential unacceptable risks associated with potential releases during drilling.

A summary of the CRAR is provided below:

- The aim of the chemical risk assessment was to evaluate the potential risks and effects of chemicals used during CSG extraction (drilling, completions and hydraulic fracturing).
- The goal of the chemical risk assessment was to demonstrate that potential risks to water resources and receptors associated with the chemicals used in CSG extraction have been eliminated or reduced as much as is reasonably practicable.
- The life cycle of the drilling, stimulation and completion was assessed specifically for the proposed operations and included:
  - Storage, usage (e.g., blending, injection), and recovery of chemicals throughout operations;
  - Beneficial reuse of recovered drilling fluids and cuttings for well lease rehabilitation; and
  - Storage of produced water.
- In accordance with the CRAF an evaluation of all chemicals proposed for use was conducted, with the majority of chemicals classified as Tier 1 chemicals.
- One hundred and sixty-nine (169) chemicals were assessed as part of this initial Chemical Risk Assessment:
  - 140 chemicals were assessed as Tier 1 chemicals.
  - 19 chemicals were assessed as Tier 2 chemicals.
  - Seven (7) chemicals were assessed as Tier 3 chemicals.
  - Three (3) chemicals were deemed to be impurities at de minimus levels within a proposed product (CAS No 4080-31-3); and
  - No chemicals were assessed as Tier 4 or 5 chemicals.
- Screening / Hazard (Tier 1), Qualitative (Tier 2) and Quantitative (Tier 3) Risk Assessments are provided for each chemical as relevant according to the identified risk category.

Qualitative and quantitative assessments considered potentially complete exposure scenarios as identified by the CRAF CEM.

- The potential for cumulative impacts associated with chemicals proposed for this Project are considered negligible following implementation of management and monitoring controls.
- The CRAR includes a summary of / references existing management controls and include additional recommendations for risk management, based on the findings of the risk assessment. Should assessments of additional chemicals indicate additional management control, the CRAR requires that associated management plans be updated accordingly.
- The chemical risk assessments completed for each chemical indicated the effects of chemicals used during CSG operations poses a low to negligible risk (drilling and completions and hydraulic fracturing) to receptors when appropriate management and mitigation controls were in place.
- Based on the screening assessment against maximum concentrations, the geogenic chemical concentrations (and in some cases added to by drilling chemicals) of residual drilling materials exceed risk-based screening levels (RBSLs) and could pose a risk to environmental receptors if not adequately managed. Identified risk will be managed through a combination of land application methodologies, management controls and the occupational health and safety plan to prevent post-beneficial use soil conditions from exceeding RBSLs.

Santos proposes to apply a number of management and mitigation measures to reduce the risk to water resources. Implementation of existing and additional recommended management practices is expected to eliminate or reduce as much as is reasonably practicable the potential risks to water resources and receptors associated with the use of chemicals in CSG extraction.

A summary of key avoidance, mitigation, management and monitoring plans to reduce and verify the risk associated with the use of chemicals is provided in Section 10.

The overall risk to water resources and EVs associated with the use of chemicals has been assessed as being low to insignificant for the Project only and Cumulative scenarios following implementation of avoidance, mitigation, management and monitoring measures as provided in Section 10.

9.1.4 Changes to Water Quality

As discussed in Section 3.4, the majority of produced water generated from the Project will be transferred to existing approved water storage (Pickanjinnie and / or Raslie Dams) and treatment facilities located adjacent to the Project Area on PLs 314 and 315 via new and existing water gathering infrastructure. These petroleum tenures and facilities are owned and operated by Santos and are subject to independent assessment and approvals.

Small volume tanks will be utilised in the Project Area from time to time to store produced water until permanent water gathering infrastructure is installed e.g. for well production testing purposes. No large water storage or treatment facilities are proposed to be constructed or operated in the Project Area.

Potential changes to groundwater quality as a result of Project development activities may occur due to:

- The use of drilling fluids in the CSG drilling process.
- Seepage from unplanned / accidental produced water leaks; and
- Infiltration in areas potentially affected by chemical spillage, beneficial reuse activities and areas affected by accidental produced water leaks.

Potential changes to surface water quality from Project activities may occur due to:

- Localised transport of suspended sediment to waters during construction or site works.
- Accidental leaks and releases of produced water.
- Accidental release of fuel and chemicals; and
- Rainfall runoff over areas potentially affected by accidental chemical spillage, beneficial use activities and areas affected by accidental produced water leaks have the potential to impact surface water and associated ecosystems.

Impacts to water quality, related to the use of chemicals, geogenic chemicals within produced water and residual drilling material associated with the Project are discussed in the CRAF / CRAR and summarised in Section 9.1.3.

Cumulative impacts are not anticipated due to the localised nature of potential impacts. Management and mitigation controls will be implemented to ensure the potential risks to water quality have been eliminated or reduced to as low as reasonably practicable. Avoidance, mitigation and management controls are summarised discussed in further detail in Section 10.

Based on the assessment results, changes to groundwater or surface water quality are unlikely and not predicted as a result of the Project, following implementation of management and mitigation controls.

9.2 Potential Impacts to Third-Party Groundwater Users

Potential long-term impacts to groundwater bores have been assessed against the Water Act 2000 bore trigger threshold of 2 m for an unconsolidated aquifer (e.g. alluvium) and 5 m for a consolidated aquifer (e.g. Cretaceous and Jurassic aged formations), using the outputs and drawdown predictions from the UWIR numerical model.

The maximum predicted drawdown was used for this assessment, irrespective of the timing of predicted drawdown. No existing bores are screened within unconsolidated aquifers (e.g. alluvium and Tertiary sediments) within 25 km of the Project Area.

Results of the predicted drawdown for the Project only scenario and Cumulative scenarios, assessed against trigger limits at individual water bores present within 25 km of the Project Area, are presented in Appendix III.

Several groundwater bores within the vicinity of the Project Area were constructed to intersect multiple formations. OGIA have assigned each bore a dominant source aquifer, with this dominant aquifer used to assess potential drawdown at each bore.

Two (RN168013 and RN168178) water supply bores do not have an aquifer attribution assigned to them. For the purposes of the report and for conservatism, these two bores have been assigned to the Gubberamunda Sandstone as this is the closest aquifer above the WCM.

Appendix III provides the attributed formation used as part of the impact assessment.

For the Project only scenario, the maximum predicted drawdown in the target formations at the locations of the 368 (existing, abandoned but usable, proposed and potential) water supply bores, is 0.03 m.

The Cumulative scenario assessment was undertaken using the same approach adopted for the Project only scenario (e.g. Water Act 2000 trigger thresholds). No bores are indicated to exceed the trigger threshold within a 25 km buffer of the Project Area.

The bore triggers are therefore not predicted to be exceeded as a result of Project only or Cumulative scenario activities and predicted impact on groundwater supply bores is assessed as negligible. The contribution of the Project does not result in any additional bores being triggered in the Cumulative scenario.

Town water supply schemes that source water from the Gubberamunda Sandstone and the Orallo Formation in the vicinity of the Project Area will not be affected by drawdown as a result of the Project only scenario or Cumulative scenarios.

9.3 Potential Impacts to Third-Party Surface Water Users

There are no surface water users identified within the vicinity or immediately downstream of the Project Area, therefore, no impacts to third-party surface water users are predicted as a result of Project development.

9.4 Potential Impacts to Groundwater Dependent Ecosystems

Impacts to potential GDEs can occur if the following conditions are met:

- Potential GDEs have been identified in the area;
- The potential GDEs are located on a GAB aquifer outcrop / sub-crop;
- It is confirmed that the potential GDEs are sourcing water from the GAB aquifer, or the GDEs are sourcing water from an alluvial system connected to a GAB aquifer. Evidence to suggest a connection include:
  - Hydraulic evidence including groundwater levels in the underlying GAB aquifer are in connection with the alluvium or there is sufficient water in the alluvium to support the potential GDE.
  - Water quality in the GAB aquifer is suitable for GDEs to survive.
- Drawdown of >0.2 m is predicted in the GAB aquifer due to the presence of the Project.

The WCM occurs at 650 mBGL within the Project Area. The WCM is over- and underlain by thick sequences of several tight aquitards which limit propagation of drawdown into the overlying and underlying aquifers.

Project only scenario drawdown greater than 0.2 m (Water Act 2000 spring and JIF GDE threshold) is not predicted in outcropping / sub-cropping geological units (Section 8.5.1).

Predicted Cumulative drawdown of more than the spring and JIF thresholds (0.2 m) is indicated for the Bungil Formation, Mooga Sandstone and Orallo Formation at distances > 12 km to the north of the Project Area. The Project contribution to the predicted cumulative drawdown for these formations are assessed to be minor to negligible (0 – 4%). This drawdown is therefore not associated with the proposed Project but is rather associated with the water production from neighbouring CSG developments operating on tenures located closer to these outcropping units.

No new springs and GDE areas are triggered due to drawdown contribution from the Project.

9.4.1 Potential Impacts to Wetlands

The Project Area and the surrounding 25 km buffer area does not include any wetlands listed in the *Directory of Important Wetlands in Australia* (Environment Australia 2001). No wetlands of High Ecological Significance or wetlands of General Ecological Significance were mapped by the EAR as present within the Project Area.

The closest notable wetlands are situated more than 120 km from the Project Area and are therefore not considered material to the current assessment. **The Project will therefore not impact upon any internationally or nationally important wetlands, nor wetlands of High or General Ecological Significance.**

9.4.2 Potential Impacts to Springs

There are no spring vents or complexes recorded within the 25 km buffer of the Project Area. The closest watercourse springs are located along the Blyth and Yuleba Creeks (associated with the Mooga Sandstone) more than 20 km to the northeast and northwest of the Project Area respectively. Drawdown exceeding 0.2 m is not predicted in any of the outcropping formations (including the Mooga Sandstone) due to drawdown associated with the development of the Project only.

The Project only contribution to cumulative drawdown in outcropping formations is anticipated to be negligible.

No material impacts on spring vents, complexes or watercourse springs as a result of Project development are identified.

9.4.3 Potential Impact to Aquatic GDEs

Surface expression GDEs are not indicated to be present in the Project Area. Small patches of low confidence surface expression GDEs associated with the Wallumbilla Creek are mapped to the west of the Project Area.

As discussed in Section 6.5 and 7.8 the watercourses in the vicinity of the Project Area are characteristically ephemeral. Limited to no groundwater contribution from the regional

groundwater system to watercourses as baseflow is anticipated within the Project Area. Quaternary and Tertiary aged systems are likely to be replenished during prolonged wet periods when the ephemeral creek system is flowing. Temporary perched groundwater conditions may result due to percolation of infiltrated rainwater along streamlines and the collection of rainwater in low lying areas underlain by material with low permeability. The EAR for the Project Area (Boobook 2024b) does not identify threatened aquatic fauna or flora to be present.

Drawdown that exceeds the JIF threshold is not predicted for the Project only scenario in outcropping or sub-outcropping formations.

Potential exceedance of the JIF threshold (greater than the 0.2 m) is indicated in outcropping units for the Cumulative scenario > 12 km to the north of the Project Area. The Project only scenario contribution to this drawdown is anticipated to be minor to negligible.

Impacts to aquatic GDEs due to the Project are not expected. No new GDE areas are triggered due to drawdown contribution from the Project.

9.4.4 Potential Impacts to TGDEs

Potential TGDEs of limited extent, associated with unconsolidated Quaternary alluvium and unconsolidated sands which may be intermittently connected to aquifers with brackish salinity, are mapped by DES (DES 2018b) at desktop level within the vicinity of the Project Area.

The WCM is over- and underlain by thick sequences of several tight aquitards which limit propagation of drawdown into the overlying and underlying aquifers. The WCM occurs at 650 mbgL (vertical depth) at the Project Area.

As discussed in Section 7.10.3, the rooting depths identified for species present in identified RE's based on available literature reviews, range to 22.6 m. Quaternary and Tertiary aged systems are likely to be replenished during prolonged wet periods when the ephemeral creek system is flowing. Temporary perched groundwater conditions may result due to percolation of infiltrated rainwater along streamlines and the collection of rainwater in low lying areas underlain by material with low permeability. Partial reliance on groundwater in these systems is possible.

OGIA completed a regional scale desktop risk assessment which did not identify any TGDE areas in the vicinity of the Project Area as being at risk due to CSG development.

If GDEs are present, a high resilience in the vegetation and aquatic communities may be expected due to the seasonality of rainfall, ephemeral nature of the creek systems and low hydraulic conductivity of outcropping / sub-cropping formations.

Drawdown that exceeds the JIF threshold (greater than the 0.2 m) is not predicted for the Project only scenario in outcropping or sub-outcropping formations.

Potential exceedance of the JIF threshold (greater than the 0.2 m) is indicated in outcropping units for the Cumulative scenario > 12 km to the north of the Project Area. The Project only scenario contribution to this drawdown is anticipated to be minor to negligible.

It is considered unlikely that groundwater present in surficial units, that potentially support TGDEs, will be impacted by CSG related drawdown due to the Project.

9.4.5 Potential Impacts to Subterranean Fauna

As discussed in Section 7.10.6, it is unlikely that *stygofauna* will be present within the target coal seams in the vicinity of the Project Area, or in the formations surrounding the coal seams due to the depth below ground level. Saturated conditions (and therefore suitable habitat for *stygofauna*) within the surficial Tertiary and Quaternary sediments are expected to be variable and dependant on rainfall and ephemeral creek flow.

The risk threshold for subterranean GDEs identified by the JIF includes:

- A long-term predicted drawdown of more than 2 m for unconfined hydrogeological units caused by CSG development; or
- A long-term predicted drawdown that dewaters the aquifer habitat for confined hydrogeological units.

Drawdown that exceeds the JIF threshold (greater than the 0.2 m) is not predicted for the Project only scenario in outcropping or sub-outcropping formations. The Project only contribution to cumulative drawdown in outcropping formations is anticipated to be minor to negligible.

Therefore, no discernible impacts to subterranean fauna as a result of the Project only and Cumulative scenarios are predicted.

10 AVOIDANCE, MITIGATION, MANAGEMENT AND MONITORING

10.1 Key Management Documents

This section provides details on Santos' proposed mitigation, management and monitoring practices for the Project that will be adopted to manage the risk of impact to water resources.

Key Santos management plans and reports related to the monitoring and management of water include:

- Hydraulic Fracturing Risk Assessment – Santos Eastern Queensland Rev 1 (HFRA) (EHS Support 2021).
- Eastern Queensland Stimulation Impact Monitoring Program (SIMP) (Santos 2021).
- Baseline Assessment Plan (BAP) for ATP 2052 and ATP 2053 (Santos 2022).
- Roma Phase 7-7B-SD20 Chemical Risk Assessment Framework (CRAF) (Santos 2024f).
- Roma Phase 7-7B-SD20 Chemical Risk Assessment Report (CRAR) (EHS Support 2024a).
- Roma Phase 7-7B-SD20 Proposed Produced Water Management Plan (WMP) (WRM 2024).
- Roma Phase 7-7B-SD20 Ecological Assessment Report – MNES / MSES (EAR) (Boobook 2024b).
- Roma Phase 7-7B-SD20 Rehabilitation Monitoring Plan (RMP) (Santos 2024d).
- Roma Phase 7-7B-SD20 Environmental Protocol for Constraints Planning and Field Development (Constraints Protocol) (Santos 2024b).
- Roma Phase 7-7B-SD20 Significant Species Management Plan (SSMP) (Santos 2024e).
- Roma Phase 7-7B-SD20 Environmental Management Plan (EMP) (Santos 2024a).

Other documents of importance:

- Surat CMA UWIR Water Monitoring Strategy (WMS) (OGIA 2021a).
- Water Act 2000 (State of Queensland 2024m) Guidelines: baseline and bore assessments and make good requirements (State of Queensland 2024f; 2024e; 2024h).
- The Joint Industry Framework (JIF) (Australian Government 2021).
- Code of Practice for the construction and abandonment of coal seam gas and petroleum wells, and associated bores in Queensland Version 2 (State of Queensland 2019a).
- Queensland CSG Water Management Policy (DEHP 2012).
- Queensland Streamlined Model Conditions for Petroleum Activities (State of Queensland 2024k).
- Queensland CSG Water Management: Measurable criteria (DES 2013).
- Queensland Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (State of Queensland 2019d).

10.2 Monitoring

10.2.1 CSG Water Monitoring

CSG Produced Water Monitoring

As per the requirements outlined in the P&G Act 2004, the volume of produced water will be monitored and recorded and provided to the DNRME in accordance with statutory obligations.

Produced water quality will be monitored in accordance with the EMP (Appendix V), the SIMP (Appendix IV) and as required by relevant EA conditions. To minimise impacts to shallow groundwater quality, as a result of beneficial use activities such as dust suppression and off-tenement irrigation, water quality will be monitored to confirm compliance with water quality objectives in the *End of Waste Code Associated Water (including coal seam gas water)* (State of Queensland 2024b), and the *End of Waste Code Irrigation of Associated Water (including coal seam gas water)* (State of Queensland 2024c), and relevant EA conditions.

The SIMP provides procedures for baseline groundwater bore assessment, stimulation fluid and flowback monitoring, and post-stimulation groundwater bore monitoring as summarised in the following sections.

Groundwater Bore Baseline Assessments

Under the Water Act 2000, Santos are required to undertake baseline assessments of water bores prior to commencement of stimulation and production activities. There is one operational water bore located within the Project Area. A baseline assessment of this water bore has been completed as documented in the ATP 2053 BAP (Santos 2022). Another groundwater bore (RN208460) was drilled on the tenement in June 2024. This new bore is indicated as “no longer used”. Santos are in the process of updating their Baseline Assessment Plan to detail baseline assessment of this bore prior to commencement of the Project.

Stimulation Fluid and Flowback Monitoring

Monitoring of stimulation fluids during the stimulation activity is to be conducted in order to characterise the quality and quantity of source water, stimulation fluid and flowback. The SIMP requires monitoring of source water, stimulation fluids and representative flowback as recovered at surface. Flowback volume(s) will be recorded to ensure 150 percent of the volume of stimulation fluids used in the stimulation event have been extracted from the stimulated well, to the extent practicable. A flowback or produced water sample will also be collected post-stimulation. In the event that an active landholder bore is pumping from an aquifer within 200 m above or below the target formation and is spatially within 2 km from the location of stimulation, Santos requires that the need for additional flowback, be assessed.

Flowback may be treated and stored for reuse in the next hydraulic fracturing event. Flowback fluid unable to be reused would be disposed of at a licensed facility or transferred to one of Santos’ engineered wastewater treatment facilities for treatment and management under existing approvals for those facilities.

Post-Stimulation Groundwater Bore Monitoring

Post-stimulation groundwater monitoring of relevant baseline bores will be undertaken at the following frequencies:

- Monthly for the first six (6) months subsequent to the stimulation activities being undertaken; then
- Annually for the first five (5) years subsequent to the stimulation activities being undertaken or until analytes and physico-chemical parameters are not detected in concentrations above baseline bore monitoring data on two (2) consecutive occasions.

Groundwater from relevant bores is to be analysed for the analytical suite detailed in Table 2, Section 5 of the (Santos 2021) (Appendix IV).

Joint Industry Framework

CSG development on tenures surrounding the Project comprises up to 4,401 CSG wells, which are authorised under existing EPBC Act approvals. These Projects are conditional to the JIF framework. The application of the JIF framework to surrounding development provides comfort that defined environmental outcomes for groundwater (as defined in the JIF) will be achieved.

10.2.2 Groundwater Monitoring

The water monitoring requirements for petroleum tenure holders within the Surat CMA are provided as part of the UWIR Water Monitoring Strategy (WMS) (OGIA 2021a), which establishes baseline trends, identifies any changes within or near petroleum development areas or locations of interest and informs future improvement of groundwater modelling. Individual tenure holders are responsible for specific monitoring obligations in accordance with the rules as outlined by the UWIR.

Under the WMS, Santos undertakes groundwater monitoring at over 150 monitoring locations throughout the Surat CMA. Revisions of the UWIR may amend the WMS according to improved understanding of groundwater risks. Santos are presently monitoring 16 nested bores in the vicinity of the site, as depicted in Figure 10.1 and listed in Table 10.1.

Two landholder bores were identified during the baseline assessment for which ongoing monitoring is required. Pre-and post-stimulation monitoring of these bores may be performed in accordance with the SIMP and applicable EA requirements.

10.2.3 Surface Water Monitoring

The Project does not involve discharges to, or abstractions from, surface water. Groundwater contribution from the regional system to watercourses as baseflow is not interpreted at the Project Area. Surface water monitoring associated with the Project is therefore not proposed.

As per the EMP, turbidity monitoring will be carried out during the construction and maintenance of linear infrastructure crossings of watercourses to ensure water release limits specified in relevant EA conditions are complied with. However, in accordance with EA conditions,

Santos preferentially undertakes construction and maintenance of linear infrastructure crossings of watercourses during periods of no or very low flows (Santos 2024a). Further discussion of mitigation and management associated with surface water systems is provided in Section 10.3.

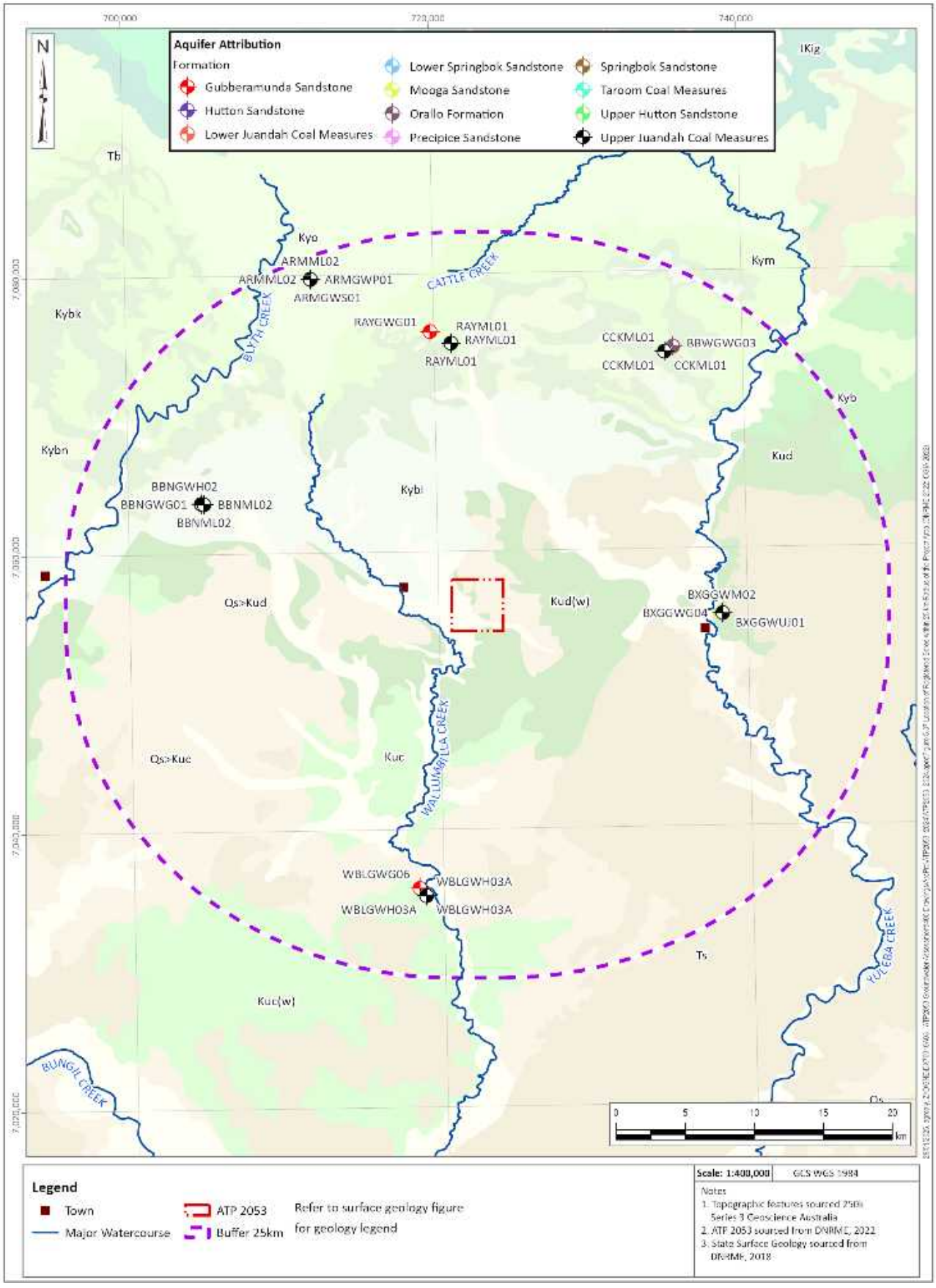


Figure 10.1 Santos UWIR Groundwater Monitoring Bores within 25 km of the Project Area

Table 10.1 Santos UWIR Groundwater Monitoring Bores within 25 km of the Project Area

Santos Name	RN	Easting[1]	Northing[1]	Well Type	Formation
ARMGWG13	160822	712054	7079697	Dedicated monitoring bore	Gubberamunda Sandstone
ARMGWP01	180014	712103	7079701	Dedicated monitoring bore	Precipice Sandstone
ARMGWS01	160823	712068	7079690	Dedicated monitoring bore	Springbok Sandstone
ARMGWS01	160823	712068	7079690	Dedicated monitoring bore	Springbok Sandstone
ARMML02	180094	712053	7079727	Multi-level monitoring - non VWP	Hutton Sandstone
ARMML02	180094	712053	7079727	Multi-level monitoring - non VWP	Lower Juandah Coal Measures
ARMML02	180094	712053	7079727	Multi-level monitoring - non VWP	Springbok Sandstone
ARMML02	180094	712053	7079727	Multi-level monitoring - non VWP	Taroom Coal Measures
ARMML02	180094	712053	7079727	Multi-level monitoring - non VWP	Upper Juandah Coal Measures
BBNGWG01	160582	704710	7063630	Dedicated monitoring bore	Gubberamunda Sandstone
BBNGWH02	160581	704726	7063632	Multi-level monitoring - non VWP	Hutton Sandstone
BBNGWH02	160581	704726	7063632	Multi-level monitoring - non VWP	Lower Juandah Coal Measures
BBNGWH02	160581	704726	7063632	Multi-level monitoring - non VWP	Springbok Sandstone
BBNGWH02	160581	704726	7063632	Multi-level monitoring - non VWP	Taroom Coal Measures
BBNGWH02	160581	704726	7063632	Multi-level monitoring - non VWP	Upper Juandah Coal Measures
BBNML02	207748	704903	7063609	Multi-level monitoring - non VWP	Upper Hutton Sandstone
BBNML02	207748	704903	7063609	Multi-level monitoring - non VWP	Lower Juandah Coal Measures
BBNML02	207748	704903	7063609	Multi-level monitoring - non VWP	Lower Springbok Sandstone
BBNML02	207748	704903	7063609	Multi-level monitoring - non VWP	Taroom Coal Measures

Santos Name	RN	Easting[1]	Northing[1]	Well Type	Formation
BBNML02	207748	704903	7063609	Multi-level monitoring - non VWP	Upper Juandah Coal Measures
BBWGWG03	160400	735491	7074509	Dedicated monitoring bore	Gubberamunda Sandstone
BBWGWO01	160391	735474	7074511	Dedicated monitoring bore	Orallo Formation
BXGGWG04	160397	738299	7055252	Dedicated monitoring bore	Gubberamunda Sandstone
BXGGWM02	160399	738309	7055270	Dedicated monitoring bore	Mooga Sandstone
BXGGWUJ01	180006	738370	7055257	Dedicated monitoring bore	Upper Juandah Coal Measures
CCKML01	180096	734941	7074157	Multi-level monitoring - non VWP	Hutton Sandstone
CCKML01	180096	734941	7074157	Multi-level monitoring - non VWP	Lower Juandah Coal Measures
CCKML01	180096	734941	7074157	Multi-level monitoring - non VWP	Springbok Sandstone
CCKML01	180096	734941	7074157	Multi-level monitoring - non VWP	Taroom Coal Measures
CCKML01	180096	734941	7074157	Multi-level monitoring - non VWP	Upper Juandah Coal Measures
RAYGWG01	58477	719759	7075840	Private Bore	Gubberamunda Sandstone
RAYML01	180105	721101	7074977	Multi-level monitoring - non VWP	Hutton Sandstone
RAYML01	180105	721101	7074977	Multi-level monitoring - non VWP	Lower Juandah Coal Measures
RAYML01	180105	721101	7074977	Multi-level monitoring - non VWP	Springbok Sandstone
RAYML01	180105	721101	7074977	Multi-level monitoring - non VWP	Taroom Coal Measures
RAYML01	180105	721101	7074977	Multi-level monitoring - non VWP	Upper Juandah Coal Measures
WBLGWG06	160402	718413	7035765	Dedicated monitoring bore	Gubberamunda Sandstone
WBLGWH03A	160673	718835	7035222	Multi-level monitoring - non VWP	Hutton Sandstone
WBLGWH03A	160673	718835	7035222	Multi-level monitoring - non VWP	Lower Juandah Coal Measures

Santos Name	RN	Easting[1]	Northing[1]	Well Type	Formation
WBLGWH03A	160673	718835	7035222	Multi-level monitoring - non VWP	Springbok Sandstone
WBLGWH03A	160673	718835	7035222	Multi-level monitoring - non VWP	Taroom Coal Measures
WBLGWH03A	160673	718835	7035222	Multi-level monitoring - non VWP	Upper Juandah Coal Measures

[1]Coordinates in GDA94, Zone 55.

10.3 Avoidance, Mitigation and Management

Santos have developed a comprehensive set of management documents as listed in Section 10.1, including an EMP with the objective to achieve ongoing environmental compliance with regulatory requirements and to facilitate implementation of best practice environmental management strategies. The EMP includes a set of supporting Environmental Control Plans (ECPs) that detail management actions, responsibility and timing relating to potential impacts. Reference to relevant management documents, including the EMP and ECPs will be made throughout this section. The EMP is included in Appendix V of this report.

10.3.1 CSG Production Wells Drilling and Construction

Measures to avoid and manage the risk of impacts to groundwater quality and avoid introducing connectivity between formations during the construction of production wells, include the following:

- Production wells will be designed, constructed and decommissioned in accordance with the Code of Practice (State of Queensland 2019a). This code outlines mandatory requirements and good practice to reduce the risk of environmental harm. Production wells will be designed to:
  - Prevent any interconnection between target hydrocarbon bearing formations and aquifers;
  - Ensure that gas is contained within the well and associated pipework and equipment without leakage;
  - Ensure zonal isolation between different aquifers is achieved;
  - Not introduce substances that may cause environmental harm; and
  - Operate within the maximum expected pressures and load conditions until final abandonment.

Santos will monitor and control operating wells remotely; each well has an automated shutdown system in the event of non-routine operating conditions (Santos 2024c).

Drilling fluids and additives used during drilling activities will be used in accordance with the mandatory requirements and good practice guidelines outlined in the Code of Practice as well as the Safety Data Sheets (SDS) and toxicological profiles provided for each fluid / additive (EHS Support 2024a). In relation to drilling fluids, the mandatory requirements include:

- Drilling fluids must be selected and managed to ensure all manufactured products used during well procedures are in accordance with the manufacturer's recommendations and relevant SDS.
- The name, type and quantity of each chemical used on each well throughout the life of the well must be recorded.

Good industry practice for drilling includes:

- Drilling fluid should be a carefully monitored and controlled mixture designed to:
  - Achieve best drilling results and ensure efficient removal of formation cuttings;
  - Control formation pressures; and
  - Minimise damage to formations.
- Petroleum tenure holders should ensure that the drilling fluid selected is appropriate for the well design to manage any locally experienced drilling problems and the geological conditions likely to be encountered.
- The use of biodegradable substances in the drilling fluid is preferred.
- The source of water for all well procedures (drilling, completion, workover and abandonment) should be recorded for future well monitoring purposes.
- Products should be chosen, stored, and used at concentrations that minimise the risk of causing environmental harm.
- Personnel, including contractors, should be aware of the environmental impact and emergency spill procedures for the products and substances in use on-site.
- Petroleum tenure holders should use established, effective drilling practices to achieve a stable, uniform and as far as possible, in-gauge hole.

The Hydraulic Fracturing Risk Assessment emphasises that where stimulation activities are designed and undertaken in accordance with the hydraulic stimulation procedures, the zone of hydraulic stimulation is contained entirely with the coal layer or target seam (EHS Support 2021). An overview of the stimulation process, fluid and flowback monitoring and post -stimulation groundwater bore monitoring, is provided in the SIMP and the EMP.

In summary, the hydraulic stimulation procedures and processes include:

- Casing and cementing are installed as barriers during well construction;
- A formal design and plan process where fracture geometry is modelled;
- Assess for indications of casing integrity loss into overlying formations:
  - Monitoring casing and wellhead pressures during stimulation activity; and
  - Monitor injection flow rates and total volumes of hydraulic fracturing fluids and comparing to predicted performance.
- Monitoring of stimulation fluids during the stimulation activity is to be performed at sufficient frequency and which represents the quality and quantity of source water;
- Source water to be used for stimulation activities is to be sampled prior to the commencement of the stimulation operations;

- One stimulation fluid sample per stimulation activity on each well is to be taken from the pad volume prior to the addition of the slurry volume; and
- A flowback or produced water sample is be collected post-stimulation and to be analysed.

Existing operational control of activities employed by Santos are in place in the form of the HFRA, CRAF, CRAR, EMP and RMP as listed in Section 10.1, that will limit the potential risks to human health and the environment.

Further details on the management practices associated with chemical and fuel storage are provided in Section 10.3.5.

10.3.2 CSG Water and Waste Management

CSG produced water and waste management will be undertaken in accordance with the WMP which has been developed to meet the requirements of the CSG Water Management Policy (DEHP 2012), as outlined in Section 3.4. Water management infrastructure will be based on the Australian Standards for tanks, to be used as water storages across the Project Area.

Treatment processes, and storage and management of brine and salt, are not located within the Project Area and are therefore not part of the proposed action. Details of these processes are included in the *Revised Coal Seam Gas Water Monitoring and Management Plan GLNG Project EPBC* (2008/4059) (Santos 2023b). Adequate water storage and treatment capacity is available on adjacent tenures to manage peak water and brine production from the Project. Santos have established procedures to prevent uncontrolled discharge of produced water (i.e. restriction of production by 'turning down' or 'shutting-in' wells). In future, produced water from the Project may potentially be processed elsewhere, subject to environmental approvals.

The EMP states that drilling fluids would be contained on the well lease in tanks during drilling and then either reused (or recycled and reused) at another well site or disposed of offsite at a licensed waste management facility. Residual drilling material (RDM) would be stored in tanks during drilling and then may be disposed of on-site in accordance with relevant EA conditions, where:

- RDM meets approved quality criteria, and the mix-bury-cover method is used; or
- RDM is certified by a suitably qualified third-party as being of acceptable quality for disposal to land by a proposed method, and that environmental harm will not result from the proposed disposal.

Assessments and monitoring will include:

- Sampling and characterisation of the RDM; and
- Baseline soil assessment of each representative soil type within the Project Area for which land application of RDM is proposed.

Alternatively, RDM may be transferred by road to existing approved waste management facilities on adjoining tenures, or to another licensed waste facility for management.

EPC 7 of the EMP details management actions, responsibility and timing relating to potential impacts associated with liquid and solid waste management (Appendix V).

10.3.3 Bore and Water Resource Impact Management Measures

The Water Act 2000 outlines requirements for make good obligations of a resource tenure holder for a bore located in immediately affected areas. Tenure holders must carry out a bore assessment and enter into a make good agreement with the bore owner if the bores are located within an immediately affected area. The UWIR assigns bores to tenure holders located within immediately affected areas.

Santos undertakes to engage with relevant stakeholders, comply with make good agreements required in future updates of the UWIR and undertake bore assessments as required as a result of make good obligations. Any future baseline assessments will be conducted in accordance with the *Baseline Assessment Guideline* (DES 2017). However, since no bores have been assessed to be impacted by the proposed Project development, make good agreements for this Project are not anticipated at present.

10.3.4 Infrastructure Location and Planning

The planning of development activities and associated infrastructure locations are detailed by the EMP and informed by the SSMP and Constraints Protocol.

Constraints planning provides a mechanism for avoidance and then minimisation of potential risks to environmental values through environmental value identification and location selection, without the need for further mitigation or management. The Constraints Protocol requires Santos to implement an internal assessment and approval process to ensure that the planning, design and decision-making processes for all new field development and land disturbance activities identify the required constraints prior to commencement of development activities.

Santos has therefore planned infrastructure locations within the Project Area to avoid impacts to environmental values. The proposed infrastructure has largely been located in cleared agricultural land. Disturbance to vegetation has been reduced to 0.31 ha. No disturbance to Threatened Ecological Communities (TEC) is proposed. Any minor changes to the disturbance footprint or infrastructure locations would be subject to the requirements of the Constraints Protocol.

Furthermore, in relation to the proposed Project infrastructure within the vicinity of water courses, no camps, laydowns or water storages will be located within the 1% AEP flood extent and all water course crossings (tracks and pipelines) will be constructed in accordance with relevant EA conditions, EMP requirements, design standards and the *Accepted development requirements for operational work that is constructing or raising waterway barrier works* (DAF 2018) under the Fisheries Act 1994 and Planning Act 2016. All well pads across the Project Area, within and outside of the 1% AEP flood extent, will be established at the topographic grade of the well location and all associated pipelines will be buried.

ECP 3 (Water resource management) of the EMP details applicable standard buffer distances for infrastructure from watercourses and wetlands (Appendix V).

10.3.5 Chemical Use and Storage

Key plans integral to the management of the risk of impacts to environmental values associated with chemical transportation, storage, use and management / monitoring of potential impacts are provided in the CRAF/CRAR and the EMP. ECP 9 of the EMP details general management

requirements and actions, monitoring, reporting and corrective action requirements pertaining to hazardous substances use and management.

The outcomes of the CRAR, in conjunction with the EMP and relevant EA conditions, will inform site selection for well lease placement and appropriate management of RDM. Additional recommendations for risk management provided on the basis of the risk assessment include:

- Production wells will be installed in accordance with the requirements of the Constraints Protocol and not within 90 m of a landholder bore.
- The theoretical concentrations of chemicals used in drilling muds poses a potential risk to ecological receptors. The estimated concentrations in untreated and treated drilling muds exceeded the generic chemical specific ecological criteria for soil. Management controls and monitoring are detailed in the EMP to ensure materials are managed to prevent unacceptable risks (as discussed in Section 10.3.2).
- Refer to Section 10.3.2 for information pertaining to early warning indicators, threshold triggers and management response related to application of residual drilling material to land.

10.3.6 Beneficial Use Activities

Beneficial use on-site is limited to activities such as water supply for drilling and hydraulic fracturing purposes and / or to provide a water source for dust suppression / construction (where the water meets relevant water quality objectives – refer to Section 10.2.1 for further detail).

Where produced water is to be beneficially reused on-site, it will be stored in portable tanks as described in Section 3.4.4. Produced water from the Project is planned to be transferred to existing water management facilities located on neighbouring tenures owned and operated by Santos (refer to Section 3.4.1 for further detail on produced water management).

The *Revised Coal Seam Gas Water Monitoring and Management Plan GLNG Project EPBC* (2008/4059) (Santos 2023b) outlines the proposed management, monitoring, beneficial use and disposal of CSG produced water (produced water) to avoid, mitigate and manage impacts to environmental values for the life of Santos GNLG Projects. It provides a risk assessment relating to beneficial use activities including dust suppression activities and details appropriate risk-based responses to avoid, mitigate and manage impacts to environmental values relevant to GNLG Projects.

Dust suppression aims to minimise dust generation during construction activities at a given location and / or during vehicle movements between locations. Water is applied to the surface using spray equipment. Beneficial use activities such as dust suppression, will be undertaken so that the WQOs and conditions in the *End of Waste Code Associated Water* (including CSG water) (State of Queensland 2024b) are met. In accordance with relevant EA conditions, no pooling or runoff is permitted during dust suppression activities, limiting the applicable pathway and exposure mechanism. Dust suppression within or adjacent to watercourses is prohibited.

ECP 3 of the EMP details management actions, responsibility and timing relating to activities (including beneficial use activities) that have the potential to impact on water resources (Appendix V).

10.3.7 Emergency and Incident Response: Spills

Santos has developed operating standards and procedures relating to incident and crisis management as per ECP 11 in the EMP. ECP 11 details triggers of a spill emergency and subsequent required management actions, responsibility and timing / frequency pertaining to spills, flooding, monitoring, reporting and corrective actions (Appendix V).

In accordance with the EMP, all incidents including environmental incidents, non-conformance events and complaints are recorded electronically and managed through the Santos Incident Management System (IMS). Environmental incidents and near misses are investigated in order to identify the causal factors and associated underlying systemic weaknesses (root causes). The process to determine the correct level of incident investigation is outlined in the relevant SMS Operating Standard. Upon completion of the investigation, the findings and recommendations will be distributed to relevant personnel force via daily prestart meetings. Where lessons are learnt from the investigation or current procedures are identified as being ineffective or inadequate, the EMP or other pertinent documentation will be revised to include the improved procedures or requirements.

The DETSI Pollution Hotline will be notified by the relevant environmental advisor within 48 hours of becoming aware of prescribed incidents.

10.3.8 Soil and Erosion Management

Procedures and protocols to prevent erosion and effectively manage soil are included in the EMP and RMP.

The risk of erosion will be managed through well-pad design (i.e. surface water run-on and run-off) and engineered management controls. Impacts on water quality are to be minimised by undertaking the works to the standard set out in the current version of the Best Practice Erosion and Sediment Control, published by the International Erosion Control Association Australasia (IECA 2008) (and in accordance with relevant EA conditions).

In accordance with the EMP, considerations for siting and constructing well leases and associated infrastructure will include:

- Environmental awareness training of employees and subcontractors;
- Preferential selection of non-sloping well leases;
- Avoidance of environmentally sensitive and restricted areas;
- Employment of additional management controls in sensitive area (as may be required);
- Construction of erosion control measures where appropriate (i.e. diversion banks or berms);
- Erosion and sediment control will be managed so as to:
  - Erosion: minimise the area and duration of soil exposure.
  - Sediment: sediment controls to be suited to soils, climate and catchment size.
  - Drainage: divert clean runoff around disturbed areas and convey drainage in a non-erosion manner.

- Good shaping and drainage of infrastructure to minimise erosion (according to standardised construction designs);
- Routine monitoring and maintenance; and
- Progressive rehabilitation / reinstatement of significant disturbances in accordance with relevant EA conditions to safe and stable landforms.

ECP 1 (Construction Site Management) and ECP 2 (Soil Resource Management) in the EMP detail management actions (including monitoring and reporting requirements), responsibility and frequency associated with potential impacts related to soil and erosion management.

10.3.9 General Environmental Management Practices

As discussed earlier in this section, the EMP provides a comprehensive framework to enable targeted management of environmental issues over the life of the Project. In addition to the ECPs already referred to in other parts of this section, the EMP also includes ECPs relating to construction site management, flora and fauna management, weed and pest management, air, vibration, light and noise management, cultural heritage management and plant and equipment management (Appendix V).

Further, the Santos Management System (SMS) and associated operating standards provide a risk management, assurance and investigation framework following ISO31000:2018 to ensure that risks are effectively identified, monitored, and managed.

Infrastructure will be monitored, inspected, and maintained during operation. The EMP and supporting ECPs detail inspection, reporting and record keeping requirements as well as the corrective action process.

10.3.10 Decommissioning and Rehabilitation

Santos will undertake rehabilitation in accordance with the EMP and RMP. Santos aims to progressively rehabilitate significant disturbances where possible, with the overarching objective of rehabilitating all significantly disturbed areas caused by petroleum activities to be non-polluting, stable, re-profiled to have contours consistent with surrounding land, surface drainage lines re-established, topsoil reinstated, and groundcover and vegetation is to be consistent with surrounding vegetation cover and species richness.

All wells are monitored throughout operations using a risk-based inspection and maintenance program. When a well comes to the end of its productive life (or if the well is deemed uneconomic), the well will be decommissioned. The primary objective of well decommissioning is to isolate hydrocarbon and water bearing formations and eliminate migration pathways (between the reservoir, other formation / aquifers and surface). During decommissioning, perforated hydrocarbon zones are isolated with cement plugs and / or bridge plugs and cement bond logs (CBL) used and assessed to ensure that the cement behind the production casing is adequate to avoid migration pathways. An additional cement plug is placed in the surface casing prior to cutting off the well head below ground level. Final rehabilitation of the well and lease area would include removing the well head, surface infrastructure and fencing; capping the well; filling in pits; respreading topsoil (after preparation) and revegetating the site to match its pre-disturbance vegetation type.

Disturbed areas no longer needed for operational purposes will be rehabilitated in accordance with relevant EA conditions and the EMP/RMP. Rehabilitation techniques are detailed in the RMP, together with final rehabilitation monitoring requirements and rehabilitation acceptance criteria.

10.4 Reporting

Santos will undertake all reporting in accordance with any relevant State and Commonwealth legislation and approval conditions, including OGIA as part of the UWIR requirements.

11 CLOSING

We would like to thank you for the opportunity to work on this assignment. Should you have any questions, please do not hesitate to contact the undersigned.

KCB AUSTRALIA PTY LTD.



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APPENDIX I

OGIA Hydraulic Conductivity Model Parameters

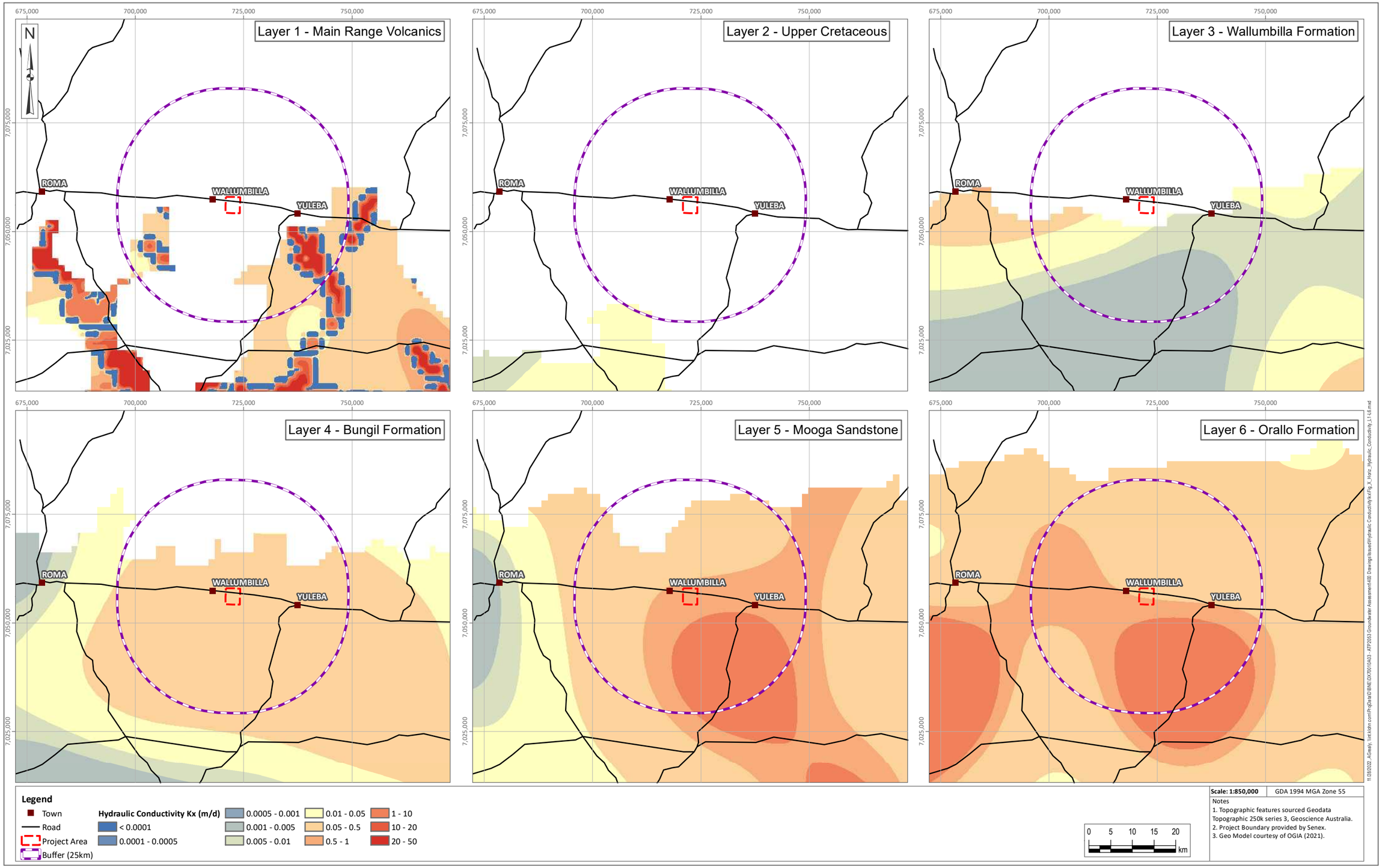


Figure I-1 Horizontal Hydraulic Conductivity (L1 – Main Range Volcanics to L6 – Orallo Formation)

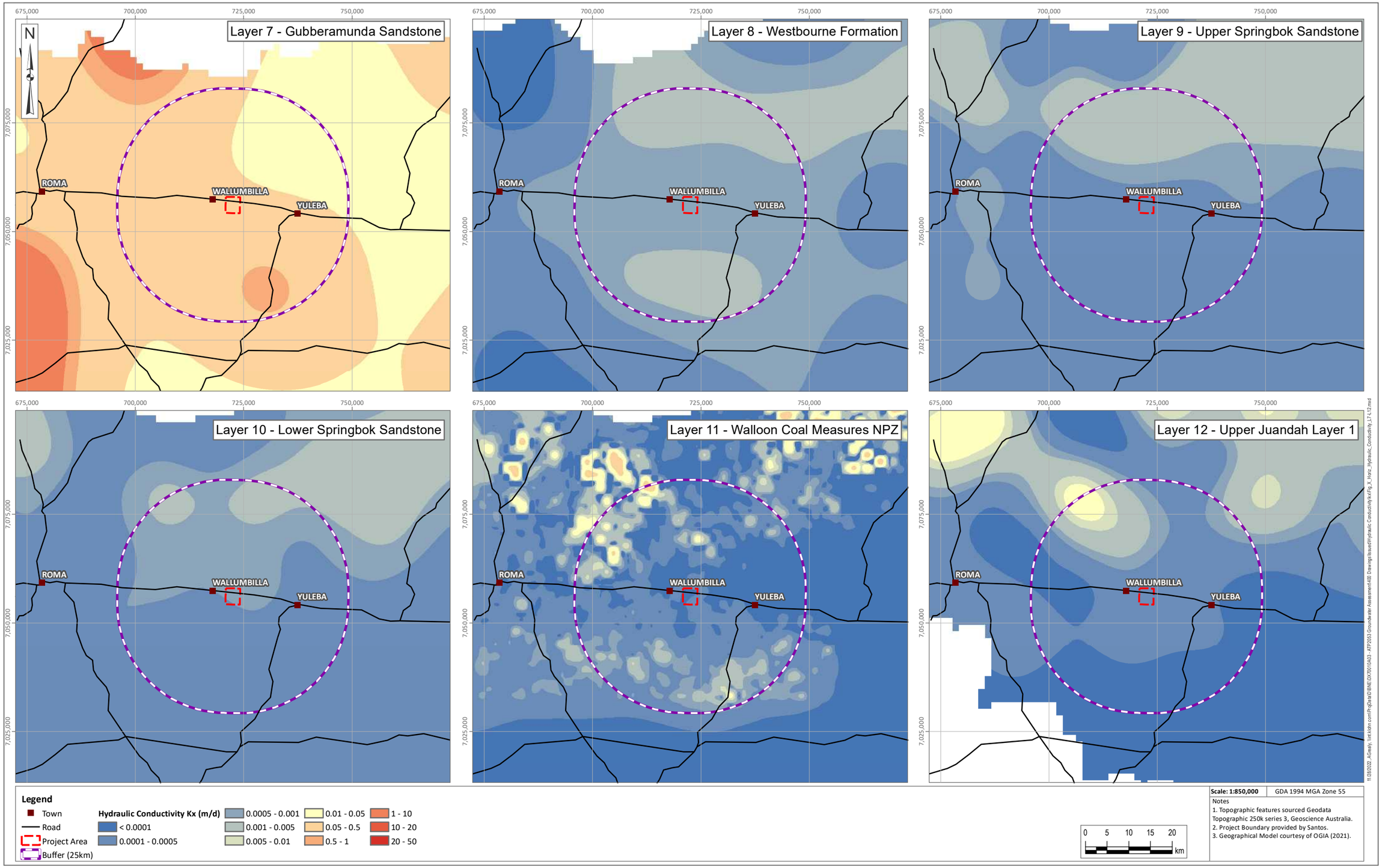


Figure I-2 Horizontal Hydraulic Conductivity (L7 Gubberamunda Sandstone to L12 Upper Juandah Layer 1)

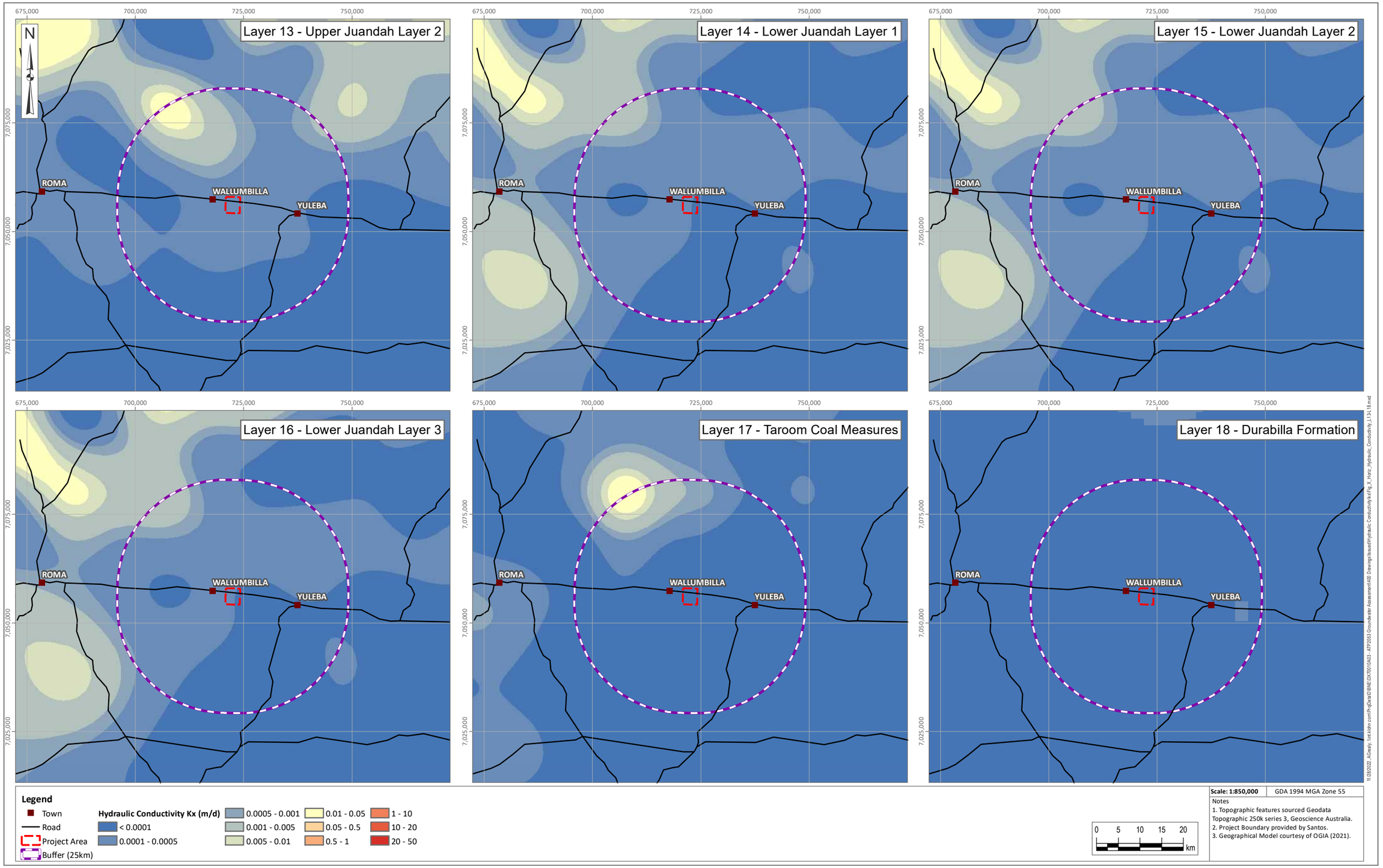


Figure I-3 Horizontal Hydraulic Conductivity (L13 Upper Juandah Layer 2 to L18 Durabilla Formation)

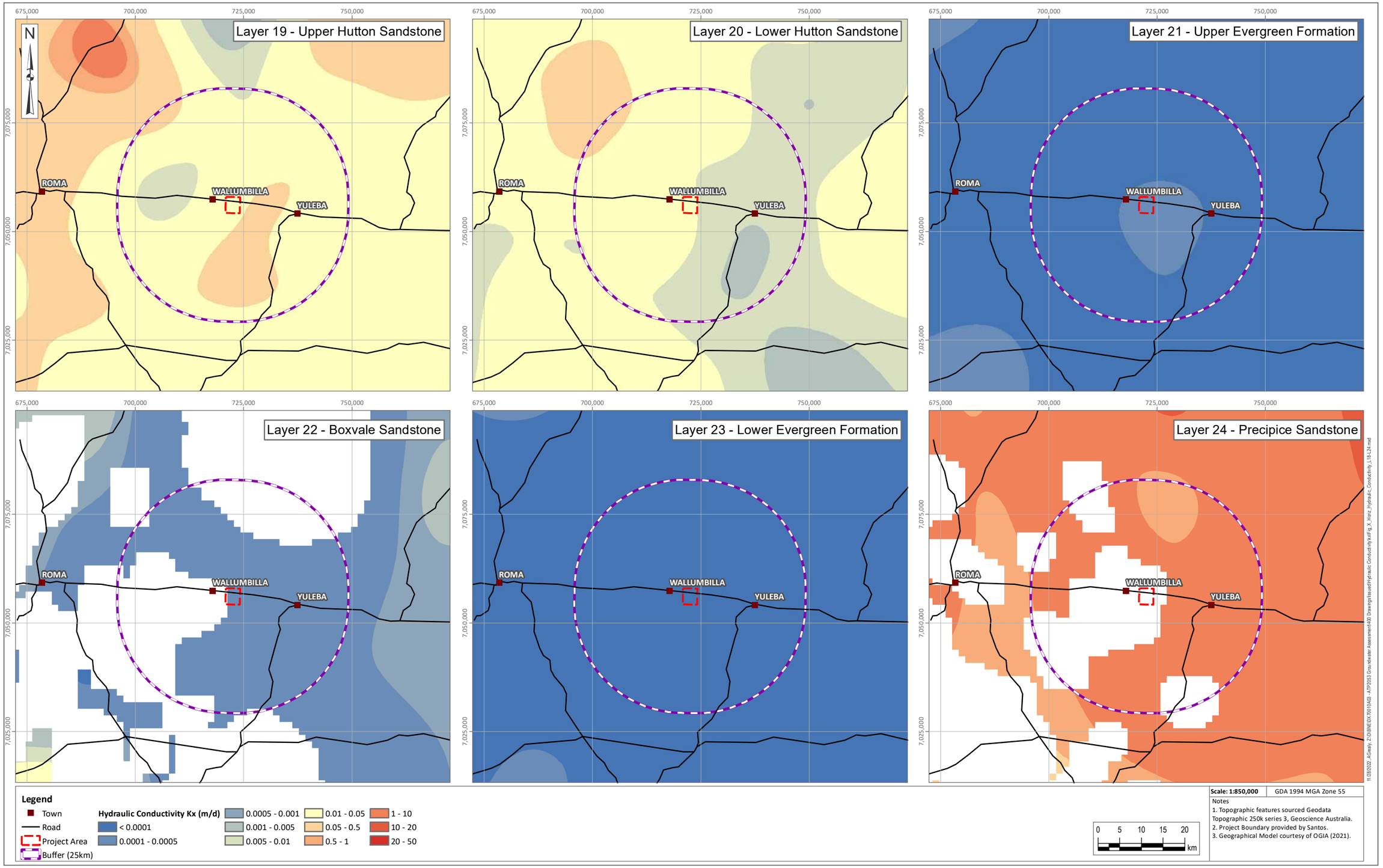


Figure I-4 Horizontal Hydraulic Conductivity (L19 Upper Hutton Sandstone to L24 Precipice Sandstone)

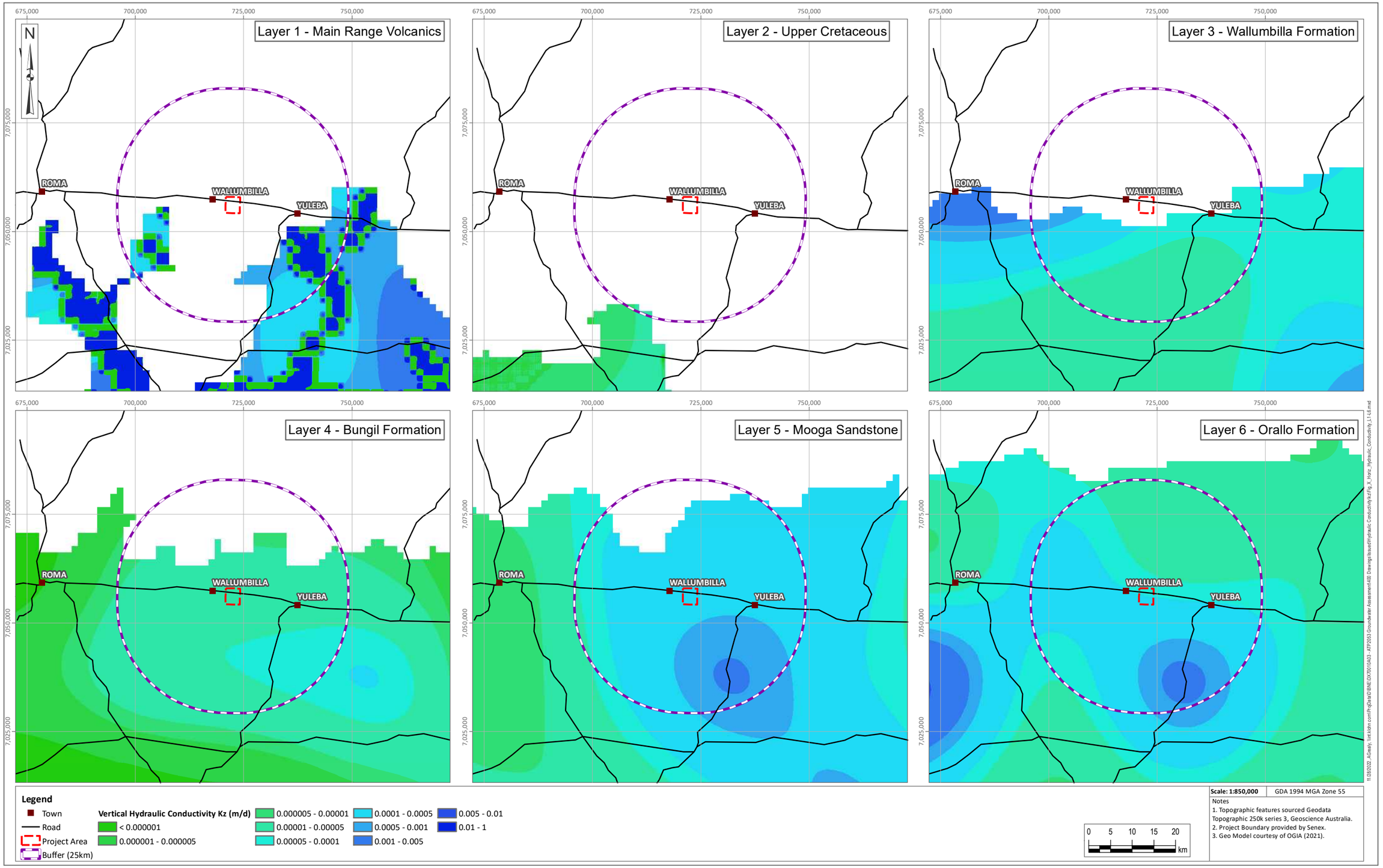


Figure I-5 Vertical Hydraulic Conductivity (L1 – Main Range Volcanics to L6 – Orallo Formation)

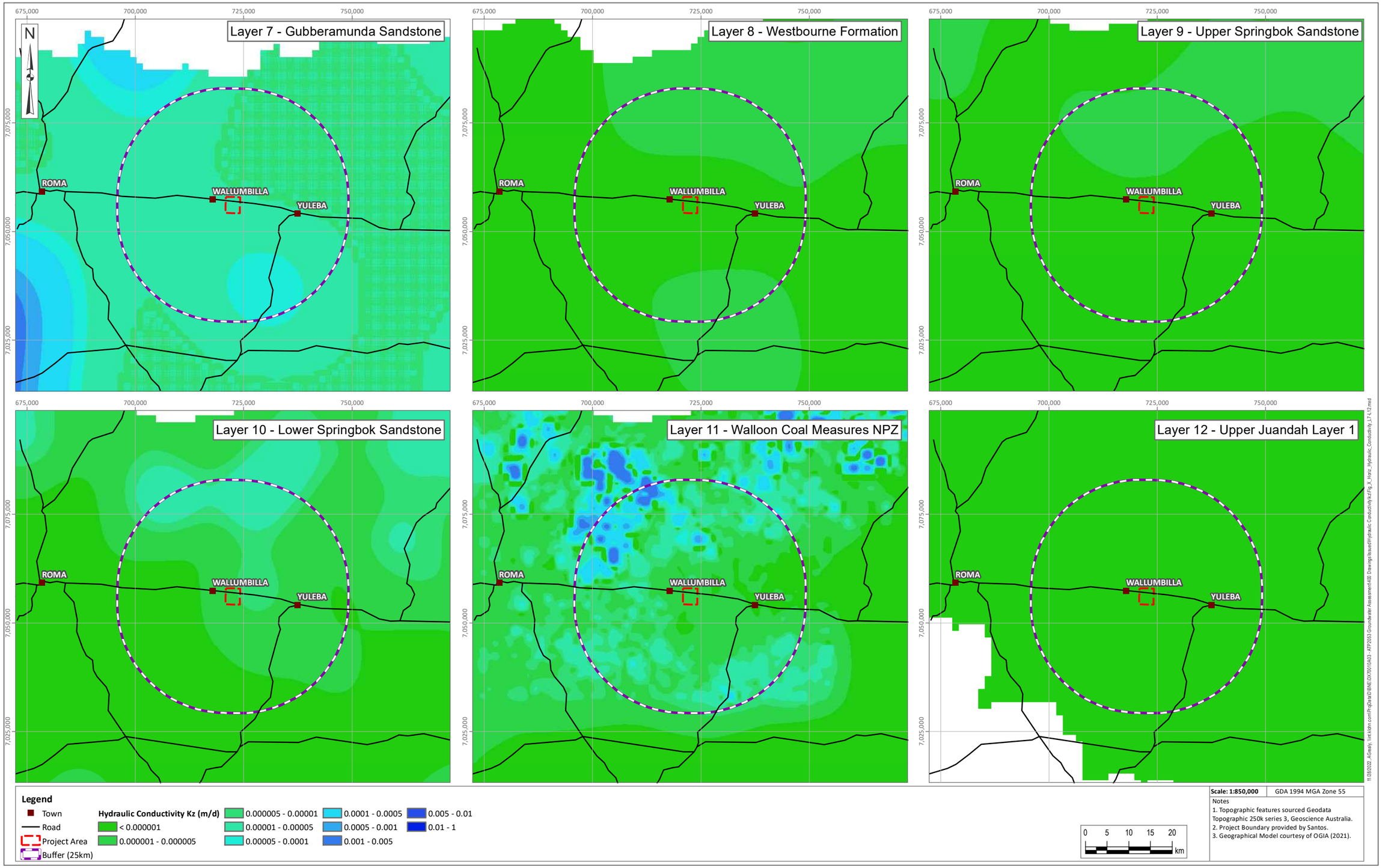


Figure I-6 Vertical Hydraulic Conductivity (L7 Gubberamunda Sandstone to L12 Upper Juandah Layer 1)

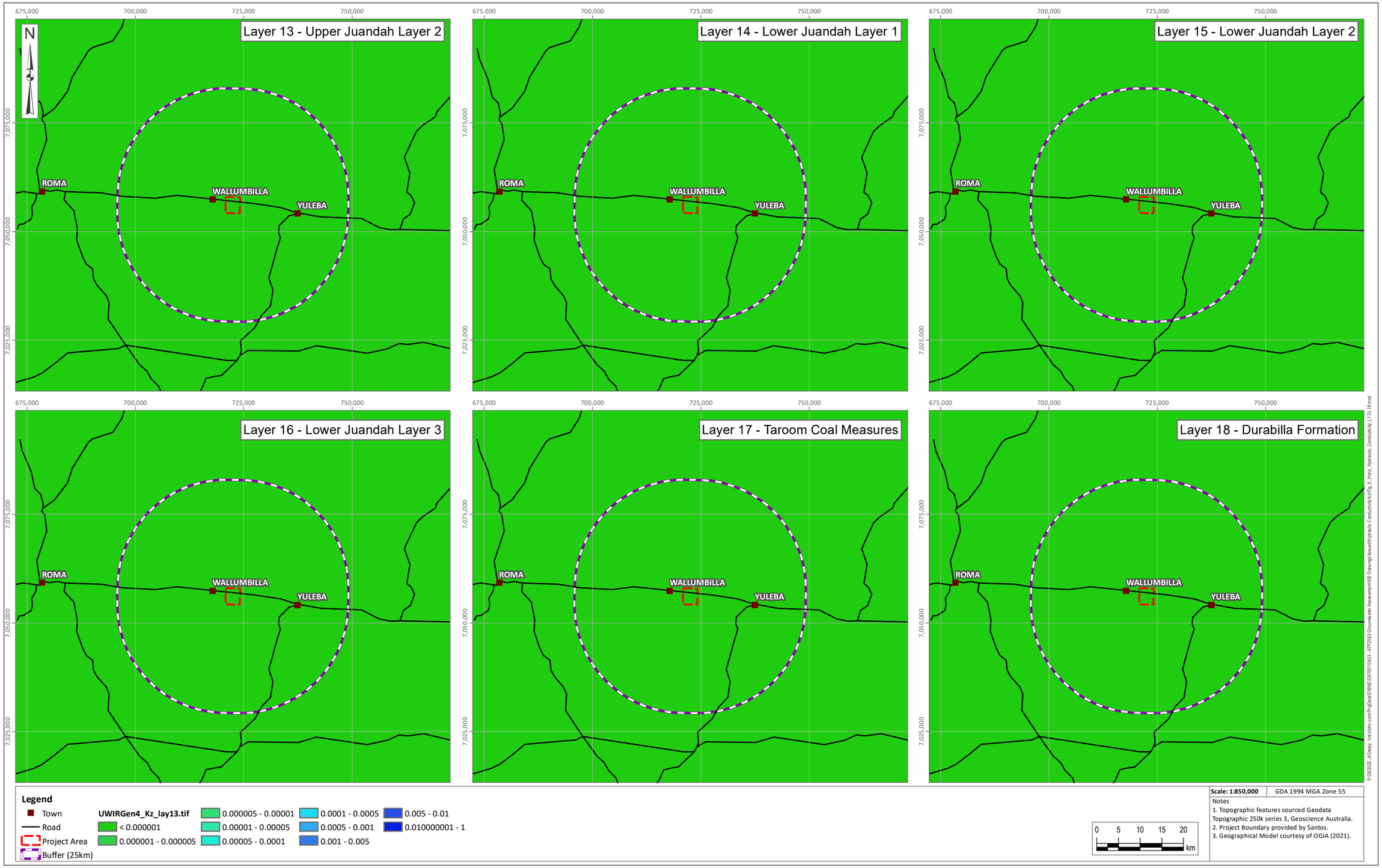


Figure I-7 Vertical Hydraulic Conductivity (L13 Upper Juandah Layer 2 to L18 Durabilla Formation)

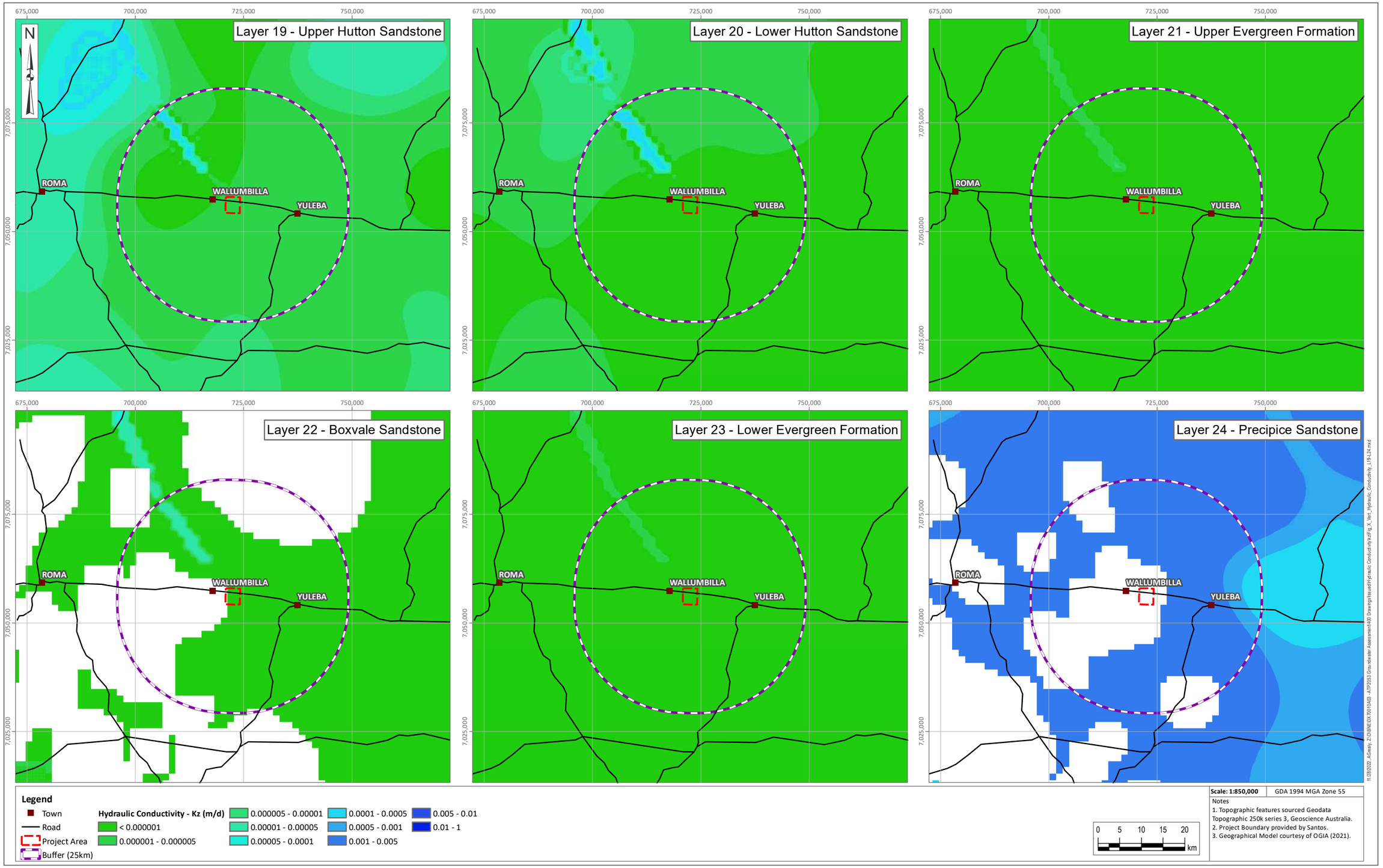


Figure I-8 Vertical Hydraulic Conductivity (L19 Upper Hutton Sandstone to L24 Precipice Sandstone)

APPENDIX II

Predicted Drawdown Extent – Project Only

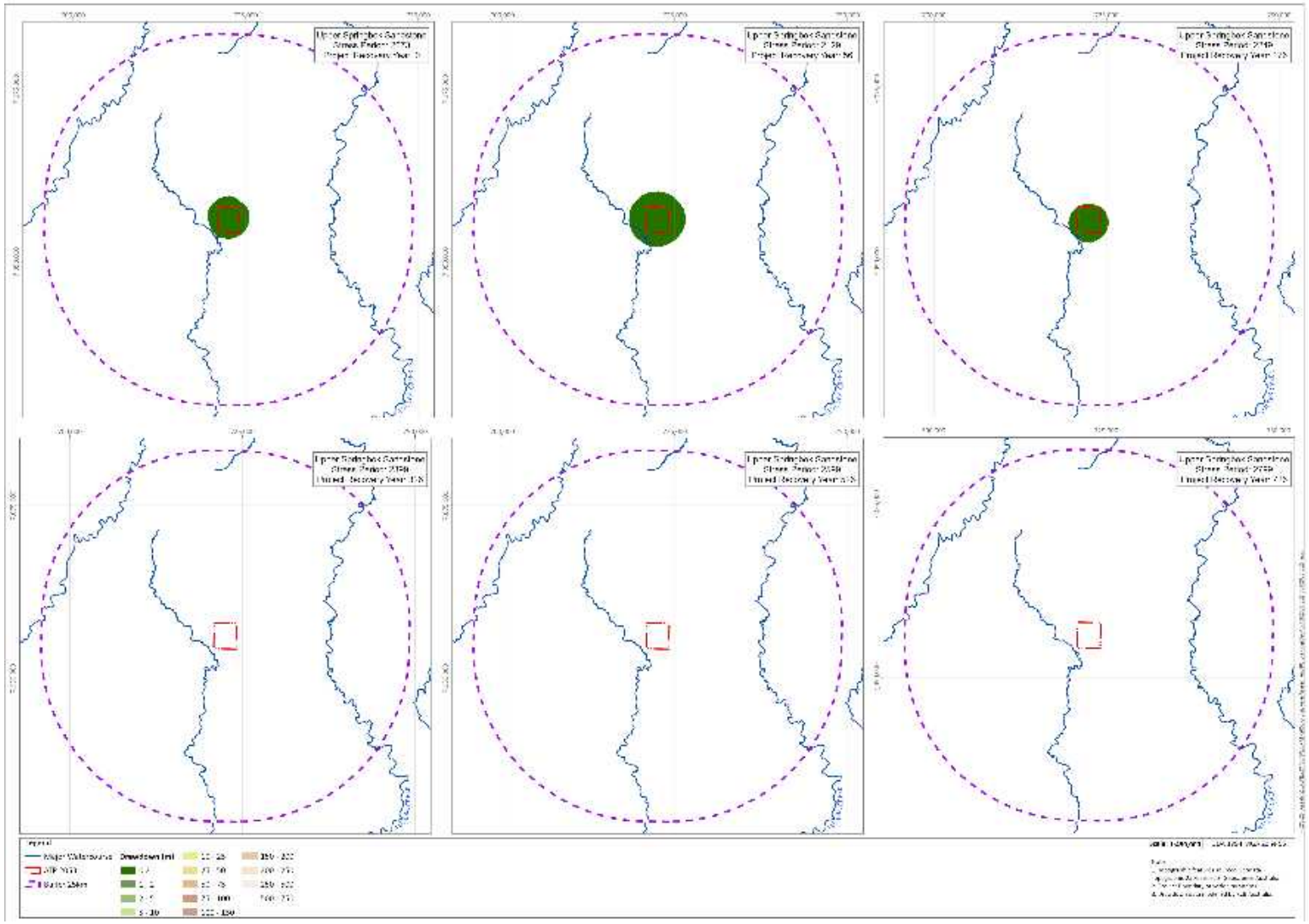


Figure II.1 Project Only Drawdown – Upper Springbok Sandstone (9)

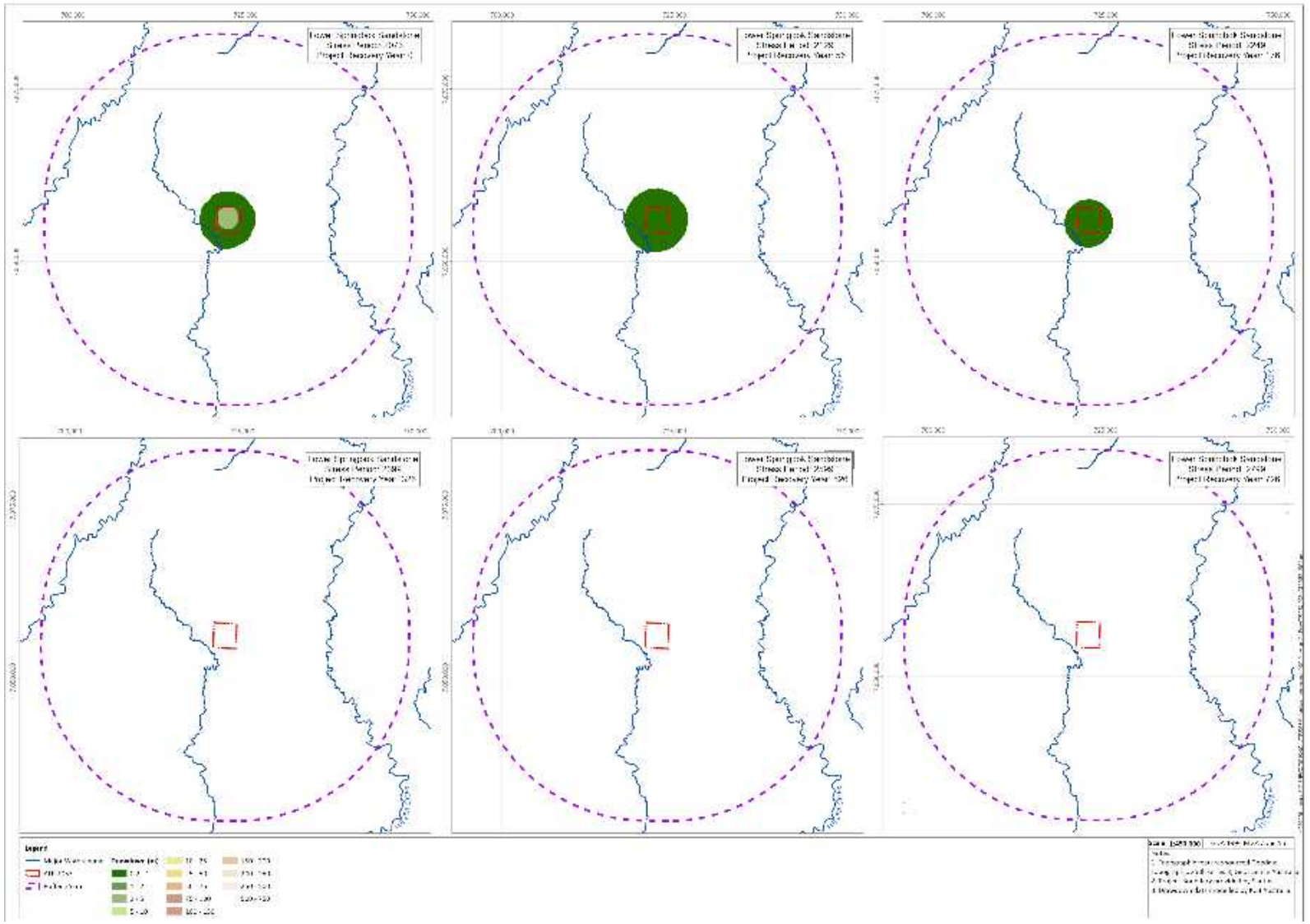


Figure II.2 Project Only Drawdown – Lower Springbok Sandstone (10)

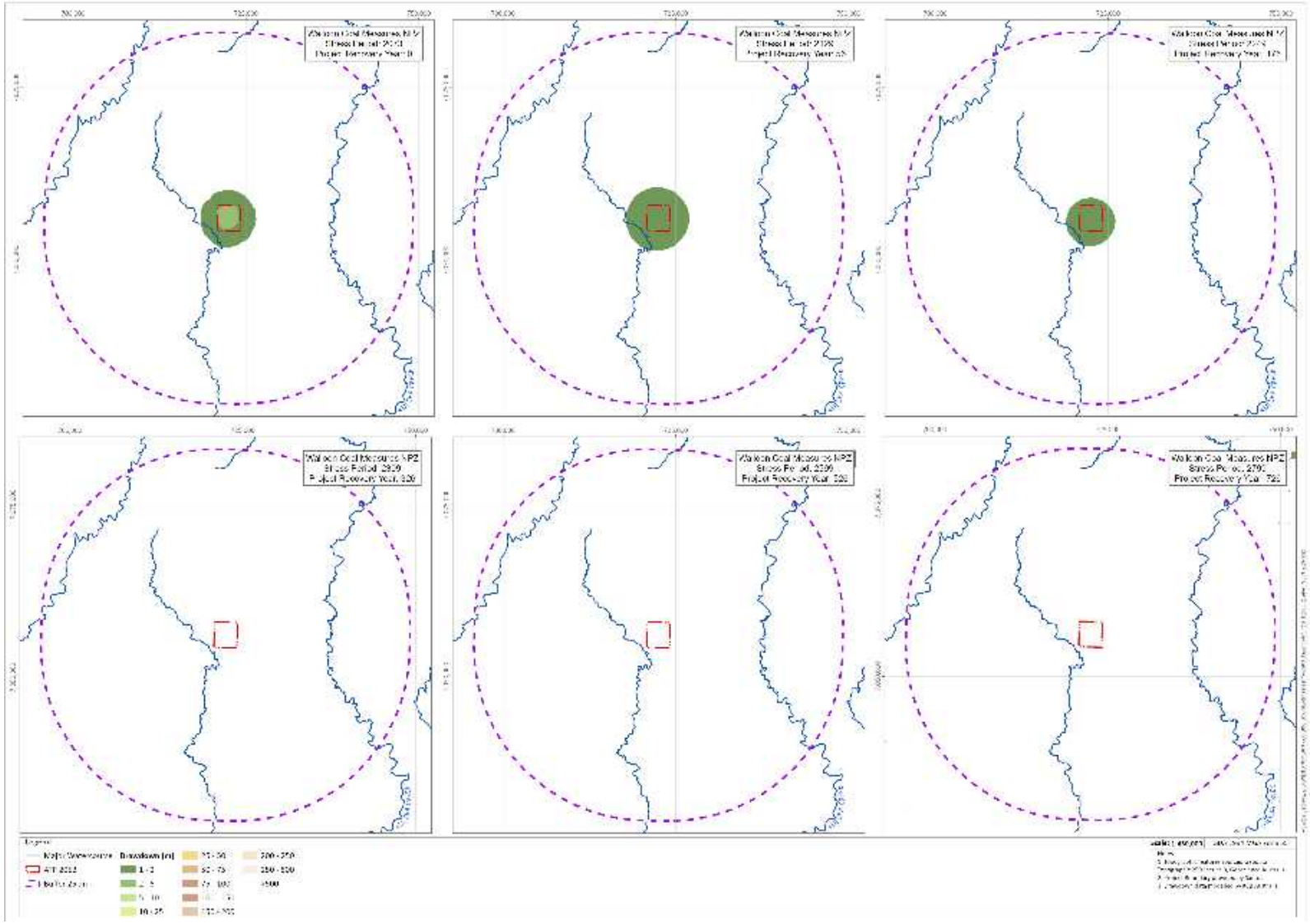


Figure II.3 Project Only Drawdown – Walloon Coal Measures Non-Productive Zone (11)

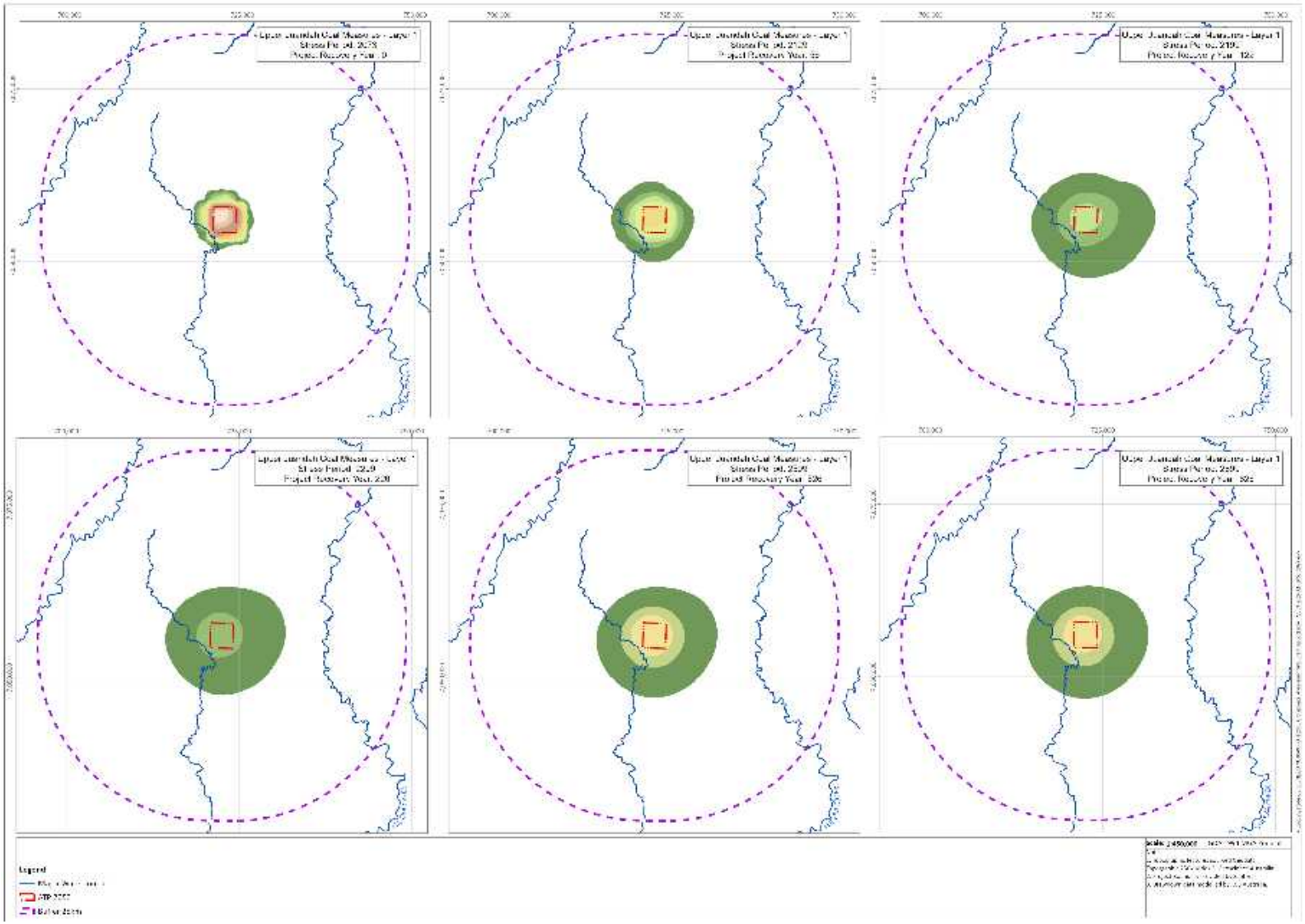


Figure II.4 Project Only Drawdown – Upper Juandah Coal Measures – Layer 1 (12)

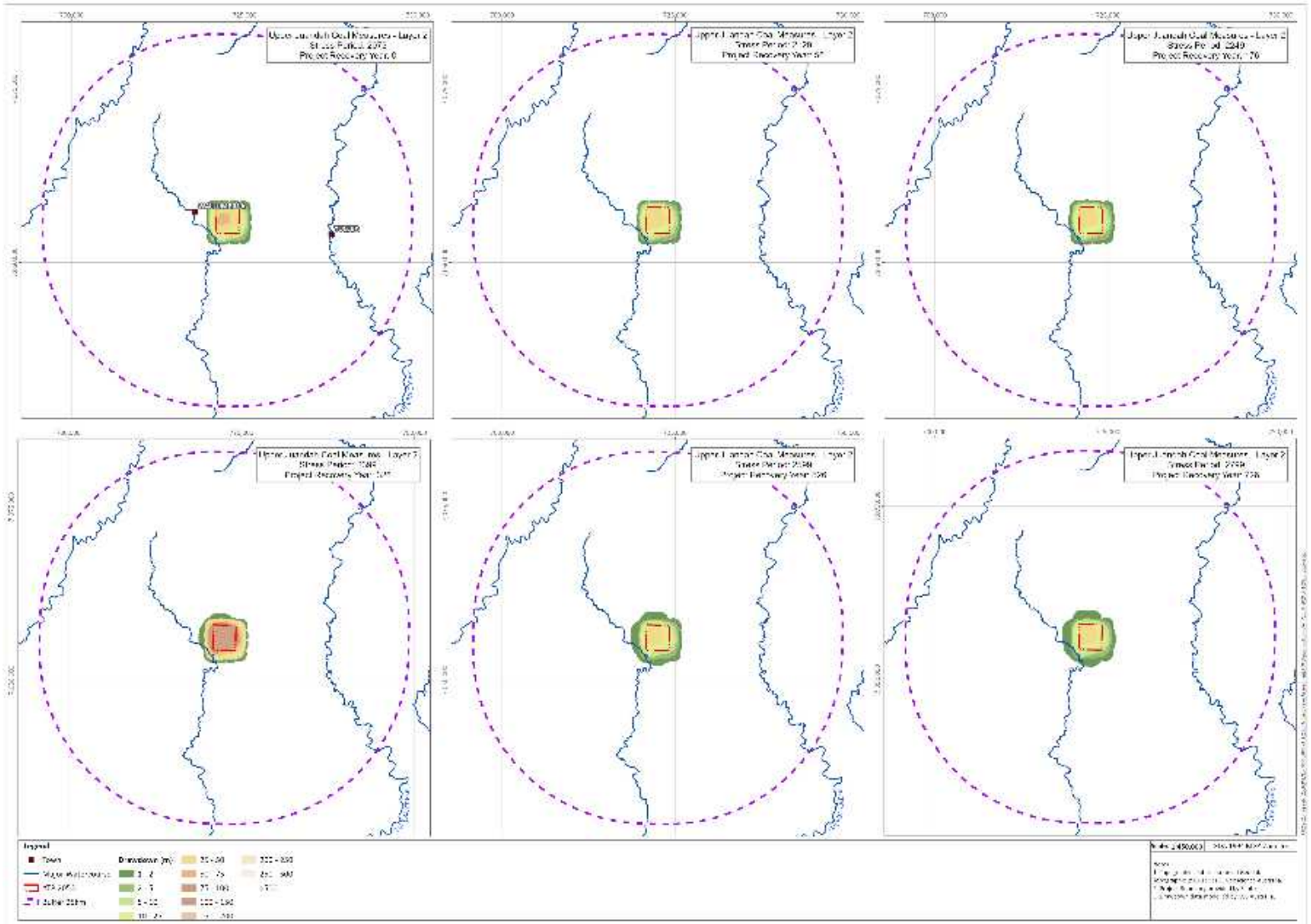


Figure II.5 Project Only Drawdown – Upper Juandah Coal Measures – Layer 2 (13)

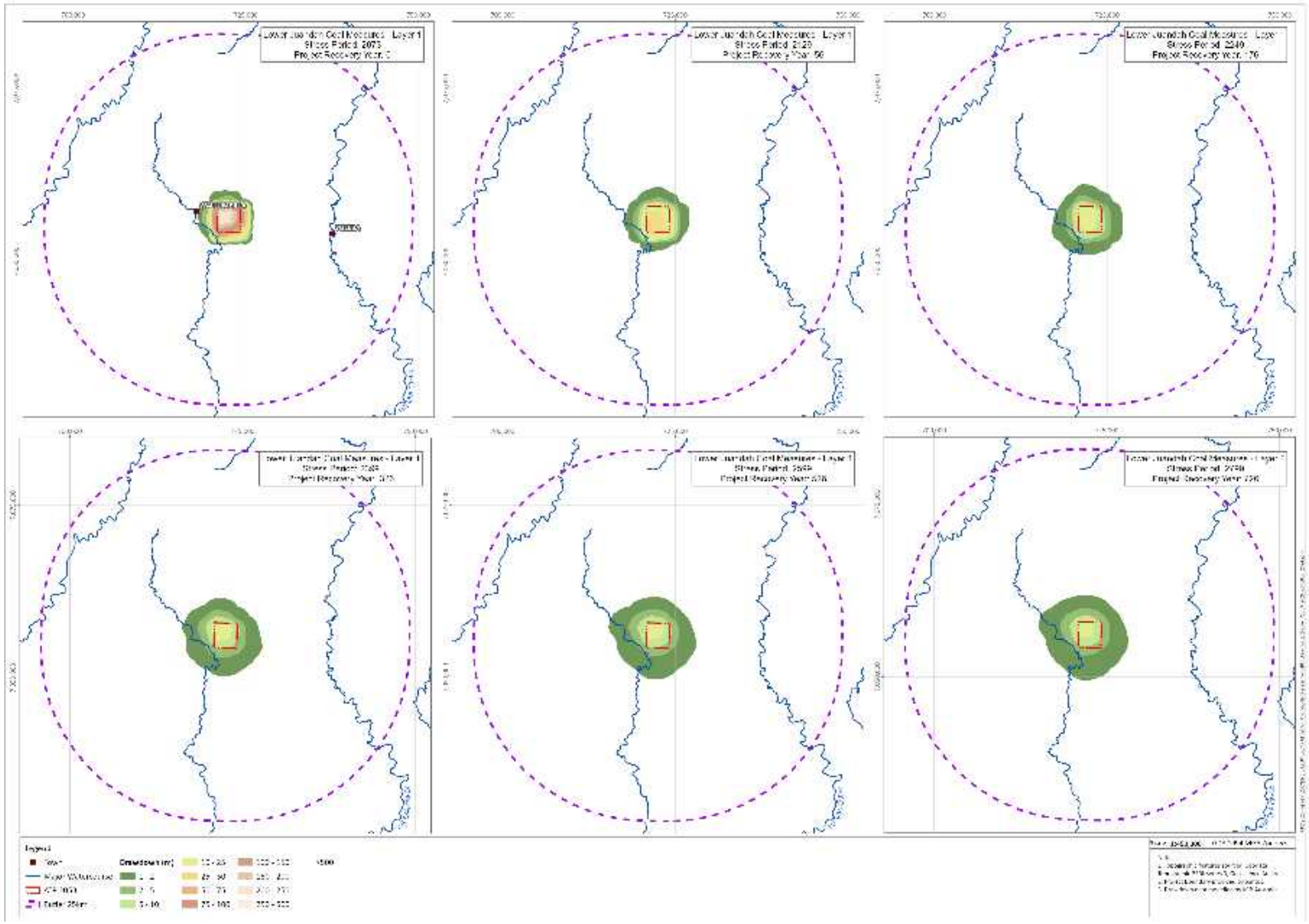


Figure II.6 Project Only Drawdown – Lower Juandah Coal Measures – Layer 1 (14)

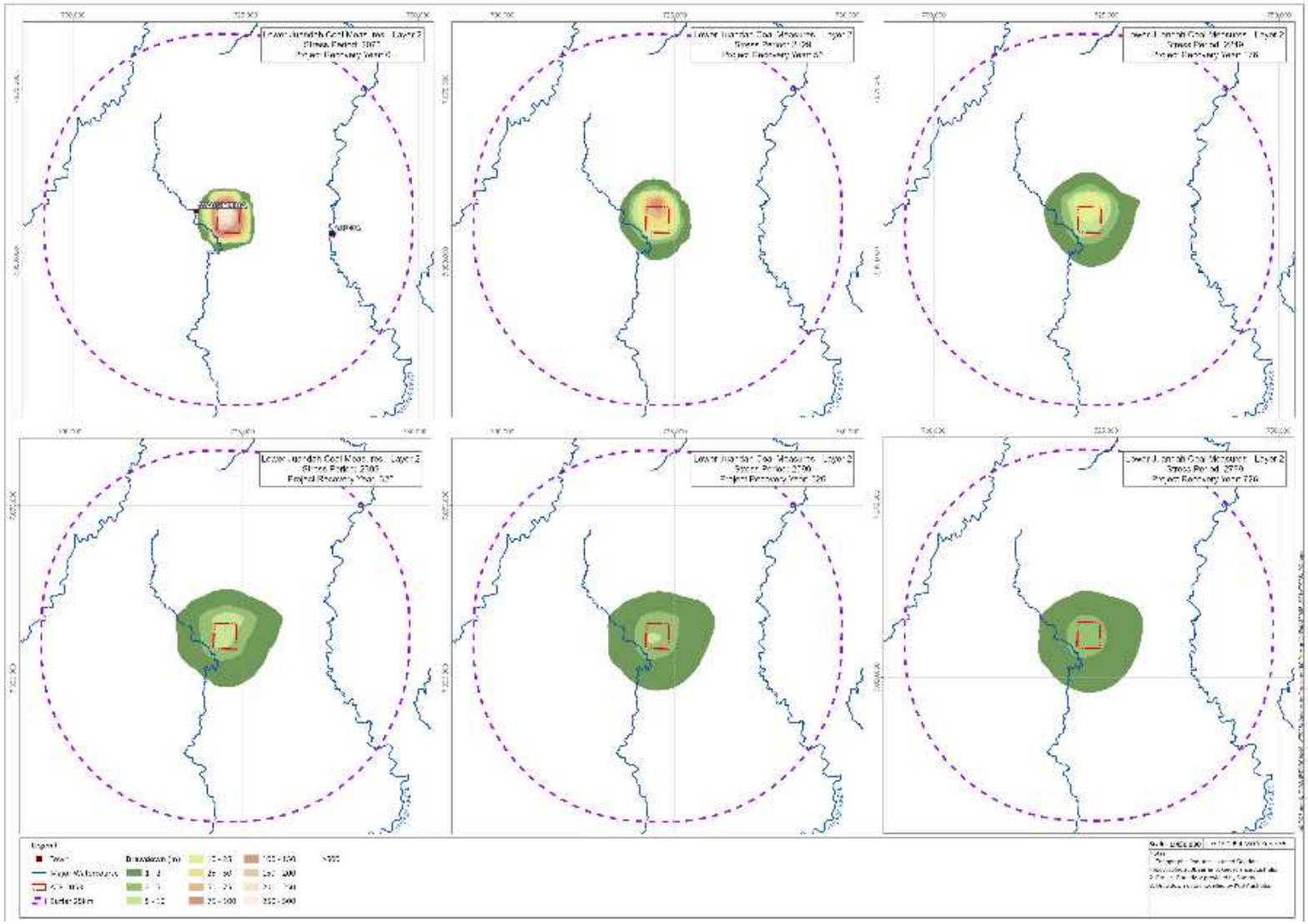


Figure II.7 Project Only Drawdown – Lower Juandah Coal Measures – Layer 2 (15)

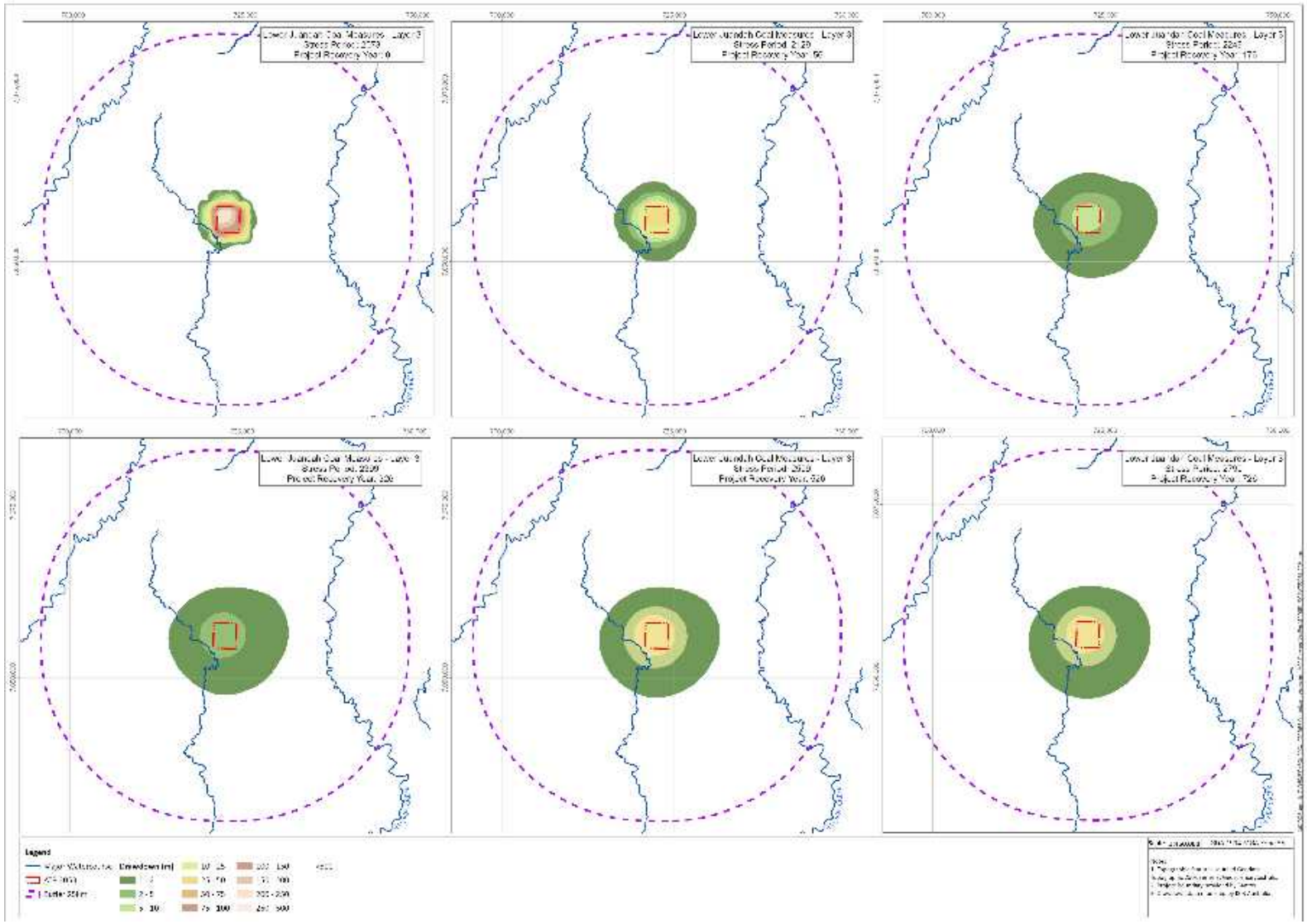


Figure II.8 Project Only Drawdown – Lower Juandah Coal Measures – Layer 3 (16)

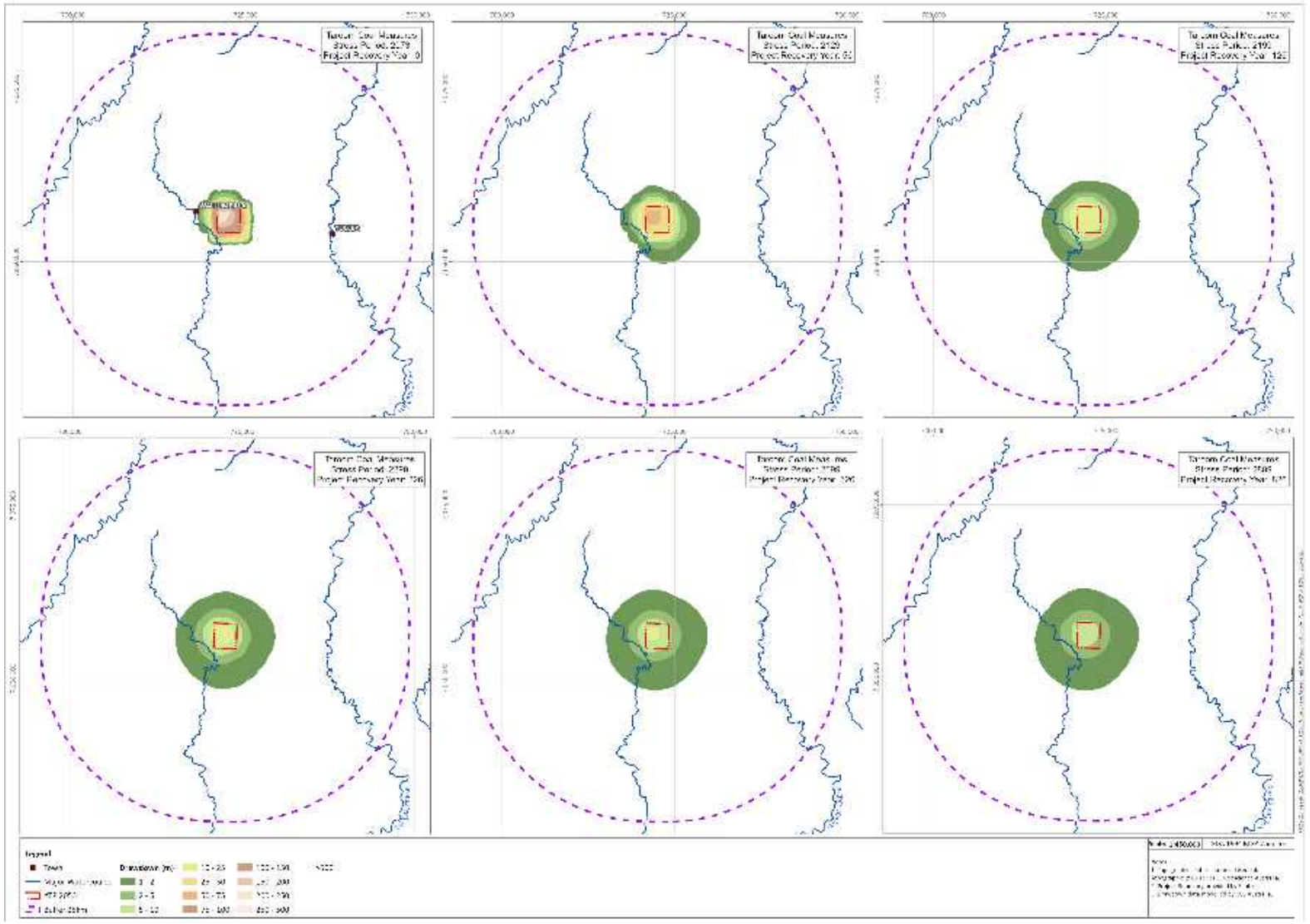


Figure II.9 Project Only Drawdown – Taroom Coal Measures (17)

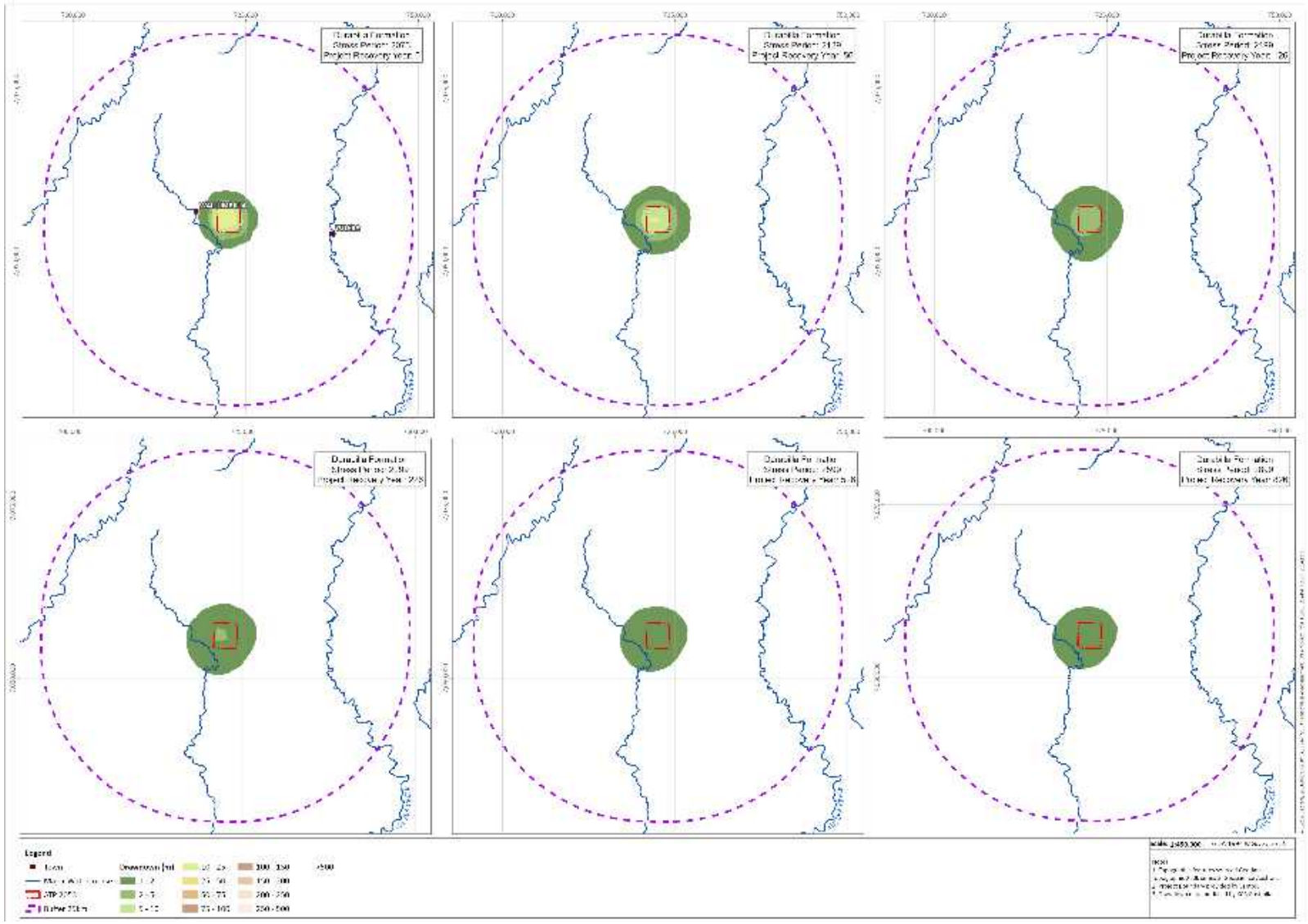


Figure II.10 Durabilla Formation (18)

APPENDIX III

Groundwater Bore – Impact Assessment Results

Appendix III
Groundwater Bore Impact Assessment

Table III-1 Predicted Project Only and Cumulative Drawdown at Water Bores Present Within 25km of the Project Area

RN	Aquifer Attribution	Project Only Drawdown (m)	Trigger Exceeded Project	Cumulative Drawdown (m)	Trigger Exceeded Cumulative	Contribution of Project to Cumulative %
244	Orallo Formation	0.00007	No	0.5473	No	0.013
405	Orallo Formation	0.00010	No	0.1849	No	0.053
5426	Mooga Sandstone	0.00006	No	0.1464	No	0.042
5427	Mooga Sandstone	0.00006	No	0.1494	No	0.041
5442	Mooga Sandstone	0.00003	No	0.0659	No	0.046
7061	Mooga Sandstone	0.00009	No	0.1066	No	0.086
7428	Mooga Sandstone	0.00003	No	0.0832	No	0.037
7760	Bungil Formation	0.00003	No	0.0589	No	0.052
7947	Bungil Formation	0.00005	No	0.0612	No	0.086
7948	Bungil Formation	0.00006	No	0.0605	No	0.102
8110	Bungil Formation	0.00006	No	0.0586	No	0.105
8129	Orallo Formation	0.00006	No	0.6035	No	0.010
9445	Orallo Formation	0.00009	No	0.2741	No	0.032
9702	Mooga Sandstone	0.00006	No	0.1837	No	0.033
9958	Mooga Sandstone	0.00009	No	0.1102	No	0.083
9968	Wallumbilla Formation	0.00005	No	0.0665	No	0.070
10192	Bungil Formation	0.00005	No	0.0551	No	0.084
10295	Orallo Formation	0.00003	No	0.3376	No	0.009
10541	Orallo Formation	0.00009	No	0.4337	No	0.021
10606	Mooga Sandstone	0.00008	No	0.1005	No	0.078
10624	Mooga Sandstone	0.00006	No	0.1354	No	0.045

RN	Aquifer Attribution	Project Only Drawdown (m)	Trigger Exceeded Project	Cumulative Drawdown (m)	Trigger Exceeded Cumulative	Contribution of Project to Cumulative %
10686	Orallo Formation	0.00009	No	0.2729	No	0.034
10710	Bungil Formation	0.00003	No	0.0508	No	0.060
10750	Wallumbilla Formation	0.00003	No	0.0362	No	0.084
10793	Orallo Formation	0.00005	No	0.3676	No	0.014
10799	Orallo Formation	0.00005	No	0.4373	No	0.012
10800	Mooga Sandstone	0.00009	No	0.1678	No	0.055
11079	Mooga Sandstone	0.00006	No	0.0974	No	0.063
11093	Orallo Formation	0.00008	No	0.4392	No	0.019
11260	Mooga Sandstone	0.00007	No	0.0927	No	0.071
11347	Mooga Sandstone	0.00009	No	0.1013	No	0.090
11351	Mooga Sandstone	0.00008	No	0.0918	No	0.091
11382	Mooga Sandstone	0.00006	No	0.1600	No	0.038
11383	Mooga Sandstone	0.00006	No	0.1576	No	0.039
11385	Bungil Formation	0.00003	No	0.0457	No	0.067
11423	Gubberamunda Sandstone	0.00006	No	0.7375	No	0.008
11431	Wallumbilla Formation	0.00003	No	0.0288	No	0.089
11437	Mooga Sandstone	0.00006	No	0.1408	No	0.040
11522	Mooga Sandstone	0.00006	No	0.1073	No	0.057
11629	Orallo Formation	0.00008	No	0.4647	No	0.017
11640	Orallo Formation	0.00006	No	0.5679	No	0.011
11677	Wallumbilla Formation	0.00003	No	0.0445	No	0.078
11718	Mooga Sandstone	0.00009	No	0.1435	No	0.064
11767	Mooga Sandstone	0.00006	No	0.0926	No	0.066
11799	Gubberamunda Sandstone	0.00007	No	1.0808	No	0.006
11852	Mooga Sandstone	0.00009	No	0.1059	No	0.086
11868	Mooga Sandstone	0.00008	No	0.1894	No	0.040

RN	Aquifer Attribution	Project Only Drawdown (m)	Trigger Exceeded Project	Cumulative Drawdown (m)	Trigger Exceeded Cumulative	Contribution of Project to Cumulative %
11870	Mooga Sandstone	0.00005	No	0.1547	No	0.034
12003	Mooga Sandstone	0.00008	No	0.1798	No	0.046
12004	Orallo Formation	0.00003	No	0.3814	No	0.009
12021	Mooga Sandstone	0.00006	No	0.1806	No	0.034
12038	Mooga Sandstone	0.00009	No	0.1088	No	0.084
12056	Mooga Sandstone	0.00009	No	0.1553	No	0.059
12059	Orallo Formation	0.00009	No	0.4757	No	0.020
12067	Mooga Sandstone	0.00009	No	0.2022	No	0.045
12068	Mooga Sandstone	0.00007	No	0.2311	No	0.030
12075	Orallo Formation	0.00006	No	0.5637	No	0.011
12076	Mooga Sandstone	0.00009	No	0.1606	No	0.057
12264	Bungil Formation	0.00006	No	0.0993	No	0.061
12316	Mooga Sandstone	0.00006	No	0.1144	No	0.053
12454	Gubberamunda Sandstone	0.00006	No	0.7349	No	0.008
12473	Mooga Sandstone	0.00006	No	0.1370	No	0.045
12476	Orallo Formation	0.00012	No	0.3599	No	0.032
12519	Bungil Formation	0.00006	No	0.0662	No	0.092
12542	Orallo Formation	0.00010	No	0.3905	No	0.026
12543	Orallo Formation	0.00012	No	0.1547	No	0.079
12570	Mooga Sandstone	0.00009	No	0.1760	No	0.052
12590	Mooga Sandstone	0.00006	No	0.0836	No	0.073
12623	Bungil Formation	0.00006	No	0.1412	No	0.043
12700	Mooga Sandstone	0.00008	No	0.0898	No	0.085
12728	Mooga Sandstone	0.00003	No	0.0885	No	0.034
12829	Orallo Formation	0.00009	No	0.0967	No	0.094
12841	Gubberamunda Sandstone	0.00006	No	0.8324	No	0.008

RN	Aquifer Attribution	Project Only Drawdown (m)	Trigger Exceeded Project	Cumulative Drawdown (m)	Trigger Exceeded Cumulative	Contribution of Project to Cumulative %
12847	Mooga Sandstone	0.00009	No	0.0979	No	0.093
12854	Bungil Formation	0.00006	No	0.0622	No	0.091
12888	Orallo Formation	0.00008	No	0.1991	No	0.041
13102	Mooga Sandstone	0.00006	No	0.0911	No	0.067
13154	Mooga Sandstone	0.00007	No	0.1003	No	0.066
13155	Wallumbilla Formation	0.00003	No	0.0355	No	0.086
13157	Mooga Sandstone	0.00009	No	0.1643	No	0.056
13158	Mooga Sandstone	0.00009	No	0.1587	No	0.058
13212	Mooga Sandstone	0.00009	No	0.1093	No	0.081
13286	Bungil Formation	0.00006	No	0.0620	No	0.098
13324	Mooga Sandstone	0.00009	No	0.1733	No	0.052
13417	Orallo Formation	0.00008	No	0.3784	No	0.022
13458	Orallo Formation	0.00008	No	0.4065	No	0.021
13582	Mooga Sandstone	0.00009	No	0.1382	No	0.066
13594	Mooga Sandstone	0.00006	No	0.0992	No	0.062
13626	Mooga Sandstone	0.00009	No	0.1693	No	0.054
13679	Orallo Formation	0.00009	No	0.3474	No	0.026
13746	Mooga Sandstone	0.00009	No	0.1816	No	0.049
13816	Mooga Sandstone	0.00006	No	0.0846	No	0.072
13961	Bungil Formation	0.00006	No	0.0646	No	0.095
14037	Mooga Sandstone	0.00007	No	0.0946	No	0.079
14065	Orallo Formation	0.00008	No	0.3026	No	0.025
14080	Mooga Sandstone	0.00009	No	0.1379	No	0.066
14116	Orallo Formation	0.00009	No	0.2895	No	0.032
14135	Orallo Formation	0.00015	No	0.2228	No	0.068
14163	Orallo Formation	0.00009	No	0.3187	No	0.029

RN	Aquifer Attribution	Project Only Drawdown (m)	Trigger Exceeded Project	Cumulative Drawdown (m)	Trigger Exceeded Cumulative	Contribution of Project to Cumulative %
14336	Orallo Formation	0.00006	No	0.3369	No	0.018
14337	Mooga Sandstone	0.00003	No	0.1303	No	0.023
14431	Westbourne Formation	0.00161	No	0.7643	No	0.211
14468	Orallo Formation	0.00009	No	0.3706	No	0.025
14509	Orallo Formation	0.00009	No	0.4499	No	0.020
14551	Mooga Sandstone	0.00008	No	0.0935	No	0.091
14651	Gubberamunda Sandstone	0.00014	No	0.1985	No	0.072
14738	Mooga Sandstone	0.00006	No	0.1123	No	0.054
14821	Mooga Sandstone	0.00006	No	0.1047	No	0.058
14845	Mooga Sandstone	0.00006	No	0.0871	No	0.070
14860	Mooga Sandstone	0.00006	No	0.1517	No	0.040
14907	Orallo Formation	0.00015	No	0.1826	No	0.084
14930	Gubberamunda Sandstone	0.00006	No	0.1116	No	0.055
14948	Mooga Sandstone	0.00003	No	0.0521	No	0.059
15024	Lower Bandanna Formation	0	No	0	No	Layer 30
15031	Mooga Sandstone	0.00007	No	0.0995	No	0.072
15529	Mooga Sandstone	0.00009	No	0.1555	No	0.056
15564	Mooga Sandstone	0.00007	No	0.3121	No	0.021
15840	Mooga Sandstone	0.00006	No	0.0867	No	0.070
16007	Orallo Formation	0.00004	No	0.2480	No	0.015
16100	Mooga Sandstone	0.00004	No	0.0819	No	0.043
16148	Mooga Sandstone	0.00007	No	0.0952	No	0.078
16159	Orallo Formation	0.00008	No	0.2505	No	0.031
16512	Mooga Sandstone	0.00006	No	0.0935	No	0.065
16631	Mooga Sandstone	0.00006	No	0.0973	No	0.063
16684	Mooga Sandstone	0.00006	No	0.0859	No	0.071

RN	Aquifer Attribution	Project Only Drawdown (m)	Trigger Exceeded Project	Cumulative Drawdown (m)	Trigger Exceeded Cumulative	Contribution of Project to Cumulative %
16805	Gubberamunda Sandstone	0.00009	No	0.0986	No	0.092
17340	Orallo Formation	0.00015	No	0.1562	No	0.098
17501	Gubberamunda Sandstone	0.00022	No	0.1393	No	0.161
17788	Mooga Sandstone	0.00006	No	0.1550	No	0.039
17807	Mooga Sandstone	0.00006	No	0.1595	No	0.038
17859	Mooga Sandstone	0.00009	No	0.0942	No	0.096
22100	Orallo Formation	0.00009	No	0.1707	No	0.054
22103	Orallo Formation	0.00011	No	0.1545	No	0.072
22107	Gubberamunda Sandstone	0.00009	No	0.1125	No	0.081
22253	Gubberamunda Sandstone	0.00009	No	0.1116	No	0.082
22254	Orallo Formation	0.00009	No	0.0965	No	0.094
22275	Upper Bandanna Formation	0	No	0	No	Layer 29
22285	Gubberamunda Sandstone	0.00014	No	0.2708	No	0.051
22292	Gubberamunda Sandstone	0.00009	No	0.1064	No	0.086
22378	Orallo Formation	0.00009	No	0.1532	No	0.060
22386	Gubberamunda Sandstone	0.00006	No	0.1340	No	0.046
22407	Gubberamunda Sandstone	0.00009	No	0.3129	No	0.028
22519	Orallo Formation	0.00006	No	0.0841	No	0.073
22525	Orallo Formation	0.00006	No	0.0872	No	0.070
22584	Gubberamunda Sandstone	0.00033	No	0.1392	No	0.238
22585	Gubberamunda Sandstone	0.00061	No	0.1544	No	0.395
22594	Gubberamunda Sandstone	0.00019	No	0.1323	No	0.146
22613	Upper Hutton Sandstone	0.02597	No	1.5375	No	1.689
22639	Bungil Formation	0.00004	No	0.0622	No	0.059
22726	Gubberamunda Sandstone	0.00008	No	1.0766	No	0.007
22791	Upper Permian	0.00001	No	0.0027	No	0.223

RN	Aquifer Attribution	Project Only Drawdown (m)	Trigger Exceeded Project	Cumulative Drawdown (m)	Trigger Exceeded Cumulative	Contribution of Project to Cumulative %
22794	Orallo Formation	0.00009	No	0.1565	No	0.058
22796	Orallo Formation	0.00009	No	0.1139	No	0.077
22800	Orallo Formation	0.00009	No	0.0996	No	0.092
22883	Orallo Formation	0.00006	No	0.0937	No	0.065
22886	Gubberamunda Sandstone	0.00010	No	0.1918	No	0.050
23153	Orallo Formation	0.00011	No	0.1952	No	0.057
23230	Gubberamunda Sandstone	0.00006	No	0.0917	No	0.067
23350	Orallo Formation	0.00012	No	0.1227	No	0.100
23368	Orallo Formation	0.00007	No	0.0901	No	0.079
23465	Orallo Formation	0.00012	No	0.2185	No	0.055
23477	Orallo Formation	0.00007	No	0.0970	No	0.073
23558	Orallo Formation	0.00007	No	0.2443	No	0.027
23641	Mooga Sandstone	0.00008	No	0.0907	No	0.084
26171	Orallo Formation	0.00006	No	0.5853	No	0.010
26258	Mooga Sandstone	0.00003	No	0.0627	No	0.049
26276	Mooga Sandstone	0.00001	No	0.0048	No	0.106
26342	Mooga Sandstone	0.00008	No	0.2014	No	0.040
30075	Mooga Sandstone	0.00006	No	0.0949	No	0.064
31874	Gubberamunda Sandstone	0.00022	No	0.8842	No	0.025
37952	Mooga Sandstone	0.00008	No	0.0898	No	0.085
38302	Mooga Sandstone	0.00009	No	0.1050	No	0.087
38527	Bungil Formation	0.00004	No	0.0570	No	0.073
43691	Mooga Sandstone	0.00006	No	0.2004	No	0.030
44144	Orallo Formation	0.00006	No	0.2636	No	0.023
48840	Orallo Formation	0.00006	No	0.5429	No	0.011
48847	Bungil Formation	0.00009	No	0.1765	No	0.052

RN	Aquifer Attribution	Project Only Drawdown (m)	Trigger Exceeded Project	Cumulative Drawdown (m)	Trigger Exceeded Cumulative	Contribution of Project to Cumulative %
48869	Mooga Sandstone	0.00007	No	0.0948	No	0.075
48871	Orallo Formation	0.00015	No	0.1609	No	0.092
48924	Orallo Formation	0.00009	No	0.3524	No	0.026
48925	Orallo Formation	0.00006	No	0.3152	No	0.020
48926	Orallo Formation	0.00009	No	0.3137	No	0.029
48969	Mooga Sandstone	0.00009	No	0.1244	No	0.074
58003	Mooga Sandstone	0.00003	No	0.1210	No	0.025
58004	Orallo Formation	0.00006	No	0.4337	No	0.014
58023	Orallo Formation	0.00009	No	0.1149	No	0.080
58030	Bungil Formation	0.00004	No	0.1236	No	0.031
58085	Mooga Sandstone	0.00006	No	0.1003	No	0.061
58094	Mooga Sandstone	0.00006	No	0.1379	No	0.044
58106	Mooga Sandstone	0.00007	No	0.0921	No	0.072
58124	Orallo Formation	0.00012	No	0.3541	No	0.033
58256	Orallo Formation	0.00010	No	0.4798	No	0.021
58287	Mooga Sandstone	0.00008	No	0.0963	No	0.087
58314	Mooga Sandstone	0.00007	No	0.0934	No	0.071
58356	Mooga Sandstone	0.00008	No	0.1007	No	0.082
58387	Orallo Formation	0.00006	No	0.2616	No	0.023
58419	Mooga Sandstone	0.00009	No	0.1042	No	0.085
58440	Orallo Formation	0.00009	No	0.5423	No	0.016
58444	Gubberamunda Sandstone	0.00090	No	0.2005	No	0.447
58469	Gubberamunda Sandstone	0.00012	No	1.0208	No	0.012
58470	Orallo Formation	0.00009	No	0.3639	No	0.025
58477	Gubberamunda Sandstone	0.00012	No	1.4932	No	0.008
58555	Mooga Sandstone	0.00006	No	0.1659	No	0.037

RN	Aquifer Attribution	Project Only Drawdown (m)	Trigger Exceeded Project	Cumulative Drawdown (m)	Trigger Exceeded Cumulative	Contribution of Project to Cumulative %
58590	Bungil Formation	0.00000	No	-0.0013	No	0.088
58605	Gubberamunda Sandstone	0.00012	No	0.1263	No	0.097
58606	Orallo Formation	0.00006	No	0.2926	No	0.021
58654	Orallo Formation	0.00013	No	0.2842	No	0.045
58728	Orallo Formation	0.00012	No	0.1183	No	0.103
58788	Mooga Sandstone	0.00006	No	0.1028	No	0.059
58941	Mooga Sandstone	0.00006	No	0.1405	No	0.043
123013	Orallo Formation	0.00006	No	0.1872	No	0.033
123079	Orallo Formation	0.00009	No	0.1786	No	0.051
123107	Orallo Formation	0.00012	No	0.1378	No	0.089
123195	Mooga Sandstone	0.00009	No	0.1285	No	0.071
123196	Gubberamunda Sandstone	0.00032	No	1.1085	No	0.029
123222	Orallo Formation	0.00007	No	0.5514	No	0.012
123236	Gubberamunda Sandstone	0.00075	No	0.4355	No	0.173
123240	Mooga Sandstone	0.00009	No	0.1175	No	0.078
123289	Mooga Sandstone	0.00006	No	0.1328	No	0.046
123309	Gubberamunda Sandstone	0.00020	No	0.2266	No	0.090
123316	Mooga Sandstone	0.00009	No	0.1000	No	0.092
123318	Gubberamunda Sandstone	0.00071	No	0.2296	No	0.308
123322	Orallo Formation	0.00012	No	0.1773	No	0.069
123342	Mooga Sandstone	0.00009	No	0.1551	No	0.059
123355	Orallo Formation	0.00009	No	0.2716	No	0.034
123429	Bungil Formation	0.00004	No	0.0628	No	0.059
123430	Gubberamunda Sandstone	0.00006	No	0.8753	No	0.007
123468	Gubberamunda Sandstone	0.00006	No	0.4349	No	0.014
123493	Gubberamunda Sandstone	0.00009	No	1.7273	No	0.005

RN	Aquifer Attribution	Project Only Drawdown (m)	Trigger Exceeded Project	Cumulative Drawdown (m)	Trigger Exceeded Cumulative	Contribution of Project to Cumulative %
123503	Orallo Formation	0.00015	No	0.1377	No	0.107
123516	Gubberamunda Sandstone	0.00067	No	0.2174	No	0.309
123528	Gubberamunda Sandstone	0.00006	No	0.3898	No	0.016
123539	Orallo Formation	0.00015	No	0.3004	No	0.051
123552	Gubberamunda Sandstone	0.00018	No	1.0359	No	0.018
123575	Orallo Formation	0.00006	No	0.1488	No	0.041
123576	Gubberamunda Sandstone	0.00035	No	0.7511	No	0.047
123577	Orallo Formation	0.00009	No	0.4375	No	0.021
123591	Orallo Formation	0.00012	No	0.3466	No	0.035
123598	Mooga Sandstone	0.00006	No	0.0924	No	0.066
123599	Orallo Formation	0.00006	No	0.6514	No	0.009
123619	Mooga Sandstone	0.00008	No	0.1026	No	0.083
123622	Orallo Formation	0.00007	No	0.5374	No	0.013
123639	Mooga Sandstone	0.00009	No	0.1858	No	0.048
123646	Mooga Sandstone	0.00006	No	0.1116	No	0.055
123660	Orallo Formation	0.00009	No	0.3947	No	0.023
123661	Orallo Formation	0.00009	No	0.1651	No	0.055
123678	Mooga Sandstone	0.00007	No	0.1504	No	0.048
123682	Gubberamunda Sandstone	0.00006	No	1.7000	No	0.004
123686	Orallo Formation	0.00006	No	0.5179	No	0.012
123702	Mooga Sandstone	0.00006	No	0.0965	No	0.063
123774	GUBBERAMUNDA SANDSTONE	0.00037	No	0.1372	No	0.272
160394	Gubberamunda Sandstone	0.00006	No	0.3898	No	0.016
168013	Gubberamunda Sandstone	0.00006	No	1.1974	No	0.005
168014	Mooga Sandstone	0.00009	No	0.1653	No	0.055
168015	Orallo Formation	0.00014	No	0.1739	No	0.079

RN	Aquifer Attribution	Project Only Drawdown (m)	Trigger Exceeded Project	Cumulative Drawdown (m)	Trigger Exceeded Cumulative	Contribution of Project to Cumulative %
168016	Orallo Formation	0.00004	No	0.3342	No	0.011
168017	Orallo Formation	0.00004	No	0.3336	No	0.013
168018	Mooga Sandstone	0.00003	No	0.0801	No	0.039
168036	Orallo Formation	0.00003	No	0.3824	No	0.008
168070	Mooga Sandstone	0.00003	No	0.1156	No	0.025
168072	Mooga Sandstone	0.00009	No	0.1771	No	0.052
168073	Mooga Sandstone	0.00009	No	0.1856	No	0.047
168074	Orallo Formation	0.00009	No	0.1705	No	0.054
168085	Mooga Sandstone	0.00003	No	0.0690	No	0.044
168149	Bungil Formation	0.00006	No	0.0931	No	0.066
168177	Orallo Formation	0.00003	No	0.3515	No	0.009
168178	Gubberamunda Sandstone	0.00006	No	1.0145	No	0.006
168179	Orallo Formation	0.00009	No	0.5230	No	0.018
168224	Bungil Formation	0.00003	No	0.0594	No	0.051
168281	Orallo Formation	0.00006	No	0.3207	No	0.019
168287	Orallo Formation	0.00006	No	0.3403	No	0.018
168310	Orallo Formation	0.00007	No	0.5460	No	0.013
168335	Orallo Formation	0.00006	No	0.3304	No	0.018
168336	Orallo Formation	0.00006	No	0.3304	No	0.018
168374	Orallo Formation	0.00014	No	0.2124	No	0.064
180014	Precipice Sandstone	0	No	0	No	Layer 24
205746	Mooga Sandstone	0.00009	No	0.1954	No	0.046
205777	Mooga Sandstone	0.00006	No	0.0937	No	0.065
206823	Gubberamunda Sandstone	0.00019	No	1.4411	No	0.013
207148	Mooga Sandstone	0.00007	No	0.2095	No	0.032
208460	Gubberamunda Sandstone	0.001053	No	0.1794	No	0.31

APPENDIX IV

Stimulation Impact Monitoring Program

Santos

Eastern Queensland

Stimulation Impact Monitoring Program

Document Number: 0007-650-PLA-0012

Date	Rev	Reason For Issue	Author	Checked	Approved
27/3/2017	0	Initial release – relevant across GLNG and GFD	JC	JC	PW
22/09/2020	1	Document review and revision	AL	AS	AS
16/08/2021	2	Administrative changes	AL	AS	PW

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Abbreviations and Units

Acronym	Description
DES	Department of Environment and Science
EA	Environmental Authority
EC	electrical conductivity
EHS	Environment, Health and Safety
EP Act	*Environment Protection Act 1994*
EPP	Environmental Protection Policy
EPP Water	*Environmental Protection (Water and Wetland Biodiversity) Policy 2019*
EQ	Eastern Queensland
EV	Environmental Value
GDE	Groundwater Dependant Ecosystem
GED	General Environmental Duty
HFRA	Hydraulic Fracturing Risk Assessment
LOR	Limit of Reporting
NATA	National Associated of Testing Authorities
PAH	Polycyclic aromatic hydrocarbons
SIMP	Stimulation Impact Monitoring Program
SMS	Santos Management System
TDS	total dissolved solids
TPH	total petroleum hydrocarbons
TRH	total recoverable hydrocarbons

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1.0 Introduction

This Stimulation Impact Monitoring Program (SIMP) has been prepared to meet relevant requirements of the Well Construction, Maintenance and Stimulation Activities Schedule of Santos' Eastern Queensland (EQ) Environmental Authorities (EAs). A list of the applicable EQ Project Area EAs is provided in Attachment A. Table 1 details these EA requirements with reference to the relevant section of this SIMP.

Table 1 – Stimulation Impact Monitoring Program Requirements

Number*	Condition	Section
I10 (j)	An assessment of the appropriate limits of reporting for all water quality indicators relevant to stimulation monitoring in order to accurately assess the risks to environmental values of groundwater.	Section 5
J4	Polycyclic aromatic hydrocarbons or products that contain polycyclic aromatic hydrocarbons must not be used in stimulation fluids in concentrations above the reporting limit.	Section 3.2
J5	Stimulation activities must not negatively affect water quality, other than that within the stimulation impact zone of the target gas producing formation.	Sections 2, 3, and 4
J11	***Water Quality Baseline Monitoring*** Prior to undertaking any stimulation activity(ies), a baseline bore assessment must be undertaken of the water quality of: (a) all landholders' active groundwater bores (subject to access being permitted by the landholder) that are spatially within a two (2) kilometre horizontal radius from the location of the stimulation initiation point within the target gas producing formation; (b) all landholders' active groundwater bores (subject to access being permitted by the landholder) in any aquifer that is within 200 metres above or below the target gas producing formation and is spatially located within a two (2) kilometre radius from the location of the stimulation initiation point; and (c) any other bore that could potentially be adversely impacted by the stimulation activity(ies) in accordance with the findings of the risk assessment required by conditions (J9) and (J10).	Section 2 Section 2 Section 2 Section 2
J12	Prior to undertaking stimulation activities at a well, the holder of this environmental authority must have sufficient water quality data to accurately represent the water quality in the well to be stimulated. The data must include, as a minimum, the results of analysis for the parameters in condition (J13).	Section 3.0
J13	Stimulation baseline bore assessments required in condition (J11) must include the minimum water quality analytes and physico-chemical parameters identified in the Baseline Assessment Guideline and any restricted stimulation fluids as defined in the *Environmental Protection Act 1994*, as amended from time to time, in order to establish baseline water quality.	Section 5
J14	***Stimulation Impact Monitoring Program***	This document

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Number*	Condition	Section
	A Stimulation Impact Monitoring Program must be developed prior to the carrying out of stimulation activities which must be able to detect adverse impacts to water quality from stimulation activities and must consider the	
	findings of the risk assessment required by conditions (J9) and (J10) that relate to stimulation activities and must include, as a minimum, monitoring of:	Section 5
	(a) the stimulation fluids to be used in stimulation activities at sufficient frequency and which sufficiently represents the quantity and quality of the fluids used;	Section 3.2
	(b) flowback waters from stimulation activities at sufficient frequency and which sufficiently represents the quality of that flow back water;	Section 3.3
	(c) flowback waters from stimulation activities at sufficient frequency and accuracy to demonstrate that 150 per cent of the volume used in stimulation activities has been extracted from the stimulated well; and	Section 3.3
	(d) all bores in accordance with condition (J11) at the following minimum frequency: i. monthly for the first six (6) months subsequent to the stimulation activities being undertaken; then ii. annually for the first five (5) years subsequent to the stimulation activities being undertaken or until analytes and physico-chemical parameters listed in condition (J13) are not detected in concentrations above baseline bore monitoring data on two (2) consecutive monitoring occasions.	Section 4
J15	The Stimulation Impact Monitoring Program must provide for monitoring of:	
	(a) analytes and physico-chemical parameters relevant to baseline bore and well assessments to enable data referencing and comparison including, but not necessarily being limited to the analytes and physico-chemical parameters in condition (J13); and	Section 5
	(b) any other analyte or physico-chemical parameters that will enable detection of adverse water quality impacts and the inter-connection with a non-target aquifer as a result of stimulation activities including chemical compounds that are actually or potentially formed by chemical reactions with each other or coal seam materials during stimulation activities.	Section 3.3

** Condition numbering may vary between EAs.*

Stimulation is defined in Santos EQ EAs and means a technique used to increase the permeability of natural underground reservoir that is undertaken above the formation pressure and involves the addition of chemicals. Stimulation includes hydraulic fracturing / hydrofraccing, fracture acidizing and the use of proppant treatments.

Restricted stimulation fluids means fluids used for the purpose of stimulation, including fracturing, that contain the following chemicals in more than the maximum amounts prescribed under section 81B of the *Environmental Protection Regulation 2008*:

- petroleum hydrocarbons containing benzene, ethylbenzene, toluene or xylene; or
- chemicals that produce, or are likely to produce benzene, ethylbenzene, toluene, or xylene as the chemical breaks down in the environment.

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The restrictions on PAHs and/or restricted stimulation fluids apply to stimulation fluid (concentrate) prior to being mixed with water (source water).

An overview of the monitoring described in this Stimulation Impact Monitoring Program, including groundwater bore baseline monitoring (pre-stimulation monitoring), stimulation source water, stimulation fluid and flowback monitoring, and post-stimulation monitoring is provided in Figure 1.

The certification of this SIMP by a suitably qualified person is provided in Attachment B.

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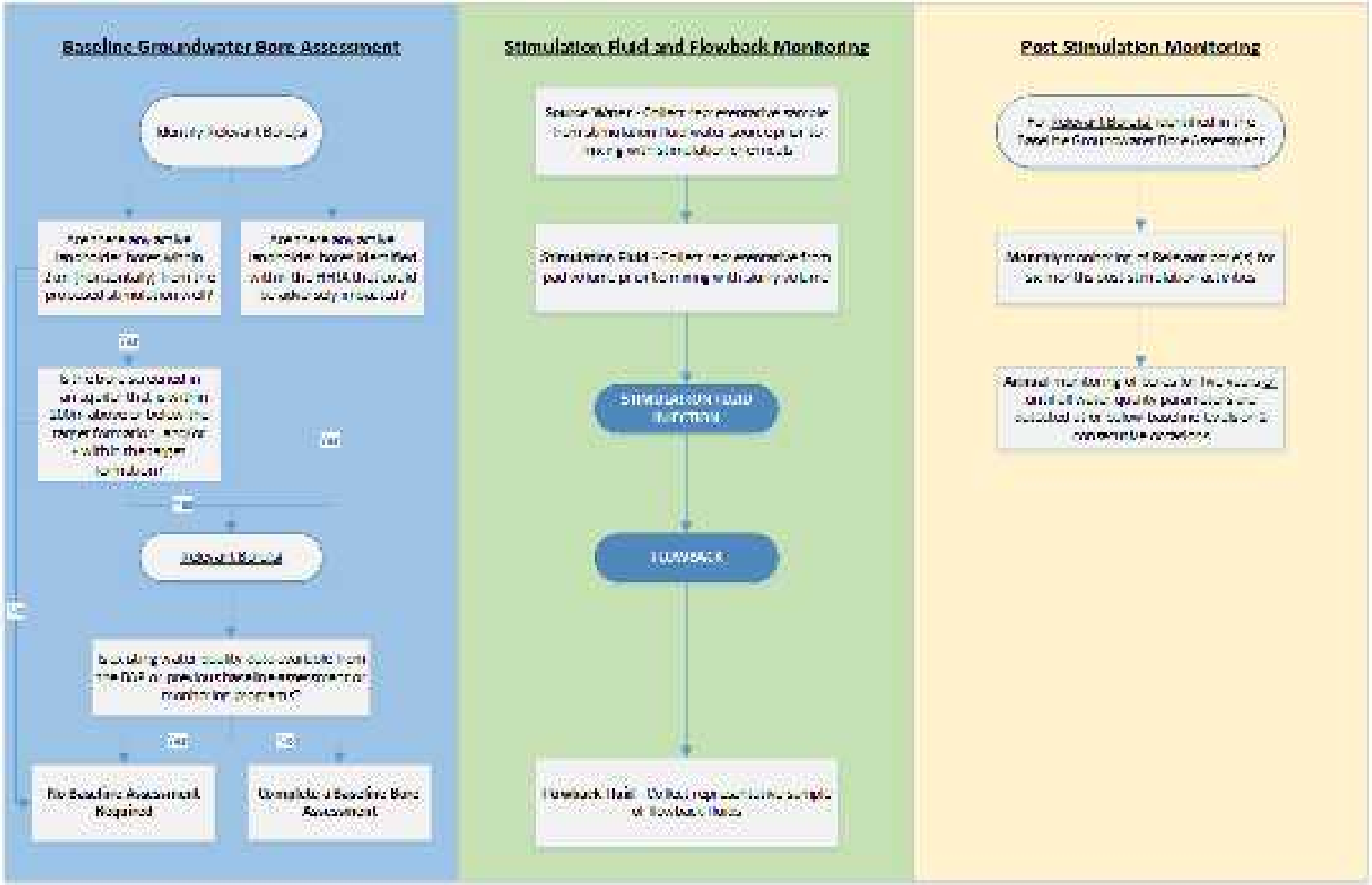


Figure 1 – Stimulation Monitoring Overview

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2.0 Baseline Groundwater Bore Assessment

Prior to undertaking stimulation activities a baseline groundwater bore assessment is be undertaken as follows:

1. Determine the target depth and formation of proposed stimulation activity.
2. Complete a search of Santos WebGIS and Queensland Government Groundwater Database (e.g. QLD Globe) to determine the potential presence of active landholder groundwater bores screened within 200 metres from the target formation and spatially located within two (2) kilometres of the well to be fractured.
3. Identify other bores from the Hydraulic Fracturing Risk Assessment (HFRA) that could potentially be adversely impacted by the proposed stimulation activity.
4. For groundwater bores identified in Steps 2 and 3 (relevant bore(s)), review existing bore information (boring logs and completion details) and water quality data obtained from studies such as:
    a) baseline assessment plan (BAP);
    b) regional monitoring assessments; and
    c) previous baseline monitoring.
5. If existing baseline water quality data identified in Step 4 is not available for the relevant bore(s), a representative baseline groundwater sample is to be collected prior to the stimulation activity.

One sample is to be collected from each relevant bore and is to be analysed for the analytical suite detailed in Table 2, Section 5.

It is important to note that restrictions to sampling such as land access or surface equipment present at the bore (such as pumps) may occur. Where sampling cannot be undertaken due to land access, physical restrictions or insufficient water, baseline water quality may be extrapolated from relevant surrounding bores.

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3.0 Stimulation Fluid and Flowback Monitoring

Monitoring of stimulation fluids during the stimulation activity (at sufficient frequency) is to be conducted in order to characterize the quality and quantity of source water, stimulation fluid and flowback.

Given the process of well perforation and stimulation it is not considered viable or practical to collect a representative water sample from the well prior to stimulation. Representative water quality data for the well to be stimulated may be extrapolated from relevant surrounding wells or storage ponds.

3.1 Stimulation Water Source Sampling

Source water to be used for stimulation activities is to be sampled prior to the commencement of the stimulation operations.

One source water sample is to be collected per stimulation activity and is to be analysed for the analytical suite detailed in Table 3, Section 5. For locations where water is regularly sourced, frequency of source water sampling may be reduced to one sample every 10 stimulation activities, i.e. 10% of stimulation activities.

3.2 Stimulation Fluid Sampling

Stimulation fluids must not include restricted stimulation fluids as prescribed by the *Environmental Protection Act 1994* (i.e. BTEX) or polycyclic aromatic hydrocarbons or products that contain polycyclic aromatic hydrocarbons in concentrations above the reporting limit as prescribed in the respective EA.

Service providers must provide confirmation (i.e. laboratory analysis, statutory declaration), that restricted stimulation fluids are not present in the stimulation fluid pad volume prior to the stimulation activity being undertaken. Service providers must record fluid pad volume.

One stimulation fluid sample per stimulation activity on each well is to be taken from the pad volume prior to the addition of the slurry volume and analysed for the analytical suite detailed in Table 3, Section 5. For stimulation activities where fluid chemicals and target formation geology are consistent across a stimulation program, frequency of fluid sampling may be reduced to one sample every 10 wells, i.e. 10% of stimulation activities.

3.3 Flowback Sampling

Post stimulation activities, a representative flowback sample is to be collected when flowback is recovered at surface. Flowback volume(s) must be recorded to ensure 150 percent of the volume of stimulation fluids used in the stimulation event have been extracted from the stimulated well, to the extent practicable.

A flowback or produced water sample is be collected post stimulation and to be analysed for the analytical suite detailed in Table 4, Section 5. For stimulation activities where fluid chemicals and target formation geology are consistent across a stimulation program, frequency of flowback sampling may be reduced to one sample every 10 wells, i.e. 10% of stimulation activities.

The HFRA indicated the geological Bowen and Surat Basins are structurally separate sedimentary depositional centres with competent aquitards separating the target coal seams from overlying and underlying aquifer systems.. The HFRA concluded that through implementation of best industry practice and Santos management controls, migration to groundwater receptors is not a potentially complete exposure pathway.

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If an active landholder bore is pumping from an aquifer within 200 metres above or below the target formation(s) and is spatially located within a two (2) kilometre radius from the location of the stimulation initiation point, additional flowback monitoring may be required to enable detection of potential adverse water quality impacts and the potential inter-connection with a non-target aquifer. Monitoring requirements are to be assessed on a case by case basis in consideration of the analytical suite detailed in Table 2, Section 5.

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4.0 Post-Stimulation Groundwater Bore Monitoring

Where relevant bores have been identified in Section 2, post-stimulation groundwater monitoring is to be undertaken at the following frequencies:

- monthly for the first six (6) months subsequent to the stimulation activities being undertaken; then
- annually for the first five (5) years subsequent to the stimulation activities being undertaken or until analytes and physico-chemical parameters are not detected in concentrations above baseline bore monitoring data on two (2) consecutive occasions.

Groundwater from relevant bores is to be analysed for the analytical suite detailed in Table 2, Section 5.

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5.0 Analytical Testing

The HFRA identifies the following environmental values (EVs) of groundwater for the Project Area:

- Groundwater Dependant Ecosystems (GDEs) and springs ;
- drinking water supply;
- stock watering;
- crop irrigation;
- farm supply/use;
- primary contact via recreation activities;
- aquaculture;
- industrial use; and
- cultural and spiritual activities.

Water/stimulation fluid sampling parameters provided in Table 2, Table 3, and Table 4 are considered appropriate for assessing the risks to the abovementioned EVs and to detect potential adverse impacts to water quality from stimulation activities. The standard laboratory limits of reporting (LOR) for analytes presented in Tables 2, 3 and 4 are acceptable for the purposes of evaluating monitoring data and assessment of the risk to the EVs of groundwater identified in the HFRA. The standard LOR for the identified parameters are provided as Attachment C.

Samples are to be collected in general accordance with the Queensland Government *Monitoring and Sampling Manual* and appropriate guidelines as required by Santos EQ EAs.

All samples will be analysed at National Association of Testing Authorities (NATA) accredited laboratories.

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Table 2 – Baseline Groundwater Bore Sampling Parameters[1]

Physical Parameters	Ions	Metals (T&D)	Alkalinity	Dissolved Gases and Others
pH (field and laboratory)	Calcium	Aluminium	Total alkalinity as CaCO3	Total recoverable hydrocarbons (TRH)
	Chloride	Arsenic		
Temperature (field only)	Fluoride	Barium	Bicarbonate as CaCO3	Methane[2]
	Magnesium	Beryllium		Carbon dioxide (field)[2]
Electrical conductivity (field and laboratory)	Potassium	Boron	Carbonate as CaCO3	Hydrogen sulphide[2]
	Sodium	Cadmium		Benzene
	Sulphate	Chromium	Hydroxide as CaCO3	Toluene
		Cobalt		Ethylbenzene
Dissolved Oxygen (field only)	Sodium Adsorption Ratio (SAR)	Copper	Total hardness as CaCO3	Ortho-xylene
		Iron		Para-and Meta-xylene
		Lead		Total Xylene
		Manganese		Naphthalene
		Mercury		Phenanthrene
Total dissolved solids (laboratory only)		Molybdenum		Benzo[a]pyrene
		Nickel		Sodium Hypochlorite and Sodium Hydroxide (measured as chlorite)
		Selenium		
		Silver		
		Strontium		Formaldehyde
		Tin		Ethanol
		Uranium		Gross Alpha
		Vanadium		Gross Beta
		Zinc		

[1] Refer Baseline Assessment Guideline

[2] Where the presence of dissolved gases is detected in the field (via the use of a multi-parameter gas detector), a dissolved gas sample must be collected through a flow-through cell, or if not practicable then in accordance with methods outlined in section 7.2 of Groundwater sampling and analysis – A Field Guide (Sundaram, et al., 2009).

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The concentration of PAHs or restricted stimulation fluids detected in monitoring per Section 3.2 and Table 3, is not measured in relation to source water . The restrictions on PAHs and/or restricted stimulation fluids apply to stimulation fluid (concentrate) prior to being mixed with water (source water). As such the concentration of PAH or restricted stimulation fluids in the source water is to be subtracted from the stimulation fluid analytical results.

Table 3 – Source Water and Stimulation Fluid Sampling Parameters

Physical Parameters	Ions	Metals (T&D)		Alkalinity	Dissolved Gases and Others
pH (field[1] and laboratory)	Calcium	Arsenic	Manganese	Total alkalinity as CaCO3	Volatile organic compounds (VOC)
Temperature (field only[1])	Chloride	Barium	Mercury	Bicarbonate as CaCO3	Polycyclic Aromatic Hydrocarbons (PAH) – Super Ultra trace (0.005µg/L – 0.02µg/L)
Electrical conductivity (field[1] and laboratory)	Fluoride	Boron	Nickel	Carbonate as CaCO3	
	Potassium	Beryllium	Lead	Hydroxide as CaCO3	Total recoverable hydrocarbons (TRH)
Total dissolved solids (laboratory only)	Magnesium	Cadmium	Selenium	Total hardness as CaCO3	Total Organic Carbon
	Sodium	Chromium	Vanadium		Dissolved Organic Carbon
	Sulphate	Cobalt	Zinc		
		Copper			

[1] *source water only*

Table 4 – Flowback Water Sampling Parameters

Physical Parameters	Ions	Metals (T&D)		Alkalinity	Others
pH (field and laboratory)	Calcium	Arsenic	Manganese	Total alkalinity as CaCO3	Total Organic Carbon
Temperature (field only)	Chloride	Barium	Mercury	Bicarbonate as CaCO3	Dissolved Organic Carbon
Electrical conductivity (field and laboratory)	Fluoride	Boron	Nickel	Carbonate as CaCO3	
	Potassium	Beryllium	Lead		
Total dissolved solids (laboratory only)	Magnesium	Cadmium	Selenium	Hydroxide as CaCO3	
	Sodium	Chromium	Vanadium	Total hardness as CaCO3	
	Sulphate	Cobalt	Zinc		
		Copper			

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6.0 Roles and Responsibilities

Santos personnel are responsible for the environmental performance of their activities, for complying with relevant approval/permit requirements and for ensuring that all environmental objectives associated with the work are achieved.

All Santos personnel and contractors must also be mindful of:

- Environmental Authority requirements as stipulated in the EQ EAs;
- the General Environmental Duty (GED) as outlined in section 319 of the *Environmental Protection Act 1994* (EP Act),

Roles, responsibilities and accountabilities specific to Stimulation Activities are defined as per SMS Compliance.

A summary of responsibilities for the Stimulation Impact Monitoring Program is provided in Table 5.

Table 5 – Roles and Responsibilities

Responsible Person	Responsibility
Santos Drilling and Completions Manager	Manage Drilling and Completion activities in accordance with Santos Management Systems (SMS)
Principal Environmental Adviser / Team Leader	Implement Stimulation Impact Monitoring Program
	Maintain management systems, processes and procedures
	Ensure SIMP data is recorded and maintained in Santos data management system (EQuIS)
	Implement monitoring outlined in the SIMP
	Perform water quality data review as required
	Schedule assurance audits to ensure compliance with the EAs
	Manage reporting in accordance with EAs
Santos Drilling and Completions Team Leader	Implement the Stimulation activities and processes as per this document
	Maintain records in accordance with the SIMP
	Manage procedures for Stimulation activities
	Manage staff and contractor compliance with the SIMP
All Employees and Contractors	Comply with EHS legal obligations and other requirements that are applicable to Santos' operations and activities.

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7.0 Evaluation and Review

7.1 Implementation

The implementation and effectiveness of this monitoring program and associated plans and procedures will be regularly assessed to ensure:

- Santos is demonstrating compliance with legal and landholder obligations;
- the overall monitoring strategy remains relevant and up to date; and
- the plan and procedures adequately manage the respective environmental issue.

Effectiveness can be assessed by a number of methods as shown in Table 6.

Table 6 – Methods to Assess Legal and Procedural Effectiveness

Assessment Tool	Description
Checklists – Santos Compliance Management System	Checklists, developed to reflect legal and procedural requirements / outcomes will be used by individual Santos assets/departments to assess and manage compliance. The results of the checklists will be evaluated for common non-conformances that may be resolved through procedural change or by implementing another measure or process.
Audits	Conduct internal and/or third party audits to formally assess the level of compliance with both regulatory requirements and with Santos procedures. Audit outcomes are used to develop corrective actions, which may include changes to procedures.
Review of Incidents	A review of internal incidents, near misses or hazards will be undertaken to identify recurrences of similar incident types. This may highlight a requirement for a change in an existing procedure, require the development of a new procedure or by implementation of another measure or process to address the recurring issue.
Review of Data	Analyse all relevant data collected for negative and/or common trends that may be prevented by procedural changes or by implementing another measure or process.

7.2 Review

The SIMP is a living document and the performance of the SIMP shall be reviewed at least every five years or sooner if any of the following occur:

- the plan is not adequately managing identified issues;
- legislative requirements change; and/or
- the area(s) of activity changes.

Similarly, the plan may also be reviewed on an ‘as needs’ basis:

- in the case that there are significant changes to conditions at any site; and/or
- changes to standard limit of reporting for relevant analytes.

As a minimum the review shall take into consideration monitoring frequency, locations, changes to water qualities and/or quantities as a result of Santos’ forward plan of operations.

Reviews and changes to the SIMP are to be communicated to relevant Santos personnel.

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ATTACHMENT A: Eastern Queensland Environmental Authorities

Permit Number	Project Area
EPPG00928713	Fairview Arcadia Project Area EA
EPPG00898213	Roma Shallow Gas Project Area
EPPG00662213	Roma Shallow Gas project Area East (PL 281 & 282)
EPPG03515915	Scotia Project Area
EA0001210	Maisey
EPPG00872113	ATP 337-1191 Environmental Authority
EPPG03516515	PL 11 Environmental Authority
EPPG03516615	PL 320 Environmental Authority
EPPG04180616	PL 321 Environmental Authority

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ATTACHMENT B: Certification

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Statutory Declaration

Resource activities other than mining

Declaration of compliance for written documents

A statutory declaration is a written statement of facts that is sworn or declared under the Oaths Act 1867. *This statutory declaration has been prepared to declare the authority holders compliance with the provisions of the* Environmental Protection Act 1994 *(EP Act) or an environmental authority condition that stipulates the requirement to submit a certified written document to the administering authority.*

Oaths Act 1867

QUEENSLAND
TO WIT

Re: Written documents relating to an environmental authority for a resource activity other than mining under the *Environmental Protection Act 1994*.

Written document: Eastern Queensland Stimulation Impact Monitoring Program, dated August 2021

(Insert type of document, e.g. contingency plan for emergency environmental incidents)

Subject matter: Compliance with Environmental Authority conditions as per Table 1 within the written document.

(Insert subject matter, e.g. compliance with environmental authority number PEN1001222222)

Authority holder: Santos Ltd

I, Nigel Goulding

(Insert full name of person making this declaration)

of, 3900 Stonewater Drive, Columbus OH 43221

(Insert suburb and city of the person making this declaration)

ABN 46 640 294 485

Great state. Great opportunity.

Queensland Government

Statutory Declaration

Declaration of compliance for written documents

in the State of Queensland do solemnly and sincerely declare that:

1. I am a suitably qualified person as defined in the environmental authority; having professional qualifications, training, skills and experience relevant to the subject matter and can give authoritative assessment, advice and analysis relative to the subject matter using the relevant protocols, standards, methods or literature. A copy of my curriculum vitae is Annexure A to this declaration[1];
2. The authority holder has fully complied with the requirements of environmental authority conditions in Table 1 of the Eastern Queensland Stimulation Impact Monitoring Program, dated August 2021
3. All relevant material has been considered in preparing the Eastern Queensland Stimulation Impact Monitoring Program, dated August 2021
4. The content of the Eastern Queensland Stimulation Impact Monitoring Program, dated August 2021 is accurate and true.
5. The Eastern Queensland Stimulation Impact Monitoring Program, dated August 2021 meets the requirements of the Environmental Authority conditions as per Table 1 within the written document.

And I make this solemn declaration conscientiously believing the same to be true, and by virtue of the provisions of the *Oaths Act 1867*.

Taken and declared before me, at BRISBANE VIA FACEBOOK
(Insert name of town or city and suburb)

this 20th day of AUGUST in the year 2021
(Insert day, e.g. 18th) (Insert month) (Insert year)

Signed
(Person making this declaration)

Signed
(Cross out whichever is not applicable)

~~Justice of the Peace / Commissioner for Declarations / Solicitor / Barrister~~

(Print ... plicable)

ROBERT JOHN BAX
Solicitor & Notary Public
753 Sandgate Road Clayfield
AUSTRALIA

[1] The signatory does ... each page of the annexure, but it does need to be marked with the following:
"This is the *[insert name of document]* or a copy of the [insert name of document] marked with the letter "A" referred to in the Statutory Declaration [insert sworn/taken/affirmed/solemnly declared] before me at [insert day] of [insert month], [insert year].

Approved By

Signature	Date

Director
Energy Regulation and Implementation Unit
Environmental Protection Act 1994
Department of Environment and Heritage Protection

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Santos

ATTACHMENT C: Standard Laboratory Limits of Reporting

Physical Parameter	Standard LOR[1] mg/L	Metals (T&D)	Standard LOR[1] mg/L	Dissolved Gases and Others	Standard LOR[1] mg/L
pH (field and laboratory)	0.01	Aluminium	0.01	Carbon dioxide	1
		Arsenic	0.001	Methane	0.01
Temperature (field only)	-	Barium	0.001	Hydrogen sulphide	0.1
		Beryllium	0.001	Chlorite	0.005
Electrical conductivity (laboratory)	1 µS/cm	Boron	0.05	Polycyclic Aromatic Hydrocarbons (PAH)[2]	0.0005 - 0.001
		Cadmium	0.0001		
Total dissolved solids (laboratory only)	10	Chromium	0.001	Total recoverable hydrocarbons (TRH)	0.02 - 0.1
		Cobalt	0.001		
Dissolved Oxygen (field only)	-	Copper	0.001	Volatile organic compounds (VOC)	0.001 - 0.05
Calcium	1	Iron	0.05	Ethanol	0.05
Chloride	0.1	Lead	0.001	Formaldehyde	0.1
Fluoride	1	Manganese	0.001	Benzene	0.001
Magnesium	1	Mercury	0.0001	Toluene	0.002
Potassium	1	Molybdenum	0.001	Ethylbenzene	0.002
Sodium	1	Nickel	0.001	Naphthalene	0.005
Total alkalinity as CaCO3	1	Selenium	0.01	Meta- & para-Xylene	0.002
Bicarbonate as CaCO3	1	Silver	0.001	Ortho-Xylene	0.002
Carbonate as CaCO3	1	Strontium	0.001	Total Xylene	0.002
Hydroxide as CaCO3	1	Tin	0.001	Dissolved Organic Carbon	1
Total hardness as CaCO3	1	Uranium	0.001	Total Organic Carbon	1
Sulphate	1	Vanadium	0.01	Gross Alpha	0.05 Bq/L
SAR	0.01	Zinc	0.005	Gross Beta	0.1 Bq/L

[1] LOR sourced from ALS for water sample analysis and reported in mg/L unless other units stated
- It should be noted that revisions to standard limit of reporting for specific analytes may occur over time
- LOR may be raised by the laboratory during analysis due to matrix interferences
[2] Note whilst standard LOR for PAH are considered acceptable for the purposes of evaluating monitoring data and assessment of the risk to the EVs of groundwater, the EA may require reduced LORs

UNCONTROLLED IF PRINTED

APPENDIX V

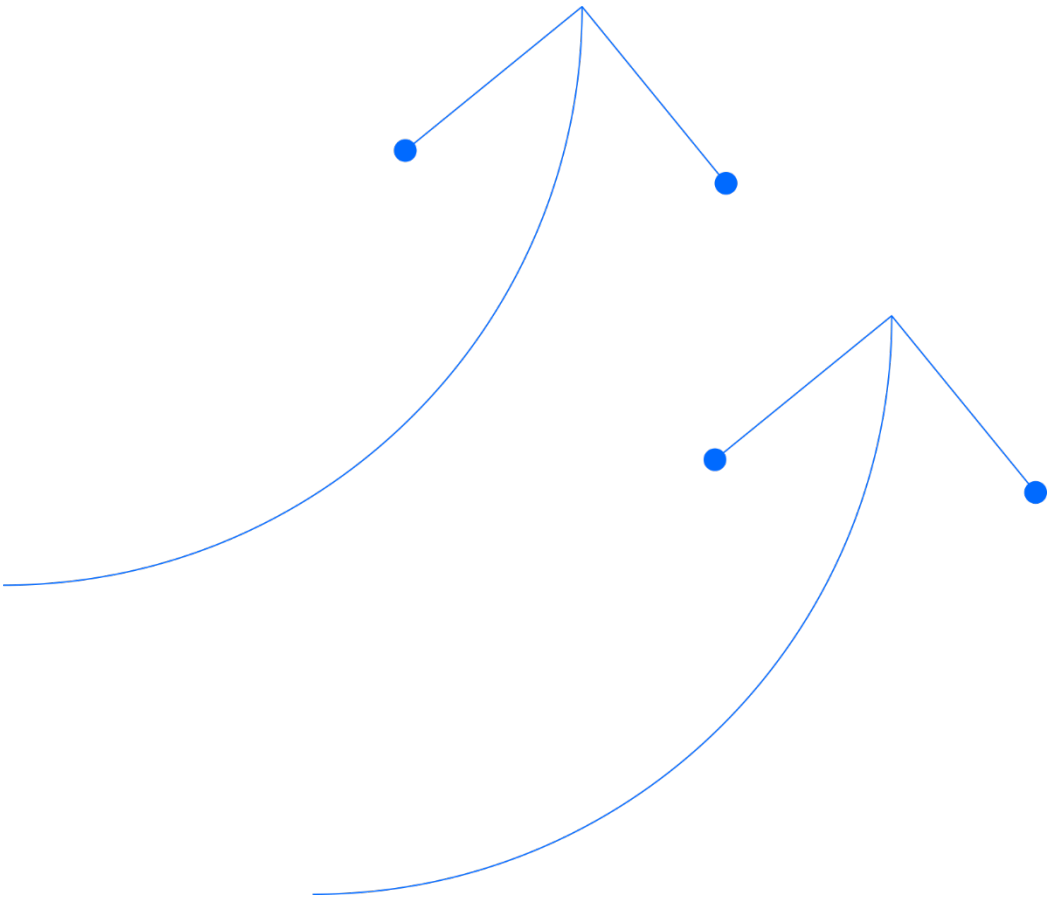
Environmental Management Plan

Santos

Santos Roma Phase 7-7B-SD20 Development

ENVIRONMENTAL MANAGEMENT PLAN

February 2025



Document Status

Date	Rev	Reason For Issue	Author	Checked	Approved
21/02/2025	0	Submission to Department of Climate Change, Energy, the Environment and Water	Santos / AECOM	AC / AG / AB / YH	BW

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Glossary

Abbreviation	Description
ACH Act	Aboriginal Cultural Heritage Act 2003 (Qld)
ADG Code	Australian Dangerous Goods Code
ADP	Advanced Depletion Pilots
ADR	Accepted Development Requirements
APGA	Australian Pipelines and Gas Association
API	American Petroleum Institute
AHD	Australian Height Datum
APIA	Australian Pipeline Industry Association
AS	Australian Standard
ATP	Authority to Prospect
BOP	Blowout Preventer
BRB	Brigalow Belt Bioregion
CBL	Cement Bond Logs
CHMP	Cultural Heritage Management Plan
CMA	Cumulative Management Area
CRAF	Chemical Risk Assessment Framework
CSG	Coal Seam Gas
DA	Development Approval
DAF	Department of Agriculture and Fisheries (Biosecurity Queensland), Queensland Government
DOA	Delegation of Authority
DTATSIPCA	Department of Treaty, Aboriginal and Torres Strait Islander Partnerships, Communities and the Arts, Queensland Government
DCCEEW	Department of Climate Change, Energy, the Environment and Water, Federal Government
DEHP	Department of Environment and Heritage Protection, Queensland Government (now DETSI)
DESI	Department of Environment, Science and Innovation, Queensland Government (now DETSI)
DETSI	Department of the Environment, Tourism, Science and Innovation, Queensland Government
DNRME	Department of Natural Resources, Mines and Energy, Queensland Government (now DNRMMRRD)
DNRMMRRD	Department of Natural Resources and Mines, Manufacturing, and Regional and Rural Development
DSDILGP	Department of State Development, Infrastructure, Local Government and Planning, Queensland Government (now DSDIP)
DSDIP	Department of State Development, Infrastructure and Planning, Queensland Government
DTMR	Department of Transport and Main Roads, Queensland Government
EA	Environmental Authority
ECP	Environmental Control Plans
EHS	Environment, Health and Safety
EMP	Santos Roma Phase 7-7B-SD20 Development Environmental Management Plan
EO Act	Environmental Offsets Act (Qld)
EOW	End of Waste
EP Act	Environmental Protection Act 1994 (Qld) and its subordinate legislation

Abbreviation	Description
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999 (Cth)
EPQ	Exploration Permit Greenhouse Gas
ESC	Erosion and Sediment Control
FIT	Formation Integrity Test
GBO	General Biosecurity Obligation
GDE	Groundwater Dependant Ecosystems
GFD	Gas Field Development
GLNG	Gladstone Liquefied Natural Gas
HDPE	High-Density Polyethylene
HES	High Ecological Significance
HEV	High Ecological Value
IESC	Independent Expert Scientific Committee (on coal seam gas and large coal mining development)
IECA	International Erosion Control Association
ILUA	Indigenous Land Use Agreements
IMS	Incident Management System
IVMS	In Vehicle Monitoring Systems
JV	Joint Venture
LAI	Land Amendment Irrigation
LGA	Local Government Area
LOT	Leak Off Test
ML	Megalitre
MNES	Matters of National Environmental Significance
NC Act	Nature Conservation Act 1992 (Qld)
NT Act	Native Title Act 1993 (Qld)
OGIA	Office of Groundwater Impact Assessment
P&G Act	Petroleum and Gas (Production and Safety) Act (Qld)
PCE	Pressure Control Equipment
PDF	Preliminary Disturbance Footprint
PE	Polyethylene
PL	Petroleum Lease
PPL	Petroleum Pipeline Licence
QA/QC	Quality Assurance / Quality Control
QH Act	Queensland Heritage Act 1992 (Qld)
QLD	Queensland
RDM	Residual drilling material
RE	Regional Ecosystem
RIDA	Regional Interest Development Approval
RMP	Santos Roma Phase 7-7B-SD20 Development Rehabilitation Monitoring Plan
RN	Registered bore Number
RO	Reverse Osmosis
ROP	Reverse Osmosis Plant

Abbreviation	Description
RoW	Right-of-way
RPI Act	Regional Planning Interests Act 2014 (Qld)
SDS	Safety Data Sheets
SF	State Forest
SIMP	Social Impact Management Plan
SMS	Santos Management System
SQP	Suitably Qualified Person
SRMS	Stakeholder Relationship Management System
SSMP	Santos Roma Phase 7-7B-SD20 Development Significant Species Management Plan
SWMS	Safe Work Method Statement
TEC	Threatened Ecological Community
UWIR	Underground Water Impact Report
VM Act	Vegetation Management Act 1999 (Qld)
WMS	Water Monitoring Strategy
WRA	Water Resources Assessment
WRR Act	Waste Reduction and Recycling Act 2011 (Qld)

1. Introduction

Santos and its joint venture partners are proposing a new gas field development located in central-eastern Queensland to supply natural gas to commercial markets. The proposed development will be known as the 'Santos Roma Phase 7-7B-SD20 Development' (the Project).

1.1. Overview

The Project will involve the progressive construction, operation, decommissioning and rehabilitation of up to 24 coal seam gas (CSG) wells, gas and water gathering flowlines and access track infrastructure in petroleum exploration tenure Authority to Prospect (ATP) 2053 (the Project Area). The Project Area is located in central-eastern Queensland, approximately 5 kilometres (km) east of the regional town of Wallumbilla. The regional location of the Project Area is shown in Figure 1.

The Project footprint located in the Project Area will cover approximately 66 hectares (ha) of land. Petroleum exploration activities undertaken by the Santos in the Project Area to date include the drilling and completion of 5 CSG appraisal wells and construction of associated infrastructure in 2022-2024. These activities are authorised under existing approved Queensland Environmental Authority (EA) 0002052. The existing 5 wells form part of the proposed 24 CSG wells.

CSG and water produced from the Project Area will be sent to existing approved centralised gas and water storage / processing and gas compression facilities located on adjacent Santos owned and operated petroleum tenures. Petroleum activities on adjacent tenures are authorised under existing EPBC Act approvals for the Gladstone Liquified Natural Gas Field Development Project (GLNG GFD) (EPBC Numbers 2008/4059 and 2012/6615) and EAs EPPG00898213 and EPPG00662213. No gas compression or water treatment facilities are proposed to be constructed or operated within the Project Area, and no significant water storage structures will be constructed or operated within the Project Area. Where required, prefabricated water storage tanks (concrete panel tanks or similar) will be assembled for water storage.

The Project will include the following components (but not limited to):

- well leases (typically 1.25 ha for single wells and 3 ha for multi-wells);
- water / gas gathering lines, trunklines and pipelines (typically 20 – 35 metres (m) wide);
- roads and access tracks (typically 10 – 15 m wide);
- other supporting infrastructure:
  - temporary water storage tanks;
  - temporary workers camps;
  - power and communications lines; and
  - other incidental and ancillary petroleum activities required to support the authorised activity.

Santos has developed a preliminary disturbance footprint (PDF) for the project to locate infrastructure to avoid disturbance to Matters of National Environmental Significance (MNES) and other environmental values. The PDF is displayed in Figure 2. The PDF was developed following multiple ecological surveys, field scouting, and desktop planning revisions to avoid impacts to MNES / other environmental values. The process for locating infrastructure, developing the PDF, and defining environmental constraints is described in the Roma Phase 7-7B-SD20 Development Environmental Protocol for Constraints Planning and Field Development Constraints Protocol (Constraints Protocol). The Constraints Protocol was informed by ecological surveys undertaken in 2022-2024 (refer to the *Roma Phase 7-7B SD20 Development Matters of National Environmental Significance Ecological Assessment Report* (Boobook, 2025)).

Design iterations as a result of these surveys and planning assessments are shown in Figure 3. Proposed infrastructure has largely been located in cleared agricultural land. No disturbance to Threatened Ecological Communities (TEC) is proposed. Any minor changes to the disturbance footprint or infrastructure locations would be subject to the requirements of the Constraints Protocol.

Well development will be phased to optimise gas production to meet Santos' gas supply obligations and opportunities. Once operational, gas produced from the Project will supply commercial markets.

Once completed and connected to gas and water gathering infrastructure, operational wells will operate continuously on a 24-hour basis for an anticipated operational life of 30-50 years. Progressive decommissioning and rehabilitation of activities and infrastructure will occur over the life of the Project, thereby reducing disturbance areas for the duration of operation, until final decommissioning and rehabilitation at end of project life.

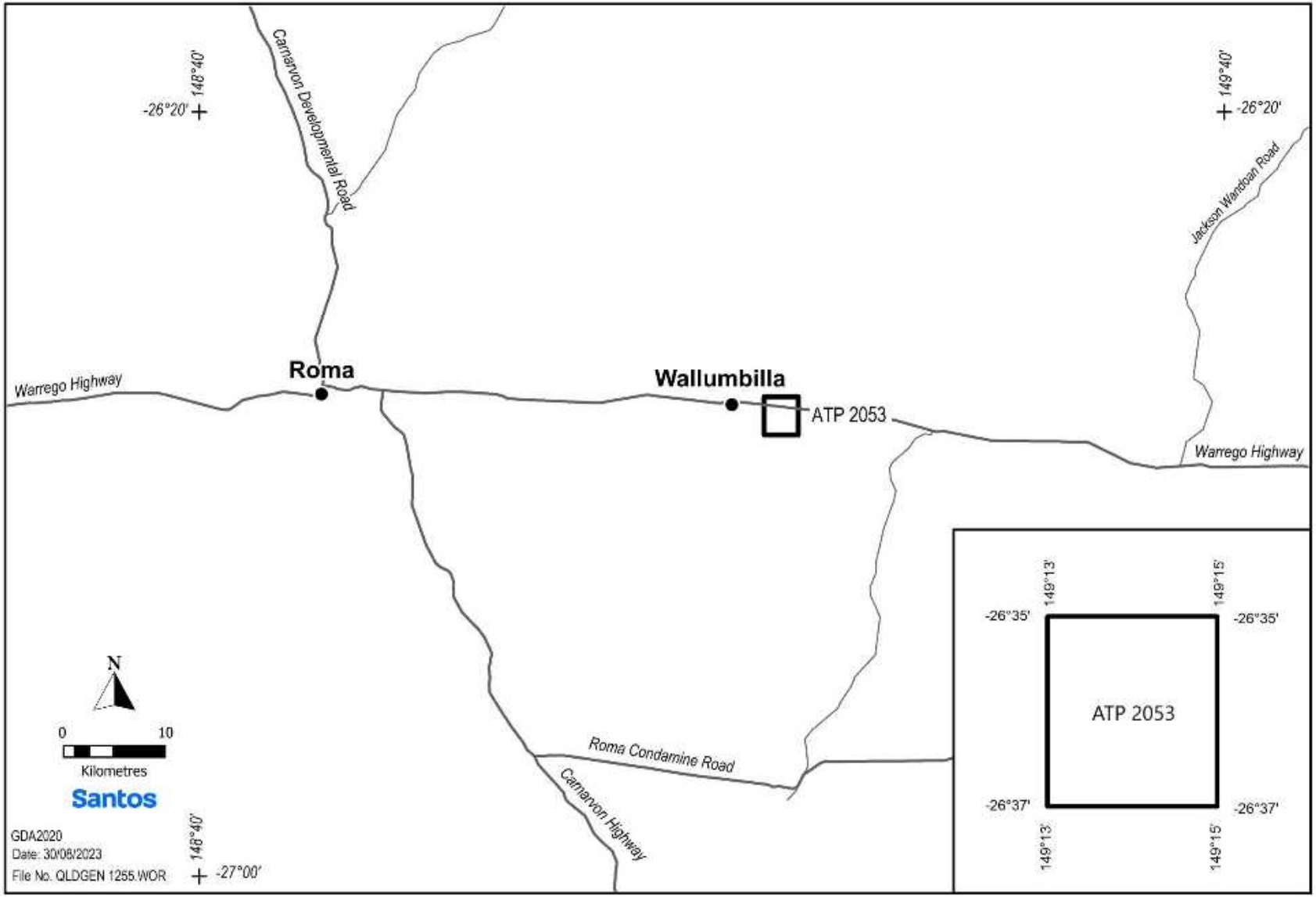


Figure 1: Santos Roma Phase 7-7B-SD20 – Project Area (ATP 2053)



Figure 2: Santos Roma Phase 7-7B-SD20 – Preliminary Disturbance Footprint

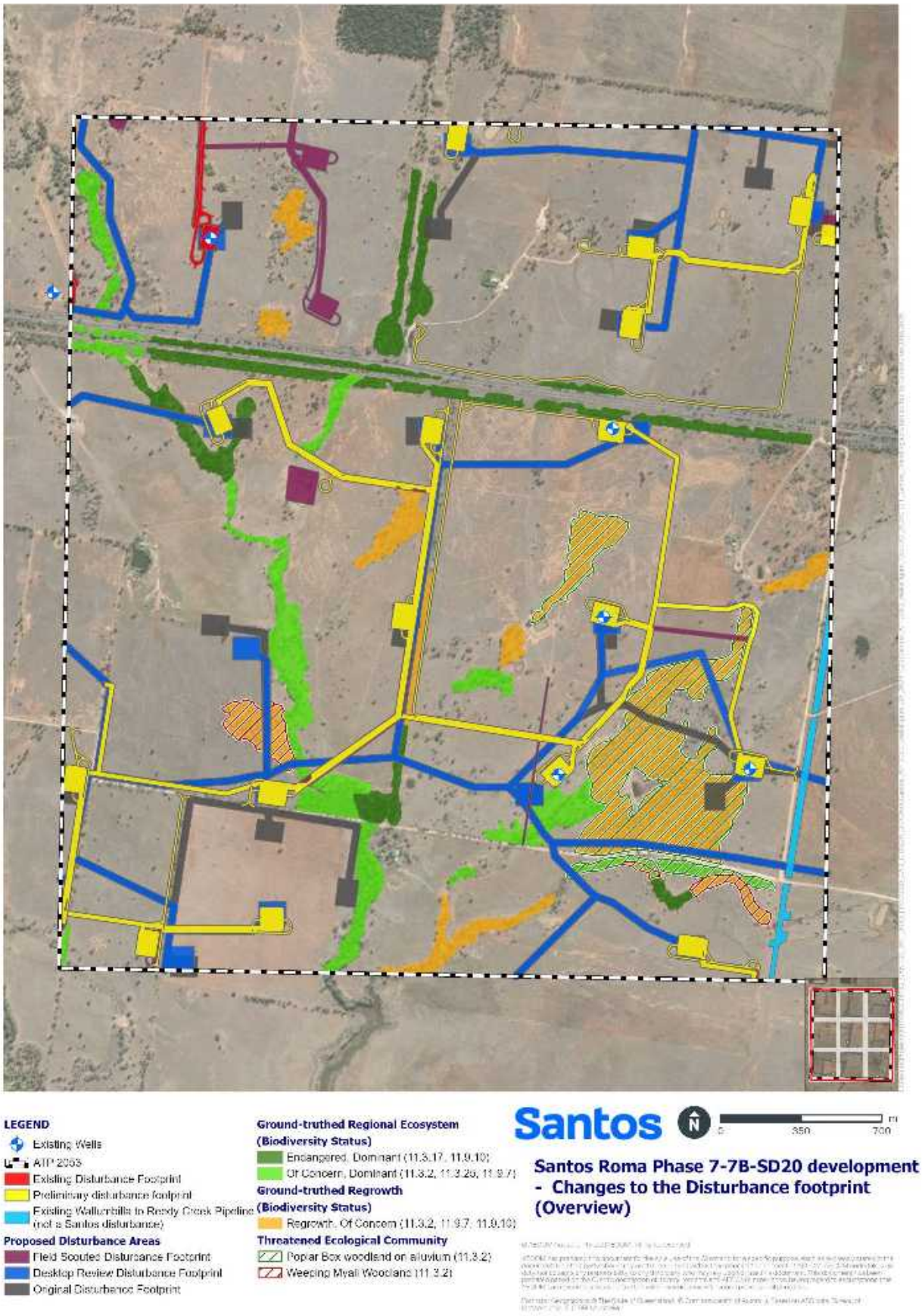


Figure 3: Santos Roma Phase 7-7B-SD20 – Disturbance footprint iterations

1.2. Purpose and scope

This Environmental Management Plan (EMP) has been developed to:

- provide a structured high-level approach to the management of environmental issues over the life of the Project;
- meet the requirements of the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act) and *Environmental Protection Act 1994* (QLD) (EP Act) (that being the conditions of the relevant EA), industry guidelines and other regulatory requirements;
- provide appropriate environmental management measures and controls to be implemented to avoid, minimise and mitigate environmental impacts; and
- document the environmental outcomes for the Project.

Effective implementation of this EMP and associated environmental control plans (ECPs) will ensure the Project meets regulatory and conditional requirements in a systematic manner with the aim to continually improve environmental performance.

Santos plans to convert the current exploration tenure for the Project Area (ATP 2053) from an ATP to a new Petroleum Lease (PL). Santos will need to apply for new a PL, granted under Chapter 2 of the Queensland *Petroleum and Gas (Production and Safety) Act 2004* (P&G Act) to replace the existing ATP. To authorise petroleum production activities on the new PL, Santos will also need to apply for a new EA under the EP Act. This EMP has been written to consider likely conditions of the new EA, however it will be revised or updated once the new EA is granted to ensure it complies with any additional conditions.

This EMP will be revised or updated from time-to-time to align with regulatory requirements. Revised versions of the EMP will be made available upon request to DCCEEW or as otherwise required under conditions of a regulatory approval, whether under the EPBC Act or any other applicable legislation.

2. Environmental Management Framework

2.1. Environmental policy

Santos has an Environment, Health and Safety (EHS) Policy which makes commitments relating to environmental responsibilities in managing the impact of our operations. The Santos EHS policy is attached in Appendix 1.

2.2. Santos Management System

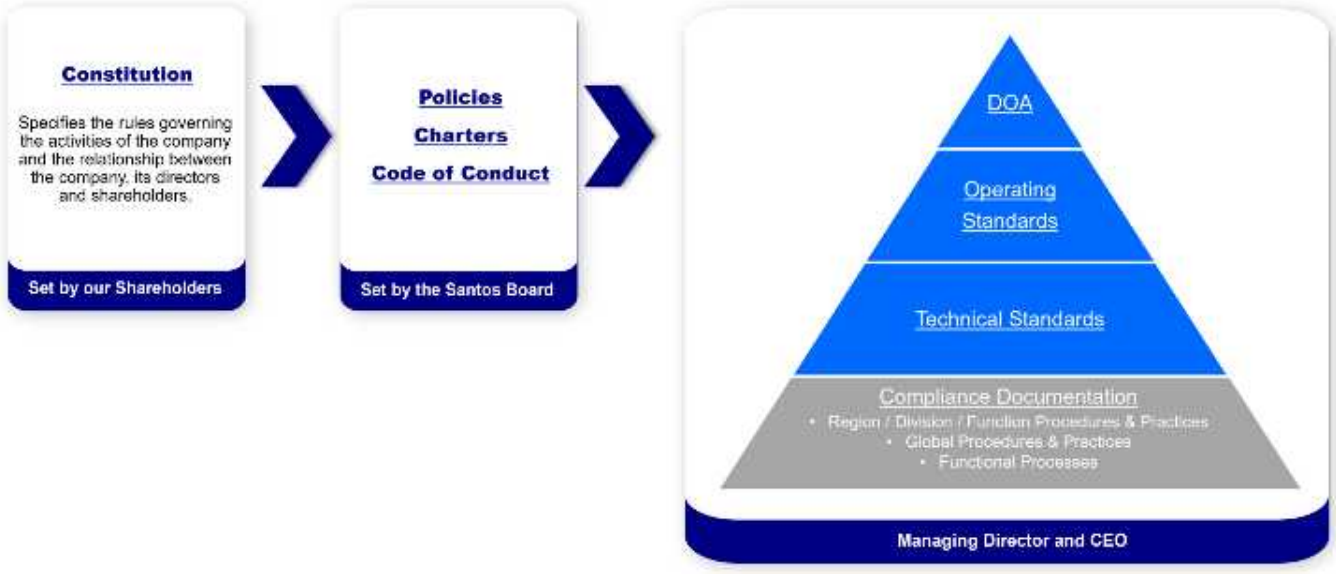
Santos will use its company-wide Santos Management System (SMS) to provide a structured framework for environmental and safety practices across Santos' activities and operations and is based on industry and Australian Standards (AS).

The SMS comprises four key parts that underpin the EHS framework and describe requirements such as organisation structure / Delegation of Authority (DOA), operating and technical standards, and compliance documentation for meeting the objectives of Santos' EHS policies. These are:

- **Delegation of Authority:**
  - the Santos Board delegates specific decision authorities to the Chief Executive Office, who in turn delegates specific authorities to members of management. These authorities are set out in the Santos DOA.
- **Operating Standards:**
  - consisting of several operating standards structured around key business activities. Compliance with the operating standards is mandatory.
- **Technical Standards**
  - detailed technical requirements or specifications that must be achieved in a consistent manner and must be followed.
- **Compliance Documentation:**
  - procedures and practices developed by and for a specific Region, Division, or Function to comply with Operating and Technical Standards.

This EMP has been developed to align with the SMS. The structure of the SMS and other system elements is depicted in Figure 4. The SMS is maintained in electronic form on Santos' central server and is accessible to all employees and contractors.

Figure 4: Santos Management System



2.3. Objectives, targets and performance indicators

The SMS operating standards require annual EHS objectives and targets to measure and drive continuous improvement in EHS, process safety, and performance across Santos.

Santos has developed lead and lag indicators for both environment and safety performance across all its assets. This enables Santos to set improvement goals and targets for continual improvement in environmental and safety performance.

Specific objectives and performance indicators have been developed for each environmental aspect and are included in Section 6.1.

2.4. Legislative requirements

Santos manages compliance with significant legal obligations in accordance with SMS operating standards, which set down requirements to ensure obligations are identified, communicated, accessible and kept up to date to achieve compliance. The standard and accompanying procedure require Santos to record the following information for each significant compliance obligation using an appropriate compliance tool:

- the requirements of the obligation and its status;
- person responsible; and
- source documents.

Non-compliances are reported internally and, if not resolved within a reasonable timeframe, escalated for appropriate resolution. Further information is available in Section 5.4.

As operator of the Project Area, Santos must comply with State and Commonwealth legislation applicable to the Project (as detailed in Sections 2.4.1 and 2.4.2), including relevant regulatory approvals / authorisations, permits and other requirements as listed in Table 1.

2.4.1. State legislation

The principal state legislation regulating petroleum and gas activities for the Project is the *Petroleum and Gas (Production and Safety) Act 2004* (Qld) (P&G Act). The principal state environmental legislation is the EP Act and associated regulation and protection policies. The EP Act introduces the "*General Environmental Duty*" (as

described in Section 319 and 320, chapter 7), which specifies that a person must not perform their duties in a manner which will cause, or is likely to cause, environmental harm unless the person takes all reasonable and practical measures to prevent or minimise the harm.

Petroleum exploration, appraisal and production testing activities are currently authorised to occur in the Project Area under the requirements of the EP Act via the existing Queensland Environmental Authority (EA) 0002052. Santos and all contractors undertaking petroleum activities within the Project Area must comply with the conditions of the EA, to meet their respective obligations under the EP Act.

Further, as discussed in Section 1.2, to enable commercial gas production activities within the Project Area, a new PL will need to be applied for and granted under the requirements of Chapter 2 of the P&G Act to replace the existing ATP. Further, to authorise commercial gas production activities in the PL, a new EA under the EP Act will also need to be applied for and granted.

2.4.2. Commonwealth legislation

The EPBC Act is the principal environmental legislation administered by the Commonwealth Government. It provides a legal framework to protect and manage, among other matters, nationally and internationally important flora, fauna, threatened ecological communities and heritage places defined under the EPBC Act as MNES.

The EPBC Act requires the principles of ecologically sustainable development to be considered for a new development proposal if that proposal is likely to a result in a significant impact on the environment.

Table 1: Applicable legislation

Name	Administering Authority	Specific Considerations
Commonwealth		
Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act)	Department of Climate Change, Energy, the Environment and Water (DCCEEW)	The EPBC Act establishes a process for environmental assessment and approval of proposed actions that have, will have or are likely to have a significant impact on MNES or on Commonwealth land. Under the EPBC Act, a referral to DCCEEW is required if the Project has the potential to cause a 'significant impact' on MNES. The Constraints Protocol will direct the siting of infrastructure and activities to avoid and minimise impacts to MNES that have the potential to occur within the Project Area. Further, a Roma Phase 7-7B-SD20 Development *Significant Species Management Plan* (SSMP) has been prepared to mitigate impacts on a threatened ecological community (TEC) or species (EPBC listed) habitat from the Project.
Native Title Act 1993 (Cth) (NT Act)	National Native Title Tribunal	The NT Act regulates recognition and protection of native title. Indigenous Land Use Agreements (ILUA) are in place.
State		
Aboriginal Cultural Heritage Act 2003 (Qld) (ACH Act)	Department of Treaty, Aboriginal and Torres Strait Islander Partnerships, Communities and the Arts, Queensland Government (DTATSIPCA)	The ACH Act provides recognition, protection and conservation of cultural heritage in Queensland and outlines duty of care obligations for issues compromising Indigenous heritage. Santos engages Traditional Owners and implements measures to protect Aboriginal cultural heritage including the development of a Santos Cultural Heritage Management Plan (CHMP) and implementing a Find Stop Notify Manage procedure.
Biosecurity Act (Qld) 2014 and its subordinate legislation	Department of Agriculture and Fisheries (DAF) – Biosecurity Queensland	Santos and all persons onsite must meet their General Biosecurity Obligation (GBO). This means taking all reasonable and practical steps to prevent biosecurity risks or events such as invasive weed and animal introductions.

Name	Administering Authority	Specific Considerations
Environmental Protection Act 1994 (Qld) (EP Act) and its subordinate legislation	Department of Environment, Tourism, Science and Innovation (DETSI)	The EP Act is the overarching environmental regulatory framework for governing the environmental management of resource activities in Queensland. Prior to the granting of a PL under the *Petroleum and Gas (Production and Safety) Act 2004* (see below), DETSI must grant an Environmental Authority (EA) that authorises resource activities subject to conditions to protect environmental values including acoustic, biodiversity, land, air, surface water, groundwater and wetlands. Petroleum exploration and production testing activities are currently authorised to occur in the Project Area under the requirements of EA 0002052. To enable future commercial gas production activities within the Project Area, a new EA to authorise petroleum production activities will need to be applied for and granted under the requirements of the EP Act. Further to the above, under the requirements of the EP Act: • all persons must implement all reasonable and practicable measures to prevent environmental harm (i.e. General Environmental Duty) • material or serious environmental harm must be reported to the DETSI • controls must be implemented for prescribed water contaminants (e.g., soil and sediment, concrete washout, fuel / oil etc.) • wastes must be managed to prevent environmental harm. Regulated waste must only be carried by licensed transporters and disposed of at appropriately licensed waste receiving facilities; and • contaminated land must be managed in accordance with State and National guidance to protect human health and the environment.
Environmental Offsets Act (Qld) *2014* (EO Act)	DETSI	Under the EO Act an environmental offset is defined as an activity undertaken to counterbalance a significant residual impact on a prescribed environmental matter, including endangered or of concern regional ecosystems (REs), riparian vegetation, connectivity areas, wetlands and watercourses and protected wildlife habitat.
Fisheries Act 1999 (Qld) (Fisheries Act)	DAF	The Fisheries Act regulates and controls waterway barrier works and marine plants. Where works within mapped waterways constitute waterway barrier works, works are to comply with the departments code for Accepted development requirements (ADR) for operational work that is constructing or raising waterway barrier works, including any temporary works. Works that cannot comply with this code are considered assessable development requiring development approval (DA) under the *Planning Act 2016*. The Project Area intersects the following waterways all associated with Washpool Creek: • 8 high impact waterways • 1 moderate impact waterway; and • 10 low-impact waterways.

Name	Administering Authority	Specific Considerations
Nature Conservation Act 1992 (Qld) (NC Act) and its subordinate legislation	DETSI	The primary purpose of the NC Act is to conserve biodiversity by protecting wildlife and its habitat. Permits are required under the NC Act for interfering with protected wildlife and their habitat requiring DETSI approval of a species management plan or other mitigation measures. Additional permits are required for clearing protected plants requiring DETSI approval of an impact management plan for the clearing and offsets for the species if required. Where wildlife listed under the *Nature Conservation (Animals) Regulation 2020* (Qld) or the *Nature Conservation (Plants) Regulation 2020* (Qld) are proposed to be disturbed, relevant NC Act management, assessment and approval requirements will apply. Requirements for managing fauna including the responsibilities of fauna catchers and spotters during clearing and construction activities are documented in the Project's Significant Species Management Plan.
Petroleum and Gas (Production and Safety) Act 2004 (Qld) (P&G Act)	Department of Natural Resources and Mines, Manufacturing, and Regional and Rural Development (DNRMMRRD)	The P&G Act facilitates and regulates activities associated with the safe exploration, development and production of petroleum and gas resources in Queensland. Petroleum tenure granted by the DNRMMRRD under the P&G Act relevant to the Project include ATP, PL and Petroleum Pipeline Licence (PPL). Prior to commencing commercial gas production activities within the Project Area, a PL to authorise petroleum production activities will need to be applied for and granted under the requirements of the P&G Act.
Planning Act 2016 (Qld) (Planning Act)	Department of State Development, Infrastructure and Planning (DSDIP)	The Planning Act establishes an efficient, effective, transparent, integrated, coordinated, and accountable system of land use planning, development assessment and related matters that facilitates the achievement of ecological sustainability. Activities outside of the area of a petroleum tenure (e.g., depots) will require assessment and approval under the Planning Act, including any DA for operational works.
Queensland Heritage Act1992 (Qld)	DETSI	The Queensland Heritage Act (QH Act) operates in tandem with the ACH Act and the *Torres Strait Islander Cultural Heritage Act 2003* (Qld) to protect Queensland's cultural heritage. The act creates a framework to protect places or objects of cultural heritage significance for aesthetic, architectural, historic, scientific, social or technological reasons. The principal mechanism through which the Act operates is the 'Queensland Heritage Register', which is administered by DETSI. The Project Area does not intersect any heritage places listed by the Queensland Heritage Register'.
Regional Planning Interests Act 2014 (Qld) (RPI Act)	DSDIP	The RPI Act provides a level of protection for agricultural land from impacts associated with development and resource activities in Queensland. These protections seek to manage the impact of resource activities and other regulated activities on areas of regional interest; and support coexistence of resource activities with other activities, including highly productive agricultural activities. The RPI Act identifies and protects areas of regional interest throughout Queensland. Under the RPI Act and associated statutory regional plans, areas are classified as 'areas of regional interest' in order to recognise their unique characteristics from a land use perspective. Key areas of regional interest relevant to resource development are identified as Priority Agricultural Areas (PAAs), Strategic Cropping Areas (SCAs), and Strategic Environmental Areas (SEAs). For a resource activity to be undertaken on an area of regional

Name	Administering Authority	Specific Considerations
		interest, in addition to other approvals, a resource company is required to have a Regional Interest Development Approval (RIDA), or an exemption prior to the activity being undertaken. Where activities are proposed in areas of regional interest, they must comply with the requirements of the RPI Act.
Vegetation Management Act 1999 (Qld) (VM Act) and its subordinate legislation	DNRMMRRD	The VM Act regulates the clearing of vegetation in Queensland in a way that allows for sustainable land use, conserves remnant vegetation, ensures land clearing does not cause land degradation, prevents loss of biodiversity, and maintains ecological processes. Further, the Act regulates the clearing of vegetation in a way that reduces greenhouse gas emissions. The purpose of the VM Act is to primarily regulate the clearing of native vegetation on freehold and leasehold land, however its requirements and definitions are linked to several other environmental Queensland environmental Acts, Regulations, and other legislative instruments including Guidelines and Environmental Authorities.
Water Act 2000 (Qld) (Water Act) and its subordinate legislation	DNRMMRRD	The Water Act provides a framework for the planning, allocation and use of surface water and groundwater in Queensland, including regulating major water impoundments (e.g. dams and weirs) and extraction through pumping for irrigation and other uses. The Project Area is located within the Surat Cumulative Management Area (CMA) and will be assessed by the Office of Groundwater Impact Assessment (OGIA) in the Underground Water Impact Report (UWIR) for the Surat CMA. Section 370 of the Water Act requires an UWIR be prepared for approval. The Surat UWIR assesses the cumulative groundwater impacts from resource operations in the Surat and Southern Bowen basins. OGIA prepared the first Surat UWIR in 2012 and updated it in 2016, 2019 and 2021. The UWIR identifies responsible tenure holder obligations under the Water Act that include 'make good' agreements, undertaking baseline assessments and implementing the water management strategy and the spring impact management strategy. Further, water licences under the Water Act may be required for other activities (e.g. licence to take water from a bore) associated with the Project.
Waste Reduction and Recycling Act 2011 (Qld) (WRR Act) and its subordinate legislation	DETSI	The WRR Act promotes resource recovery through End of Waste (EOW) codes, including EOW Code *Irrigation of Associated Water (including CSG produced water),* EOW Code *Associated Water (including CSG produced water)* and EOW Code *CSG Drilling Mud.*

3. Existing Environment

The Project Area is located approximately 5 km east of the regional town of Wallumbilla in central Queensland in the Maranoa Regional Local Government Area (LGA). This Project Area is located in the southern extent of the Brigalow Belt Bioregion (BRB).

3.1. Land use

The Project Area is predominantly rural land characterised non-remnant derived grasslands dominated by introduced pastoral grasses with occasional native trees and shrubs. The area is used largely for agricultural development, primarily cattle grazing. The Project Area is comprised of predominantly non-remnant vegetation that is generally disturbed and fragmented as a result of land use practices (Boobook, 2025).

The agricultural land uses of the region coexist with existing petroleum, energy and mining activities. Existing permits overlapping the Project Area include:

- EPC 1763 held by Wanbei Coal Electricity International Mining (Australia) Pty Ltd;
- EPG 2034 held by Within Energy Pty Ltd;
- Wallumbilla to Reedy Creek Pipeline (Petroleum Pipeline Licence (PPL) 2023) held by APA Reedy Creek Wallumbilla Pty Ltd; and
- a powerline easement crossing the northern portion of the Project Area held by Ergon Energy.

Two State-controlled roads are in the vicinity of the Project Area, including the Warrego Highway running east to west through the northern half of the Project Area, and Wallumbilla South Road located approximately 3 km west of the Project Area, providing efficient access for local and heavy vehicle traffic.

In the wider local area, a number of State Forests (SF) occur within 20 km of the Project Area, including Inglebogie, Yuleba and Wallabella SF, which are located approximately 15-20 km east, east and south of the Project Area, respectively.

3.2. Topography

This is a landscape of low relief comprising a broad floodplain with meandering streamlines flanked by slightly elevated areas. Ground elevations within the Project Area range from approximately 300 m to 350 m Australian Height Datum (AHD). Beyond the Project Area, to the east, an abrupt north-south trending plateau rises up to 50 m above the surrounds, forming the Grafton Range.

3.3. Climate

The climate of the Project Area is classified as subtropical with hot, wet summers and moderately dry, cold winters. Mean maximum temperatures range between 34.6°C in the summer months and 20.4°C in the winter months (Bureau of Meteorology station 043091, Roma Airport) (Bureau of Meteorology, 2024). Mean minimum temperatures range between 21.1°C in the summer months and 3.7°C in the winter months. The highest rainfall occurs during December to February, with an average highest rainfall of 75.2 mm in December, the lowest rainfall occurs during June to September with a lowest average rainfall of 24.9 mm in August.

The average annual evaporation in the vicinity of the Project Area is between 2,000 millimetres (mm) and 2,400 mm. The highest evaporation occurs during the summer months (average monthly pan evaporation 300 mm), while the lowest evaporation occurs during the winter months (average monthly pan evaporation 80 mm) (Bureau of Meteorology, 2024).

3.4. Regional catchment and surface water quality

The Project Area is located within the Bungil Creek catchment of the Maranoa-Balonne Rivers Basin (WQ4222) as described by the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (DESI, 2023). The Maranoa–Balonne Basin is a subset of the broader Condamine-Balonne catchment of the Murray-Darling Basin. Environmental values and water use associated with the Bungil Creek catchment include aquatic ecosystems, irrigation, farm supply / use, stock water, aquaculture, human consumption, primary recreation, secondary recreation, visual recreation, drinking water, industrial use and cultural, spiritual and ceremonial values. No High Ecological Value (HEV) waters are mapped within the Project Area.

While the Project Area generally has a uniform low elevation, ranges in the surrounding region include the Great Dividing Range to the north, Grafton Range to the west, and the Dulacca Range to the south-east. Most watercourses in the Project Area are ephemeral. There are no major watercourses mapped within the Project footprint, only one watercourse mapped within the Project Area, the closest major watercourses include:

- Washpool Creek: is a minor creek, which originates 5km north of the Project and flows through the Project before joining Wallumbilla Creek 2 km south of the Project;
- Wallumbilla Creek: originates 16 km northwest of the Project and flows south – southwest close to the township of Wallumbilla. The creek continues to flow south before reaching the Balonne River confluence downstream of Yuleba Creek, 54 km south of the Project; and
- Middle Creek: is a tributary of Wallumbilla Creek, which originates 15 km northwest of the Project and flows south between the township of Wallumbilla and the Project before joining Wallumbilla Creek 2 km west of the Project.
- Yuleba Ck (consists of SO 1-5 tributaries) is identified by the *Qld Water Act 2000* as a major watercourse and flows for approx. 187 km from near the Great Dividing Range before joining the Balonne River 45 km south of Yuleba. Yuleba Ck flows predominately south, close to the township of Yuleba, located 13 km east of the Project Area and joins the Balonne River, 46 km southeast of the Project Area.

Other minor, unnamed watercourses occur within the Project Area, almost all of which drain into one of the watercourses listed above.

The Sustainable Rivers Audit 2 for rivers within the Murray-Darling basin (Murray–Darling Basin Authority, 2012) found that the Condamine Valley, which includes the region around the Project Area, had an overall poor ecosystem health rating. The physical form of the Condamine Valley river system was rated as being in moderate condition, characterised by enlarged channels and evidence of widening and channel bed degradation. The cause of this condition was not specified.

According to assessment (Queensland Government, 2024), there are no wetlands of High Ecological Significance (HES) or HEV within or immediately adjacent to the Project Area, with the nearest mapped HEV wetland located approximately 39 km south-west of the Project Area.

There are no active springs mapped within 30 km of the Project Area. There is a low confidence of mapped terrestrial groundwater-dependent ecosystems (GDE) within and near the Project Area. There are no known or mapped subterranean GDEs or groundwater-dependent spring ecosystems located within the Project Area.

There are two registered groundwater bores located in the Project Area, these bores are recorded as Registered bore Numbers (RNs) 123195 and 208460 in the Groundwater Database - Queensland, which are sub-artesian bores for private water supply.

3.5. Regional geology

The regional geology of the Project Area comprises sediments from the Early Cretaceous to Quaternary age Surat Basin. Stratigraphic units of relevance to the Project Area include:

- quaternary alluvial systems within majority of the Project Area;
- early cretaceous age mudrock along the mid-eastern border of the Project Area; and

- fine grained sedimentary rock north-eastern corner of the Project Area.

Land zones are categories that describe the major geologies, the associated landforms and geomorphic processes in Queensland, and are a critical component of the RE classification scheme. The land zones identified within the Project Area using state mapping (Queensland Government, 2023) are detailed in Table 2.

Table 2: Land zones occurring within the Project Area

Land zone	Description as per Wilson & Taylor (2012)
3	Recent Quaternary alluvial systems, including closed depressions, paleo-estuarine deposits currently under freshwater influence, inland lakes and associated wave built lunettes. Excludes colluvial deposits such as talus slopes and pediments. Includes a diverse range of soils, predominantly Vertosols and Sodosols; also with Dermosols, Kurosols, Chromosols, Kandosols, Tenosols, Rudosols and Hydrosols; and Organosols in high rainfall areas.
4	Tertiary-early Quaternary clay deposits, usually forming level to gently undulating plains not related to recent Quaternary alluvial systems. Excludes clay plains formed in-situ on bedrock. Mainly Vertosols with gilgai microrelief, but includes thin sandy or loamy surfaced Sodosols and Chromosols with the same paleo-clay subsoil deposits.
9	Fine grained sedimentary rocks, generally with little or no deformation and usually forming undulating landscapes. Siltstones, mudstones, shales, calcareous sediments, and labile sandstones are typical rock types although minor interbedded volcanics may occur. Includes a diverse range of fine textured soils of moderate to high fertility, predominantly Vertosols, Sodosols, and Chromosols.

3.6. Regional ecology

The BRB bioregion is characterised by *Acacia harpophylla* (brigalow) forests and woodlands on clay soils (Sattler & Williams, 1999). Other ecosystems that are widespread throughout the bioregion include eucalypt forest and woodland, grassland, dry rainforest, cypress pine woodland and riparian communities (Sattler & Williams, 1999).

The majority of the Project Area has been cleared of native vegetation to form non-remnant derived grassland dominated by introduced pastoral grasses with occasional native trees and shrubs. Areas of remnant and regrowth native vegetation occur as irregular, discontinuous corridors along streamlines or as small, isolated fragments. River Red Gum (*Eucalyptus camaldulensis*) dominates riparian woodland along the banks of larger streams, while Poplar Box (*E. populnea*) dominates floodplain woodlands (Boobook, 2025).

The likelihood of occurrence of threatened flora, fauna, Threatened Ecological Communities (TECs), migratory fauna, fish and gastropod species listed under the EPBC Act within the Project Area are listed in Table 3. No threatened flora were identified to have potential to, or are likely, to occur within the Project Area.

Refer to the *Roma Phase 7-7B SD20 Development Matters of National Environmental Significance Ecological Assessment Report* (Boobook, 2025) for further information on the ecology of the Project Area.

Table 3: Likelihood of occurrence of MNES within the Project Area

MNES	EPBC Act Status	NC Act Status	Likelihood of Occurrence[1]
Threatened Ecological Communities			
Poplar Box Grassy Woodlands on Alluvial Plains TEC	Endangered	-	Known
Weeping Myall Woodlands	Endangered	-	Known
Birds			
Sharp-tailed sandpiper (*Calidris acuminata*)	Vulnerable, Migratory	Special Least Concern	Potential
Glossy black-cockatoo (eastern) (*Calyptorhynchus lathami lathami*)	Vulnerable	Vulnerable	Potential
Latham's snipe (*Gallinago hardwickii*)	Vulnerable, Migratory	Special Least Concern	Potential
White-throated needletail (*Hirundapus caudacutus*)	Vulnerable, Migratory	Vulnerable	Likely
Australian painted snipe (*Rostratula australis*)	Endangered	Endangered	Potential
Migratory Birds			
Fork-tailed swift (*Apus pacificus*)	Migratory	Special Least Concern	Likely
White-throated Needletail (*Hirundapus caudacutus*)	Migratory, Vulnerable	Vulnerable	Likely
Common Sandpiper (*Actitis hypoleucos*)	Migratory	Special Least Concern	Potential
Sharp-tailed Sandpiper (*Calidris acuminata*)	Migratory	Special Least Concern	Potential
Pectoral Sandpiper (*Calidris melanotos*)	Migratory	Special Least Concern	Potential
Latham's Snipe (*Gallinago hardwickii*)	Migratory, Vulnerable	Vulnerable	Potential
Mammals			
Koala (*Phascolarctos cinereus*)	Endangered	Endangered	Potential
Reptiles			
Yakka skink (*Egernia rugosa*)	Vulnerable	Vulnerable	Potential
Grey snake (*Hemiaspis damelii*)	Endangered	Endangered	Potential

Notes: EPBC Act 'Marine' listed species, and species unlikely to be present within the Project Area, have been excluded from Table 3. Likelihood of occurrence determination made in Boobook 2025.

4. Project Activities

4.1. Gas field infrastructure

4.1.1. Wells

Santos proposes to drill and operate up to 24 CSG production wells in the Project Area.

A well lease will be constructed to accommodate drilling, well completion equipment and support services. Typically, well construction will involve a drill rig and other equipment including storage for fuel, chemicals, drilling fluids, produced water and raw water supply. An operational production well lease will generally include gas and water metering, separation and filtering equipment, electrical and control systems and water and gas pipeline connections.

Well locations will be selected based on proximity to the subsurface target location and with consideration to environmental, cultural heritage, landholder and access constraints on the surface. Locating and developing a new well and supporting infrastructure will also take into account and ensure compliance with relevant environmental legislation and Federal and State government approvals.

Hydraulic fracture stimulation will be used to complete all wells (where required). On well completion, a pump will be installed to depressurise the coal seam and facilitate gas production. Well construction will involve the use of drilling muds, and hydraulic fracturing fluids where hydraulic fracturing stimulation is required (refer to Section 4.2 for further detail). Produced water and waste drilling muds, hydraulic fracturing fluids will be generated and managed in accordance with Section 4.3.4.

CSG production wells will be designed, constructed and decommissioned in accordance with the "*Code of Practice for the construction and abandonment of coal seam gas and petroleum wells, and associated bores in Queensland Version 2*" (the Code). The Code outlines mandatory requirements and good practice to reduce the risk of environmental harm. Production wells will be designed to:

- prevent any interconnection between target hydrocarbon-bearing formations and aquifers;
- ensure that gas is contained within the well and associated pipework and equipment without leakage;
- ensure zonal isolation between different aquifers is achieved;
- not introduce substances that may cause environmental harm; and
- production wells will not be installed within 90 metres (m) of a landholder bore.

Well leases will be constructed for each well to create a stable working platform suitable for safely undertaking drilling, and completions and well operations. The lease incorporates safe access and areas for the drilling rig, generators, fuel, chemical, casing and pipe storage, and associated portable buildings. Each well pad is also designed for subsequent operations like hydraulic stimulation generally incorporates the following standard features:

- a compacted and stable drilling rig hard stand area;
- tanks for management and disposal of drill cuttings and the recirculation of water into the mud system;
- an access road or track with clear entry and exit points for vehicles;
- mobile wastewater treatment systems for the disposal of ablutions waste from well site offices and accommodation;
- water storage tanks or ponds for drilling and / or hydraulic fracturing water and flowback fluid; and
- proppant and chemical storage for drilling and / or hydraulic fracturing operations.

The size and layout of the well lease will vary depending on a number of factors such as the number of wells to be drilled (multi-well leases), the size and type of drilling rig, the number of hydraulic stimulation stages, the need for on lease water storage, the program for completion of the well(s) and the surrounding environment / topography.

The lease size required to accommodate a single petroleum well is typically 1 to 1.25 ha. Minimum disturbance leases (consisting of matting placed on the ground to create a hardstand surface) would be used where topography and vegetative cover allows. Minimum disturbance leases can be less than one ha. Where additional area is needed to accommodate infrastructure such as a water tank, single well leases may be up to 1.5 ha in size. Well leases located on native slopes exceeding 4% require cut and fill construction techniques, and these areas will require leases greater than 1 ha in size.

Multi-well leases may be necessary to maximise gas recovery, reduce overall disturbance associated with multiple single leases, and / or accommodate landholder requirements. These may be up to a maximum 3 ha in size, resulting in a larger footprint per lease area but a reduced footprint per well.

Well lease construction methods vary depending upon the land system and soil type on which the well is to be drilled. Typically, topsoil with rootstock and vegetation is cleared and stockpiled for use later in restoration. Material sourced from borrow pits is imported where required to construct the lease pad, access roads and associated infrastructure. Borrow material is watered and rolled to achieve adequate compaction, provide a stable and trafficable surface and reduce dust. The risk of erosion is managed through the well pad design (i.e. surface water run-on and run-off) and engineered management controls. Considerations for siting and constructing well leases and associated infrastructure include:

- selection of non-sloping well leases is preferable (this minimises the requirements for cut and fill or importation of borrow material to level the site);
- employment of additional management controls in sensitive areas such as floodplains and proximity watercourses (where required);
- constructing erosion control measures where appropriate (i.e. diversion banks or berms);
- capping of sensitive terrain to preserve the underlying soils where required;
- avoiding environmentally sensitive and restricted areas and ensuring compliance with terms of the Santos Cultural Heritage Management Plan (CHMP); and
- minimising disturbance of native vegetation and fauna habitat.

Where practicable, minimum disturbance leases may be used as an alternative to traditional lease construction.

4.1.2. Access tracks

Construction of typical access roads (typically 10 - 15 m wide) will be required to accommodate heavy and light vehicles associated with project activities. Wherever practicable, existing access tracks will be upgraded for use, and new access roads will be co-located with gas and water gathering (and electrical and communications infrastructure) corridors wherever practicable to reduce the overall construction footprint.

Access tracks are required for construction activities. Where practicable, existing access tracks would be upgraded for use and new access tracks would be co-located with gas and water gathering (and electrical and communications infrastructure) corridors to reduce the overall construction width required. Co-located linear infrastructure corridors may be wider than 20 - 35 m where several services are co-located, and they typically do not exceed greater than 40 m total width, other than when several services are co-located.

Typically, bed level crossings are used for access tracks. Design and construction vary depending on the land system, expected frequency of use, traffic loadings and safety requirements. Where required they are constructed to withstand heavy and light vehicles associated with the activities and would typically be 10 - 15 m in width.

Access track crossings would be designed to comply with Queensland's existing framework for "waterway barrier works" under the *Planning Act 2016* (Qld), which is administered by DAF; only "accepted development" which

complies with specific standards may be carried out without a permit from the DAF. These standards include (but are not limited to):

- development work minimises impacts to waterways and fish habitat through the following actions:
  - minimise disturbance to the instream bed and banks e.g. use geofabric as a work base;
  - if it is necessary to remove vegetation, aim to cut vegetation no lower than ground level and leave the root in the ground to aid in stabilisation. If deep excavation is required during construction the roots may only be removed within the construction footprint area;
  - minimise the area of land disturbed or compacted;
  - ensure the least volume of soil or sediment is disturbed;
  - limit the use of machinery within waterways;
  - use machinery no greater than the capacity required for the purpose;
  - implement sediment and erosion protection measures; and
  - undertake works at times that minimise disruption to fish migration and fish habitat.
- impacts on water quality are to be minimised by undertaking the works to the standard set out in the current version of the Best Practice Erosion and Sediment Control, published by the International Erosion Control Association (IECA), Australasia (and in accordance with relevant EA conditions).
- for any part of the waterway bed or banks adjacent to the works that has been altered by the waterway barrier works, the site is restored and / or rehabilitated so that as a minimum:
  - stability and profiles of the bed and banks are re-instated to natural stream profiles and stability upon completion of the works;
  - the waterway bed is retained with natural substrate or reconstructed with substrate comparable to the natural substrate size and consistency; and
  - site conditions allow the rapid re-establishment of native vegetation and cover or native species are replanted to re-establish the natural plant community.

4.1.3. Gas and water gathering network

A construction right-of-way (RoW) approximately 20 - 35 m wide will be required for standard gathering line / pipeline construction including the excavation of a trench, pipeline laying, backfilling the trench, and reinstatement of the RoW.

Santos will utilise new and existing water and gas gathering lines / pipelines to transfer produced gas and water from the proposed CSG wells to existing approved water and gas processing facilities. These facilities are located on adjoining Santos owned and operated tenures in the broader Roma Gas Field. Gathering infrastructure RoW corridors are typically 20 - 35 m in width for individual services. As discussed in Section 4.1.2, where practicable, access tracks will be co-located with gas and water gathering (and electrical and communications infrastructure) corridors to reduce the overall construction width required. Co-located linear infrastructure corridors may be wider than 20 - 35 m where several services are co-located, and they typically do not exceed greater than 40 m total width, other than when several services are co-located.

During the field development planning process, Santos will assess stabilisation risks for pipeline watercourse crossings to inform crossing design. The assessment considers:

- watercourse cross-section geometry at the crossing location;
- watercourse catchment area; and
- watercourse longitudinal slope (bed slope / channel slope) at the crossing location.

The assigned risk level is a function of cross section geometry and flow erosivity (i.e. crossings with steeper banks and larger catchment areas / greater flow have higher risk levels). The crossing design is chosen based on assigned risk. Standard designs for low, medium and high-risk crossings are appended to this EMP in Appendix 2.

Gathering lines and pipelines would be constructed of high-density polyethylene (HDPE) pipe of 100 - 1000 millimetres (mm) in diameter. Low point drains and high point vents would be installed at intervals along the gathering lines to allow drainage of condensate from gas, and the release of minor entrained gas from produced water as required.

Gas gathering lines would be designed and constructed to comply with Australian Standard *AS/NZS 2885 – Pipelines Gas and Liquid Petroleum* (Standards Australia, 2018) and the Australian Pipeline and Gas Association (APGA) *Code of Practice Upstream PE Gathering Networks – CSG Industry*, *Version 6* (2024).

Gathering lines would be constructed using a combination of conventional earthmoving equipment and specialist pipeline trenching and lifting equipment. Gathering lines would be constructed using a standard construction methodology including:

- clearing and grading;
- trenching and padding;
- pipe stringing, laying and welding;
- backfilling and reinstating natural ground level; and
- installing marker signs as required.

Pipelines would be preferentially built during periods of no stream flow; as such, no impacts to natural stream flows are expected.

Once installed, the construction corridor would be rehabilitated back to the minimum width (termed the 'operational RoW') required for operation and regular inspection of the pipeline. Groundcover would be re-established along the operational RoW.

4.1.4. Other incidental activities

Supporting infrastructure, which may include small temporary workers camps (less than 2 ha), power and communications lines (co-located with gas gathering lines and pipelines) and other incidental petroleum activities such as borrow pits and laydown areas (less than 1 ha).

A small, temporary camp site may be required to provide accommodation for drilling, completions and associated support personnel. Camp sites are located within proximity to well leases to minimise travel related risks. Construction methods for camps are similar to those employed for laydown areas. The camp site location is flexible and will be constructed in an area where disturbance of native vegetation, particularly woody vegetation can be avoided or minimised. The camp location will also take into consideration landholder requirements, such as the potential for noise and dust generation and other operational hazards such as traffic. The camp will include a sewage treatment plant and associated irrigation area.

Other ancillary infrastructure and incidental petroleum activities required to support the construction activities for the Project may include:

- laydown, stockpile, storage and vehicle cleaning areas;
- storage tanks;
- power and communication lines;
- borrow pits;
- fencing;
- environmental monitoring equipment and management controls;

- geophysical, geotechnical, geological, topographic, cadastral and ecological surveys; and
- external infrastructure, such as transport, energy supply, water supply and communications.

4.2. Well drilling and completions

4.2.1. Site set up

The well lease needs to provide a stable working platform suitable for safely undertaking drilling and associated activities such as hydraulic fracturing and well workover (i.e. well maintenance) operations. The lease area provides adequate space for the drilling and hydraulic fracturing vehicles and equipment, generators, fuel and chemical storage, casing and pipe storage and associated portable buildings. The well lease area generally incorporates the following standard features:

- a compacted and stable hard stand area;
- an access road or track with clear entry and exit points for vehicles;
- mobile wastewater treatment systems for the disposal of ablutions waste from well site offices and accommodation;
- water storage tanks or ponds for hydraulic fracturing make up water and flowback fluid; and
- proppant and chemical storage for drilling and / or hydraulic fracturing operations.

4.2.2. Drilling

Wells would be constructed in accordance with the Code. The Code mandates that the design basis for wells must:

- consider casing setting depths that take into account aquifer and production zone locations;
- provide for installation of pressure control equipment (PCE) based on risk assessment, e.g. Blowout Preventor (BOP) equipment to American Petroleum Institute (API) standard 53;
- use appropriate casing weight and grade with appropriate casing running procedures. This includes consideration for casing corrosion risk and connection suitability;
- use appropriate well design and construction materials;
- use appropriate casing centralisation;
- use engineered cement slurries with both appropriate and effective cement placement techniques;
- ensure all fluids produced from the well travel directly from the production zone to the surface without cross contamination; and
- ensure they are constructed, maintained and abandoned in such a manner that it can be demonstrated there are two verified well barriers between a hydrocarbon bearing or abnormally pressured formation and the surface.

Drilling fluids and additives used during drilling activities will be used in accordance with the mandatory requirements and good practice guidelines outlined in the Code as well as the Safety Data Sheets (SDS) provided with each fluid / additive. With relation to drilling fluids, the mandatory requirements include:

- drilling fluids must be selected and managed to ensure all manufactured products used during well procedures are in accordance with the manufacturer’s recommendations and relevant SDS; and
- the name, type and quantity of each chemical used on each well throughout the life of the well must be recorded.

Good industry practice for drilling includes:

- drilling fluid should be a carefully monitored and controlled mixture designed to achieve best drilling results and ensure efficient removal of formation cuttings;
- control formation pressures;
- minimise damage to formations;
- petroleum tenure holders should ensure that the drilling fluid selected is appropriate for the well design to manage any locally experienced drilling problems and the geological conditions likely to be encountered;
- the use of biodegradable substances in the drilling fluid is preferred;
- the source of water for all well procedures (drilling, completion, workover and abandonment) should be recorded for future well monitoring purposes;
- products should be chosen, stored, and used at concentrations that minimise the risk of causing environmental harm;
- personnel, including contractors, should be aware of the environmental impact and emergency spill procedures for the products and substances in use on site; and
- petroleum tenure holders should use established, effective drilling practices to achieve a stable, uniform and, as far as possible, in-gauge hole.

During drilling, fluid is pumped through the inside of the drill string to the drill bit and back up the outside of the drill string to lift drill cuttings out of the hole. The drilling fluid / drill cuttings are then channelled into tanks where the drill cuttings are separated from the drilling fluid, and then drilling fluid is recycled down hole in a continuous process. Drilling fluids are also typically recycled onto other wells in a multi well scenario. Casing, which is concentric steel pipe, is installed into the well and cemented in place to provide the structural integrity and well integrity barriers for the life of the well. A typical drilling rig layout and lease and access roads required for drilling operations is shown in Figure 5.

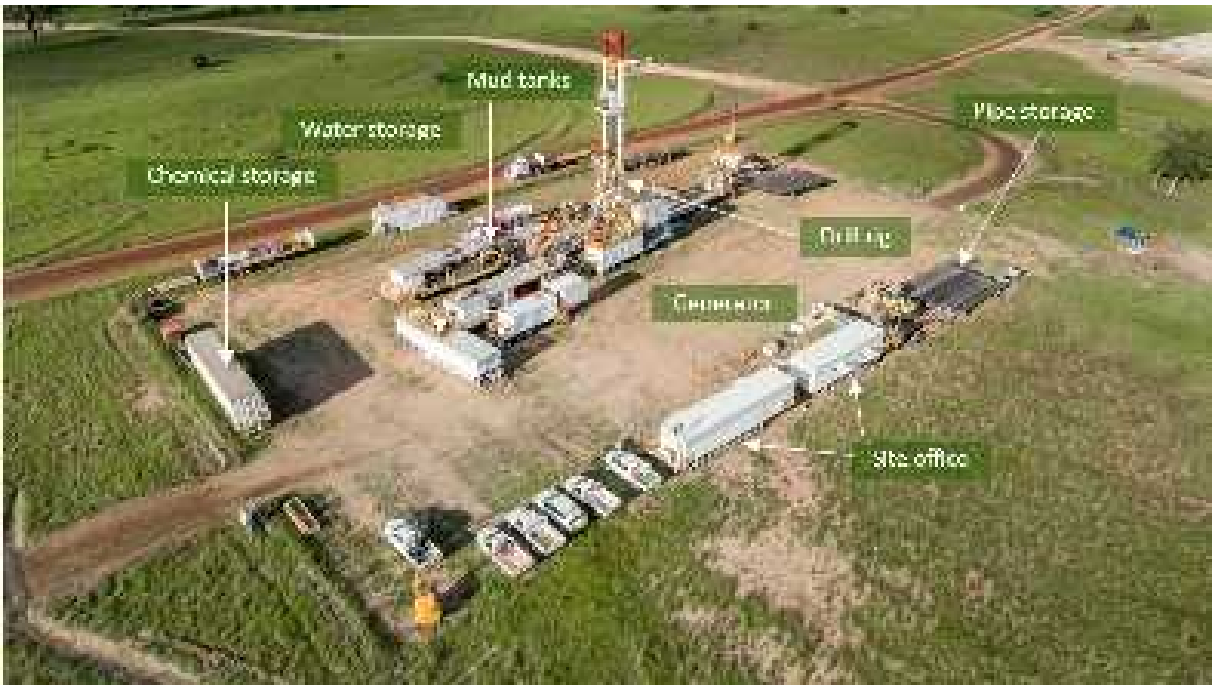


Figure 5: Example of well lease and drilling rig

Wells are drilled to such a depth as to reach the gas formation targets through a series of ‘hole sections’. Each hole section serves a specific purpose for well construction and well integrity as outlined below.

1. A shallow Conductor Hole Section may be drilled and cased to stabilise shallow surface sediments from the drilling of subsequent drilling phases (i.e. it prevents the loose soils from caving into the borehole). A conductor casing string is installed by exception and only if required based on local conditions for well construction purposes.
2. The Surface Hole Section is drilled and cased to achieve regulatory requirements for isolating shallow aquifer systems (if present) and to stabilise the well for subsequent hole sections. The hole section is drilled with drilling fluid that exerts a higher hydrostatic pressure on the rock face, than what is present naturally in the rock pore space, ensuring formation fluids do not enter the wellbore. The surface casing is cemented in place from bottom to top to ensure effective pressure isolation of shallow aquifers (if present) from deeper hydrocarbon bearing zones encountered in subsequent hole sections. Finally, it is pressure tested to simulate well life design specifications.
3. After the surface casing is installed, a Blowout Preventer (BOP) is installed onto the well at surface to provide a second barrier along with the drilling fluid. At the commencement of drilling the next hole section (i.e. after approximately 3m of new hole drilled), a Leak Off Test (LOT) or Formation Integrity Test (FIT) is conducted on selected representative wells to determine the rock strength in the local area. This will ensure the well is drilled without risk of the rock failing due to exerted pressure.
4. The Production Hole Section is drilled to intersect formation targets and is drilled to a depth below the lowest hydrocarbon bearing target. The hole section is typically drilled with drilling fluid that exerts a higher hydrostatic pressure on the rock face, than what is present naturally in the rock pore space, ensuring formation fluids do not enter the wellbore.
5. Open hole logging may be performed after the production hole section has been drilled and prior to the production casing being run. Wireline logging operations for Santos are undertaken by a number of different industry recognised specialist service companies. Different energy sources are lowered into the well via wireline including density, neutron, acoustic and electrical logging tools. Calculations based on the received signals are undertaken to evaluate the different parameters of the formation such as porosity, permeability, rock type and hydrocarbon saturation.
6. After the production hole is drilled and logged, production casing is installed to the total depth of the wellbore, cemented in place and pressure tested. The purpose of the production casing is to provide hydraulic isolation between the hydrocarbon reservoirs and all other overlying formations, to contain the pressurised fluid used to hydraulically stimulate the target zones, and to provide effective wellbore integrity for well production. The steel casing is manufactured and certified to strict Quality Assurance / Quality Control (QA / QC) standards and installed in a configuration specific for each well.

4.2.3. Casing and cementing

Casing design scenarios are modelled through specialist software to simulate the design loads for collapse, burst, tensile failures, and tri-axial failures observed during the operational, stimulation and production phases. Results of this analysis direct the selection of casing grade and weight. All casing is tested by Santos and the contractor using specific Quality Assessment and Quality Control (QA / QC) procedures prior to installation to ensure compliance with the Santos engineering and regulatory specifications.

After each hole section is drilled, the steel casing is cemented in place. The correct composition, volume and placement of cement is the construction aspect that is most important for well integrity. The cement serves two purposes – it provides protection and structural support to the casing while also providing zonal isolation between different formations, including aquifers (if present). The cement and required additives are high quality materials produced specifically for oil and gas operations with the materials selected designed to address the specific conditions of a particular well.

Santos and the cementing contractor must ensure the cementing material and equipment is adequate to achieve the well design objectives and ensure effective isolation. Prior to pumping the cement, it must be lab tested against the engineering design and actual downhole conditions such as temperature. The cement is tested using specific QA / QC procedures and includes the following:

- slurry density;
- thickening time;
- fluid loss control;
- free fluid;
- compressive strength development;
- fluid compatibility (cement, mix fluid, mud);
- sedimentation control;
- expansion or shrinkage characteristics of the set cement;
- static gel strength development; and
- mechanical properties.

Cased hole logs may be run on selected wells as required inside the cemented casing to validate the quality and integrity of the cement sheath bond to the casing and to the formation. Typically, these logs include:

- gamma ray - measures naturally occurring gamma radiation to characterise the rock or sediment in a borehole;
- casing collar locator - a magnetic device that detects the casing collars; and
- cement bond log - an acoustic device used to measure the properties of the cement sheath and the quality of the cement bond between the casing and the formation.

The cement bond log is an acoustic device that can detect cemented or non-cemented casing. It works by transmitting a sound or vibration signal into the casing, and then recording the amplitude of the arrival signal. Casing that has no or poor-quality cement surrounding it (i.e. free pipe) will have large amplitude acoustic signal because the energy remains in the pipe and isn't transmitted to the formation. Casing that has a good cement sheath (fills the annular space between the casing and the formation and effectively couples the two) will have a much smaller acoustic amplitude signal as the energy is absorbed by the formation due to effective acoustically coupling.

Santos uses experienced contractors to identify the key features of the cement quality to ensure the integrity of the cement seal for each casing pipe sheath. If cement is not of sufficient height or quality and deemed by the operator to be unsafe for continued operations, hydraulic stimulation will not proceed until it can be effectively remediated.

4.2.4. Hydraulic fracture stimulation

Due to the characteristic of the geological formations located within the Project Area, all proposed CSG wells will require hydraulic fracturing to produce commercially viable gas volumes / rates.

This process has been used extensively in the petroleum industry since 1947. Santos has successfully used this technique on wells in the Cooper Basin for over 50 years. Santos is currently performing the process in many basins around Australia, including for CSG wells within Santos' approved GLNG (EPBC No. 2008/4059), GFD (EPBC No. 2012/6615) and Towrie (EPBC No. 2021/8979) projects in the Surat Basin.

Hydraulic fracture stimulation is not part of the drilling process but is a completion technique applied after the well is drilled and is typically performed on newly installed production wells. The intent of hydraulic stimulation is to place highly conductive channels into the target reservoir that increase the permeability of the coal seam immediately adjacent to the well and improve flow of groundwater and gas into the well bore. Production wells may be subject to multiple fracturing events over their operational life.

The stimulation process involves injecting hydraulic fracturing fluids (water, sand / proppant and minor chemical additives) at high pressure into a cased wellbore. It is usually conducted over a number of intervals along the

production zone of the well. The proppant keeps the fractures open once the pump pressure is released which improves the productive potential of the well.

Hydraulic fracturing is a predominantly physical process in which hydraulic pressure is applied to a fluid to increase the effective permeability of the formation rock. The process creates narrow pathways (fractures) in the target formation to improve its ability to transmit gas back to and then out of the well.

After a pre-fracturing assessment and hydraulic fracturing design, onsite activities include site setup, perforation of the well casing and cement into discrete targeted sections of the cased bore (to access most viable gas bearing formation), injection of hydraulic fracturing fluid and flowback of the injected fluid. These processes are described in the following sections.

4.2.5. Pre-fracturing assessment and design

Operators investigate the subsurface conditions, including hydrogeological and mechanical properties of the target and surrounding geological units, to design the hydraulic fracturing program to strategically identify and reduce the possible risks involved (IESC, 2014).

To understand the geological formation and priorities for the hydraulic fracturing program, key aspects of subsurface characterisation (Beckwith, 2010) include:

- describing all geological units;
- assessing target formation permeability;
- analysing subsurface distribution of stresses and faults; and
- assessing fluid loss characteristics.

The hydraulic fracturing program is designed after the subsurface characterisation is complete. Part of this design is the prediction of fracture growth within the target zone. Specific hydraulic fracture simulation software is used to predict the geometry of fractures (fracture length, conductivity and height), while the orientation is determined from the in-situ stress field (IESC, 2014). Typical inputs to numerical models include volume and properties of the fluid and proppant, closure stress, pressures within pores, permeability, mechanical properties and layer geometry.

A number of considerations influence the final design for each stimulation treatment, including:

- depth and thickness of the formation target;
- lithology of formation target and bounding layers;
- minimum and maximum horizontal stress across all layers (target and bounding);
- thickness of the seals above and below the target reservoir formation;
- porosity and permeability of the formation;
- pore fluid saturations (percentage of formation pore volume occupied by oil, gas or water);
- pore fluid properties (e.g. density, water salinity);
- well performance data, including flow rates, formation pressure and produced fluid properties;
- formation boundaries (as identified from seismic data);
- bulk rock density, elastic properties and compressibility;
- natural fracture networks; and
- stress field analysis to determine the maximum principle stress direction and the minimum principle stress direction.

4.2.6. Well perforation

Holes are created in the well casing pipe at locations which align to the centre of the coal seams targeted for gas production (these are referred to as 'perforations'). A section of the casing pipe typically less than one metre long is selected for perforation to allow the well to discretely access the coal seam. They are generally aligned slightly below the midpoint of the coal seam being fractured to accommodate the tendency for upward propagation of the fracture (in the direction of least stress).

The perforations, or holes, are created by blasting a jet of water or fine sand / water mix at high pressure at the pipe wall or using small explosives. The perforations penetrate the steel casing and the cement grout layer, and into the coal seam by up to half a metre.

4.2.7. Acid injection

If the coal seam cleats[1] are found to be naturally filled with calcite mineral (calcium carbonate) then a diluted acid mix is injected through the perforation holes into the coal seam to dissolve the calcite away prior to hydraulic fracturing. This is found to be necessary in less than 10% of CSG wells only. It is carried out after completion of the well casing and directly prior to hydraulic fracturing operations, typically completed by the fracturing spread.

The selected coal seam can be pressurised with a 15% solution of hydrochloric acid (with preservatives), with typical volumes pumped of approximate 1 cubic metre (m^3). Hydraulic fracturing can then be carried out.

4.2.8. Hydraulic fracturing fluid

Hydraulic fracturing fluid generally consists of three parts: base fluid (the largest constituent by volume), additives and proppant. Base fluid (water) and proppant (sand) make up around 99% of the hydraulic fracturing fluid, with additives making up the remaining 1%. The purpose of the proppant is to keep the fractures open once the pump pressure is released which improves the productive potential of the well. Each chemical additive serves a specific, engineered purpose such as:

- viscosity: gelling agents and crosslinkers are added to the water to provide viscosity to enable the proppant material such as sand or ceramic beads to be transported down the well and into the created fractures;
- breakers: added to reduce the viscosity of the fluid when flowing back the well, enhancing recovery of fracturing fluid and additives to surface;
- friction reduction: to reduce the force required to pump the fluid, friction reducers are added, making the fluid more 'slippery' and easier to pump at the high pressures and rates required to create the fracture network;
- biocide: biocides or disinfectants are added to reduce the amount of naturally occurring microbes or organisms present in the water which can impact fluid stability and also to ensure they will not enter and contaminate the reservoir;
- scale and corrosion: scale and corrosion inhibitors are added to prevent deposition of mineral scales and to prevent corrosion of the steel casing or tubing; and
- surface tension: surfactants or surface tension modifiers are added to assist the back flow of fluids from the formation.

The chemicals used in hydraulic fracturing (and drilling) are subject to a chemical risk assessment process (under the *Roma Phase 7-7B-SD20 Development Chemical Risk Assessment Framework* (CRAF) (Santos, 2025a)).

4.2.9. Stimulation process

A number of steps are involved in the hydraulic stimulation process to pump the designed fracture treatment. These include:

[1] Coal seams have natural fractures, known as cleats. Cleats act as a major transport system for gas and water flow within a coal seam.

- Diagnostic Fracture Injection Test (DFIT) to validate and update the proposed stimulation design. This involves injecting a small volume of water, shutting down the surface pumps and monitoring pressure decline to evaluate near wellbore entry friction, fracture gradient, fluid leak off, and minimum horizontal stress. This stage is typically only performed in the exploratory/ appraisal stages of development, or until localised fracture characteristics are defined;
- drift run to check there are no obstructions in the wellbore;
- in the case of Plug and Perforation stimulation conveyance method, perforation of stimulation stage one (deepest stage) to gain access to the reservoir from the wellbore;
- in the case of coiled tubing stimulation conveyance method, all stimulation stages are perforated before the fracturing crew and equipment arrive at the wellsite;
- main stimulation treatment consisting of pad volume injection, slurry stage injection(s) with increasing proppant concentrations, and flush stage to displace last slurry stage through the perforations and into the fracture;
- mechanical isolation of the completed fracture stimulation stage;
- perforate the next stage to be hydraulically stimulated and repeat the processes above until the final fracture stimulation stage is completed;
- remove all mechanical isolation devices by milling out the mechanical isolations; and
- flowback well to clean up fracture stimulation fluids and monitor hydrocarbon production.

Hydraulic stimulation operations typically take 1 to 2 days to complete at a CSG well. Hydraulic fracture stimulation initial fluid flowback may occur for a period of 1 to 30 days, depending on the reservoir and clean up profile before being connected into gathering network.

4.2.10. Injection and isolation of hydraulic fracturing fluid

Once the well has been perforated in the depth interval that is to be hydraulically fractured, fluid injection is performed.

Hydraulic fracturing fluid is injected into the well at the surface through the wellhead. The perforation zones are isolated by either a coiled tubing unit with packers, a bridge or frac plug set by a wireline operator, or by a baffle and ball-drop system.

Following isolation of the perforated zone, injection of fluid commences. The hydraulic fracturing fluid is forced into fractures and remains within the target reservoir. The bore design and construction, comprising multiple physical barriers such as cement and steel casing, ensure that the hydraulic fracturing fluid does not come into contact with overlying strata, including aquifers. The integrity of these barriers is tested before hydraulic fracturing activities are undertaken.

The injection pressure, injection rates, slurry volumes, fluid viscosity, additive concentrations and proppant concentration are monitored in real-time during each injection. Downhole pressure information is also recorded and reviewed during the hydraulic fracture stimulation operation. Down-hole pressures are calculated based on wellhead pressure, fluid density, casing diameter and the depth to the target formation. When a coiled tubing unit is used as part of the operation pressure is monitored: inside the casing above the top packer of the tool, inside the coiled tubing delivering the fluid and inside the wellhead at surface.

Once the entire hydraulic fracturing operation is complete for a well, a completions rig or coiled tubing unit will generally mill out the bridge plugs or baffles that were installed for the hydraulic fracturing operation, to clear them from the well.

4.2.11. Return of injected fluid and water (flowback)

Once the injection process is complete, the internal pressure of the rock formation typically causes fluid to return or “flowback” to the surface through the gas well. Flowback fluid contains the dissociation or broken-down products of the injected chemicals plus naturally occurring geogenic compounds.

The volume of the injected fluids which is recovered as flowback is variable depending on the formation, treatment execution, and fluid type used. Immediately after stimulation, typically 0% to 20% of the stimulation volume is recovered within a few days of the completion of the fracturing operation. The well then continues to flowback once connected into the gathering network, where often >100% of the stimulation volume is recovered.

The flowback water is typically temporarily stored tanks before treatment for reuse or disposal.

4.2.12. Flowback fluid management

The recovered fluid, or flowback, may be treated and stored for reuse in the next hydraulic fracturing event. Flowback fluid unable to be reused would be disposed of at a licensed facility or transferred to one of Santos’ engineered treatment facilities for treatment and management under existing approvals for those facilities.

4.2.13. Wells

Once completed and connected to gas and water gathering infrastructure, wells would operate continuously on a 24-hour basis. Operating wells would be monitored and controlled remotely. The wells would also have automated shutdown systems in the event of non-routine operating conditions. As per the requirements outlined in the P&G Act, the volume of produced water will be monitored and recorded and provided to the DNRMMRRD in accordance with statutory obligations.

Ongoing activities at well sites during operations would include routine inspections and maintenance of wellhead infrastructure. Maintenance activities would include repair or replacement of downhole pumps and pump components, clearing of blockages from within the wells that may be limiting production capacity, and other actions as necessary to improve production efficiency.

Well maintenance activities usually require the use of a workover rig (which is smaller than a drilling rig) and are contained within the fenced lease area for the well.

4.2.14. Completions and connections

At the end of the clean-up phase, a workover rig would be required to install the production tubing and associated completion equipment such as packers, nipple profiles, tubing hanger, and the production tree, in preparation for connecting the well for inline production flow.

Production from each well is controlled with a metering skid which includes features such as overpressure protection, flow rate control, well safety shut-in, pressure and temperature monitoring.

After the drilling, stimulation, completion and connection activities are complete, the well lease is transitioned towards the operational phase which involves:

- backfilling the well conduits
- removal of drilling and completions equipment and waste; and
- pumping out additional water from the turkey’s nest (if installed) and removing the liner or removal of the temporary storage tank.

4.3. Production Operations

4.3.1. Wells

Once completed and connected to gas and water gathering infrastructure, wells will operate continuously on a 24-hour basis for an anticipated 30 - 50 years.

An operational production well lease will generally include gas and water metering, initial gas and water separation and filtering equipment, electrical and control systems, and water and gas pipeline connections (and tanks where on site water storage is required).

Operating wells will be monitored and controlled remotely. Each well has an automated shutdown system in the event of non-routine operating conditions.

Ongoing activities at well sites during operations will include routine inspections and maintenance of wellhead infrastructure. Maintenance activities will include repair or replacement of downhole pumps and pump components, clearing of blockages from within the wells that may be limiting production capacity, and other actions as necessary to improve production efficiency.

Well maintenance activities usually require the use of a CSG well workover rig (which is smaller than a CSG well drilling rig) and are contained within the established lease area for the well.

4.3.2. Gas processing

Gas produced from the Project Area is planned to be transferred to the existing Roma Hub Compressor Station 2 (R-HCS-02) located on PL 314 via new and existing gas gathering infrastructure.

R-HCS-02 and PL 314 are owned and operated by Santos. Petroleum activities located on PL 314 (including compression) are authorised be EA EPPG00898213 and EPBC Act Approvals 2008/4059 and 2012/6615. In the future, gas from the Project Area may potentially be processed elsewhere, subject to environmental approvals.

4.3.3. Gathering lines and pipelines

Gas and water gathering lines and pipelines will be monitored, inspected, and maintained during operation. This may include inspection of low point drains and high point vents as part of routine field maintenance activities, and vegetation slashing within operational RoWs.

4.3.4. Produced water management

The Project peak produced water forecast is estimated at 0.24 Mega L/day in 2028. The majority of produced water generated from the Project is proposed to be transferred to existing approved water storages and treatment facilities located adjacent to the Project Area, namely on PLs 314 and 315, via new and existing water gathering infrastructure. Produced water is then proposed to be transferred to existing approved water treatment facilities located on PL 314, where the water will be processed through a fines and sludge removal facility before being further processed, or bypassed around, the Roma Reverse Osmosis Plant (ROP) to meet re-use criteria in accordance with Qld End of Waste Code Irrigation of Associated Water (ENEW07546918). The Roma ROP is located approximately 25 km northwest of the Project Area.

Adequate water and brine storage and treatment capacity has been assessed by the WMP to be available on adjacent tenures to manage peak water and brine production from the Project. Further, Santos have established procedures to prevent uncontrolled discharge of produced water (i.e. restriction of production by “turning down” or “shutting-in” wells). In future, produced water from the Project Area may be processed or sent elsewhere, subject to relevant approvals.

4.3.5. Waste management

Drilling fluids would be contained on the well lease in tanks during drilling and then either re-used (or recycled and reused) at another well site or disposed of offsite at a licenced waste management facility. Residual drilling

material (RDM) would be stored in tanks during drilling and then, if agreed with the landholder, may be disposed of on-site in accordance with EA conditions, where:

- RDM meets approved quality criteria, and the mix-bury-cover method is used; or
- RDM is certified by a suitably qualified third party as being of acceptable quality for disposal to land by a proposed method, and that environmental harm will not result from the proposed disposal.

The potential risk to MNES receptors from application of RDM to land has been assessed to be low given the following:

- EA conditions adequately regulate land application techniques and a methodology to avoid environmental harm has been developed by a suitable qualified third-party
- the physical and chemical properties of the RDM is largely benign (The Project's CRAF, Santos, 2025a)
- potential application areas will be remote from surface water receptors, and surface watercourses are ephemeral; and
- there is large vertical separation of groundwater receptors from surface activities.

Although no environmental receptors are predicted to be at risk of being impacted from application of RDM, assessments and monitoring will occur to demonstrate that environmental outcomes have been achieved. Assessments and monitoring will include:

- sampling and characterisation of the RDM; and
- soil samples to characterise baseline conditions of each representative soil type within the Project Area for which land application of RDM is proposed.

Alternatively, RDM may be transferred by road to existing approved waste management facilities on adjoining tenures, or to another licensed waste facility for management.

Further, early warning, trigger thresholds and limits for managing the risk of adverse impacts to surface water and groundwater resources from the beneficial reuse of produced water or from land application of RDM is provided in Section 6.1.

4.4. Decommissioning and Rehabilitation

Santos will undertake rehabilitation in accordance with the *Santos Roma Phase 7-7B-SD20 Development Rehabilitation Monitoring Plan* (RMP) (Santos, 2025b).

4.4.1. Wells and well pad rehabilitation

Santos has developed a catalogue of standardised construction designs that focus on long-term stability for the operational life of the well, generally greater than 20 years. Using standardised designs Santos achieves consistent and high-quality execution whilst minimising future disturbances. Where standard designs are deemed not fit for purpose, site-specific designs are developed.

All wells are monitored throughout operations using a risk-based inspection and maintenance program. Santos has a standardised well inspection program, whereby every well lease is inspected on a planned / scheduled basis. Inspections target a range of environmental aspects / criteria for assessment. Maintenance works are scheduled by the civil works team based on priority / severity of maintenance issue.

When a well comes to the end of its productive life or if the well is drilled and deemed uneconomic to move to the 'complete' phase, a decision is made to decommission the well. The primary objective of well decommissioning is to isolate hydrocarbon and water bearing formations and eliminate migration pathways (between the reservoir, other formation / aquifers and surface). Wells earmarked for decommissioning are subject to individual evaluation to determine the most appropriate decommissioning program.

Perforated hydrocarbon zones are isolated with cement plugs and / or bridge plugs and cement bond logs (CBL) used and assessed to ensure that the cement behind the production casing is adequate to avoid migration pathways. If isolation is not evident behind the production casing following CBL integrity checking, the casing will be perforated and squeezed (with cement) to effect isolation. An additional cement plug is placed in the surface casing prior to cutting off the well head below ground level.

Consideration of the following is taken into account when plugging and decommissioning the well:

- isolate all formations that have hydrocarbon shows;
- isolate formations with different pressure regimes;
- set plugs across intermediate casing shoe (if present) to minimise the potential for cross flow between aquifer systems and hydrocarbon bearing intervals;
- set plugs across surface casing shoe; and
- at the surface set a plug in the well prior to cutting off the surface casing bowl.

Final rehabilitation of the well and lease area would include removing the well head, surface infrastructure and fencing; capping the well; filling in pits; respreading topsoil (after preparation) and revegetating the site to match its pre-disturbance vegetation type. Infrastructure that is useful to the landowner (for example pits or hardstand areas) may be handed over to the landowner in accordance with EA conditions.

4.4.2. Gathering line and pipeline RoW rehabilitation (following installation)

Gathering line and pipeline RoWs are cleared, gathering and pipelines installed, and the trench and RoW is reinstated in quick succession.

This methodology reduces exposure of unprotected subsoils, preserves topsoil characteristics e.g. structure, native seed bank etc, and minimises potential impacts from significant rainfall events.

As per relevant EA conditions, gathering line and pipeline trenches must be backfilled, and topsoils reinstated within three months after pipe laying.

RoW reinstatement is undertaken to ensure the following:

- a stable landform;
- re-profiled to a level consistent with surrounding soils;
- re-profiled to original contours and established drainage lines; and
- vegetated with groundcover which is not a declared pest species, and which is established and growing.

In addition, RoWs (including ancillary infrastructure i.e. temporary laydowns) are reinstated immediately following pipeline construction (typically within 3 months or in accordance with EA conditions) with considerations made for a range of factors including Erosion and Sediment Control (ESC), soil amelioration, fertiliser and seeding. These considerations are applied to ensure timely (within 6 months) revegetation of the pipeline RoW.

Santos has standardised watercourse reinstatement designs that are assigned to crossings based the site-specific risk profile (refer to standard watercourse designs drawings in Appendix 2). Watercourses are assessed as part of the planning phase and designs advised for each crossing based on several inputs e.g. soil type, catchment, modelled flows, bank profiles. There are five key options for reinstatement, three standard reinstatement designs (low, medium and high), a fourth site-specific design and a fifth where standard pipeline reinstatement is deemed adequate.

4.4.3. Gathering line and pipeline decommissioning

At the cessation of production, gas and water gathering lines and pipelines are isolated from the wellhead and other connection points i.e. risers and tie-in locations. Once isolated, gathering lines are drained/purged, vented and capped in accordance with the *Australian Pipeline Industry* (APIA) *Code of Environmental Practice - Onshore*

Pipelines (Revision 5) (2022) or applicable code in place at the time of decommissioning. Subsurface components of the gathering network are drained / purged, cleaned and left in-situ, and the RoW is then rehabilitated in accordance with relevant EA conditions. Subsurface pipelines proposed to be abandoned in-situ will be decommissioned in such a way to ensure that ground subsidence and the risk of contamination of the soil or groundwater is minimised. Further, where there is a potential risk of collapse or subsidence, consideration will be given to filling the abandoned pipeline with an inert substance e.g. filling the pipeline with cement to mitigate collapse at road crossing locations.

4.4.4. Access tracks

Access tracks and roads no longer required for petroleum activities will be initially offered to the underlying landholder as an asset. Any access tracks and roads unwanted by the landholder will be rehabilitated.

Access tracks would be rehabilitated or handed over to the landowner in accordance with relevant EA conditions (and State requirements i.e. in accordance with DETSI Guideline *Petroleum activities Transferring petroleum infrastructure to landholders Versions 2.01 - ESR/2020/5403*). If rehabilitation is required, rehabilitation will include removal of any gravel, ripping, levelling and re-profiling to reinstate natural contours of the land (including any watercourses) and revegetating to match the surrounding land-use. For unsealed roads and tracks the key techniques to minimise erosion and damage are good shaping (camber, elevation etc.) and good drainage. These techniques are imbedded in the standardised construction designs.

Watercourse crossings are assessed as part of the early planning phase and designs advised for each crossing based on several inputs e.g. soil type, catchment, modelled flows, bank profiles. In some instances, the standardised design is deemed unsuitable, and a site-specific design will be developed.

When planning for roads, considerations are made for existing and / or proposed adjacent infrastructure. Where construction occurs alongside adjacent infrastructure, the erosion and sediment controls marry into both pieces of infrastructure so as to not cause unwanted drainage or erosion impacts from one to the other i.e. surface waters are controlled across the entire disturbance footprint.

Roads will undergo routine maintenance grades throughout the life of the infrastructure. These will typically follow high vehicle traffic and / or wet weather. In addition to the routine maintenance, any unforeseen issues are captured and stored within a central database for priority maintenance.

4.5. Water Management and Monitoring

4.5.1. Groundwater monitoring

The groundwater monitoring requirements for petroleum tenure holders within the Surat CMA are provided as part of the UWIR Water Monitoring Strategy (WMS) which establishes baseline trends, identifies any changes within or near petroleum development areas or locations of interest and informs future improvement of groundwater modelling.

Santos under the *Water Act 2000* (QLD) developed and implemented a WMS as stipulated in the UWIR for the Surat CMA. This comprises of groundwater monitoring at over 150 monitoring locations throughout the Surat CMA. Revisions of the UWIR may amend the WMS according to the improved understanding and certainty of groundwater risks. Further, Santos undertakes baseline assessments for relevant water bores in accordance with the requirements of the Baseline Assessments Guideline (ESR/2016/1999) and *Water Act 2000* (QLD).

4.5.2. Water supply

Preference would be given to the use of non-potable water supplies for washdown, dust suppression and construction activities where economically and practically feasible.

Santos would only extract water from constructed wetlands and other farm dams for construction purposes with the permission from the landholder when water supplies are abundant. No specific monitoring of water quality within the constructed wetland is proposed given Santos' minimal use.

4.5.3. Water management

Water management will be undertaken in accordance with this EMP which has been developed to meet the requirements of the Queensland government's *CSG Water Management Policy 2012* (DESI, 2023). The *CSG Water Management Policy* guides operators in managing CSG water to comply with their EA requirements and encourages the beneficial use of CSG water in a way that protects the environment and maximises its productive use as a valuable resource.

Portable tanks used to temporarily hold produced water on site will be designed and constructed in accordance with relevant Australian Standards.

4.5.4. Produced water monitoring

Produced water quality will be monitored in accordance with the EMP, *Stimulation Impact Monitoring Program*, and as required by relevant EA conditions and the EoW Code *Irrigation of Associated Water (including coal seam gas water)* (ENEW07546918).

4.5.5. Surface water monitoring

Turbidity monitoring will be carried out during the construction and maintenance of linear infrastructure crossings of watercourses to ensure water release limits specified in relevant EA conditions are complied with. However, in accordance with EA conditions, Santos preferentially undertakes construction and maintenance of linear infrastructure crossings of watercourses during periods of no or very low flows.

4.6. Bore management

The *Water Act 2000* outlines requirements for make good obligations of a resource tenure holder for a bore located in immediately affected areas. Tenure holders must carry out a bore assessment and enter into a make good agreement with the bore owner if the bores are located within an immediately affected area. The UWIR assigns bores to tenure holders located within immediately affected areas.

Santos will comply with make good agreements required in future updates of the UWIR and undertake bore assessments as required as a result of make good obligations. Any required bore assessments will be undertaken in accordance with the Queensland government's *Bore Assessment Guideline* (ESR/2016/2005). If it is determined through the bore assessment that a bore has, or is likely to have, an 'impaired capacity' the make good agreement must provide details on the make good measures to be undertaken by the resource tenure holder to 'make good' the impact. Santos will comply with the *Bore Assessment Guideline* and any make good agreements that are determined to be required for the Project Area.

5. Implementation of EMP

This EMP will be implemented by Santos from the commencement of site mobilisations until completion of Project activities.

5.1. General environmental duty

All persons have a responsibility for their own environmental performance and compliance with the "*General Environmental Duty*" as described in section 319 and 320, chapter 7 of the EP Act:

All Santos staff, contractors, and subcontractors, are required to:

- comply with all requirements of environmental legislation;
- comply with specific requirements of the relevant EA and associated approvals / licences;

- undertake all activities in accordance with the agreed management plans, procedures, work method statements and safe work method statements (SWMS);
- ensure they are aware of the contact person regarding environmental matters;
- report any activity that has resulted in, or has the potential to result in an environmental incident or non-compliance;
- participate in investigations and undertake corrective actions (where required) to reduce or remediate environmental harm or to prevent the re-occurrence of an incident; and
- ensure they attend any environmental training provided.

5.2. Roles and responsibilities

Santos will be responsible for the implementation of environmental management procedures and mitigation measures contained in the relevant EA and its conditions, any EPBC Act decision / approval and conditions, and this EMP. All employees and contractors will meet the requirements of these documents.

Responsibility for a particular piece of infrastructure, such as a well lease, will depend on the phase of development and activities being carried out on the infrastructure at the time.

SMS operating standards and related procedures require all role levels at Santos to have an applicable role description which defines responsibilities and accountabilities including those relating to environmental and safety compliance.

Please see below the roles and responsibilities of personnel.

5.2.1. Project Director

The Project Director is responsible for:

- ensuring the SMS operating standards and EMP are established and implemented effectively throughout the life of the Project to achieve legislative compliance and acceptable standards for safety, health and environment performance;
- providing appropriate training to foster awareness of risks, ensure implementation of relevant controls and maintain acceptable standards of health, safety and environmental performance;
- encouraging all personnel to maintain acceptable standards of health, safety and environmental work practices and foster awareness of health, safety and environmental matters; and
- encouraging all incidents, events and other concerns to be reported and ensuring appropriate feedback on proposed corrective actions.

5.2.2. Construction Manager

The Construction Manager will be responsible for:

- preparation, review and approval of environmental documentation (including management plans, procedures and work instructions) prior to commencement of work;
- incorporation of key environmental aspects and associated impacts in the ECPs to maintain safety, quality and environmental standards to the highest level across the works;
- overall planning, coordination and control of the Project from inception to completion;
- maintaining safety, quality and environmental standards to the highest level across the works;
- environmentally acceptable work methods and practices and proper operation and maintenance of plant and equipment to maintain safety, quality and environmental standards to the highest level across the works;

- leading and managing all aspects of each site on a daily basis to ensure all personnel implement and adhere to the requirements of this EMP;
- promoting environmental awareness of all personnel on site;
- ensuring construction activities are undertaken in accordance with the requirements of the EMP including timely planning and effective communication;
- ensuring potential hazards are identified, risk-assessed and control measures are planned and implemented in consultation with all relevant personnel; and
- participating in environmental incident and non-conformance report investigations and ensuring that any proposed corrective and preventative action effectively implemented.

5.2.3. Environment Adviser

The Environmental Advisor is responsible for:

- ensuring that all relevant environmental approvals and permits are in place for the scope of work, prior to commencing construction activities;
- assurance for implementation and effectiveness of environmental controls and reporting required to achieve legislative compliance;
- reviewing performance against environmental objectives and performance indicators;
- reviewing implementation of ECPs to effectively minimise the potential impact to the environment as a result of construction activities;
- undertaking periodic assurance inspections to review suitable control measures were implemented in line with commitments in this EMP and provide feedback to improve ongoing implementation;
- ensuring all environmental monitoring activities and processes occur as required;
- assist in the review of environmental control measures to assess their ongoing applicability and effectiveness;
- assist all staff and contractors engaged to work on site are appropriately inducted and trained in the environmental issues and controls relevant to the Project, and provide assurance function for the following tasks:
  - being the principal source of functional environmental expertise available to Santos personnel;
  - facilitate environmental reporting requirements for the duration of the Project;
  - facilitate reporting of significant environmental incidents internally and externally (as required by regulator); and
  - participating in environmental incident and non-conformance report investigations and ensure that any proposed corrective and preventative action effectively implemented.

5.2.4. Contractors and subcontractors

All Santos contractors, and subcontractors, are required to:

- comply with legislative requirements, conditions of approval, including EA and EPBC Act conditions and other permits;
- undertake all activities in accordance with the agreed management plans, procedures, work method statements and SWMS;
- report any activity that has resulted in, or has the potential to result in an environmental incident or non-compliance;

- participate in investigations and undertaking corrective actions (where required) to reduce or remediate environmental harm or to prevent the re-occurrence of an incident; and
- attend any environmental training provided.

5.3. Inductions and training

The SMS operating standard defines expectations for ensuring employees, contractors and visitors have the necessary knowledge and skills to conduct their activities safely, in an environmentally responsible manner and without damaging plant and equipment.

All personnel working or visiting a Santos site or premise must complete the appropriate EHS inductions. Training and induction records are maintained for staff and contractors.

The following levels of induction are required:

Applicable Personnel	Induction Requirements
Santos personnel and contractors working on Eastern Queensland assets	Level 2 Onshore Induction Level 2 Environment, Health and Safety induction for Eastern Queensland
Santos personnel and contractors working in Eastern Queensland operational sites	Level 3 Site-Specific induction for staff and contractors attending the field Land Access - QLD induction Biosecurity Management at Santos
If working or driving in the field	Heat Stress training Safe Driver Training

Level Two inductions are maintained by a delegate of the sites / premises and provide information on the location's significant EHS hazards and controls implemented to minimise risk as well as the location's generic emergency response protocols. The Level Two induction is available on-line.

Level Three inductions are maintained by a delegate of the location / activity and provide information on significant EHS hazards and controls implemented to minimise risk as well as site-specific emergency response protocols. The Level Three Induction is specific to the field location.

5.3.1. Environmental awareness training

Santos and contractors must facilitate employees and subcontractors to undergo environmental awareness training through a site induction prior to the commencement of construction activities. The environmental awareness training will cover significant environmental aspects, actual or potential impacts associated with the construction activities (e.g. flora & fauna management, erosion and sediment control, waste management and hydrocarbon and chemical management) and environmental management processes, controls and onsite responsibilities.

5.3.2. Pre-start meetings

Pre-start meetings with site personnel will be convened throughout construction activities. The meetings will detail work planned for the day and cover weather forecast, site conditions, recent environmental issues / incidents and future environmental requirements to be planned / scheduled and responsibility assigned.

5.3.3. Toolbox talks

As a minimum toolbox talks will be conducted on a monthly basis, to discuss construction relevant environment matters and will be attended by staff, contractor personnel and sub-contractors. Additional site toolbox talks may also occur in the field with specific crews and may cover topics outlined for specific tasks, or as identified by the Construction workers themselves. Environmental toolbox topics may include, but are not limited to, Santos's legislative commitments, contractual requirements, emergency spill response an incident management, soil

management and erosion and sediment control, flora and fauna, water, dust, fuel and chemical management. All records of such toolbox talks and attendees register must be kept on file for auditing purposes.

5.4. Incidents and emergencies

Santos has developed the operating standards and procedures relating to incident and crisis management. These documents require a risk-based emergency and crisis management framework be in place which includes:

- a tiered response and management structure with defined criteria and authority levels for enacting each level of response;
- emergency preparedness and response plans based on credible scenarios and risks where required by legislation;
- sufficient equipment, facilities and trained personnel available to enact plans;
- scheduled emergency and crisis preparedness activities; and
- review of findings from exercises and actual events to identify learnings and opportunities for improvement.

All incidents including environmental incidents, non-conformance events and complaints are recorded electronically and managed through the Santos Incident Management System (IMS) in EHS Toolbox.

EHS incidents and near misses are investigated in order to identify the causal factors and associated underlying systemic weaknesses (root causes). The process to determine the correct level of incident investigation is outlined in the relevant SMS Operating Standard.

The DETSI Pollution Hotline will be notified by the relevant environmental advisor within 48 hours of becoming aware of various prescribed incidents including, but not limited to:

- unauthorised significant disturbance to land;
- unauthorised release of contaminants above thresholds described in the EA; and
- potential or actual loss of well integrity.

Depending on the risk, and in addition to the contractors investigation (if involved), environmental incidents may be investigated by Santos in accordance with Santos' incident investigation process.

Upon completion of the investigation, the findings and recommendations will be distributed to relevant personnel force via daily prestart meetings. Where lessons are learnt from the investigation or current procedures are identified as being ineffective or inadequate, the EMP or other pertinent documentation will be revised to include the improved procedures or requirements.

In the event a contractor performing works on behalf of Santos is involved in an environmental hazard, near miss or incident, the Santos Construction Manager must be notified. Where an environmental incident occurs, verbal notification to the Santos Construction Manager must be given as soon as possible. An incident response report is to be completed by the contractor detailing the incident itself and all identified corrective and preventative actions. Where incidents are classified as moderate or higher a more detailed investigation is to be completed with a final report provided to Santos. All reporting must be completed in accordance with the requirements and timeframes outlined in the relevant operating standard.

5.5. Complaints management

Santos records and manages responses to complaints within a Stakeholder Relationship Management System (SRMS). All complaints received are recorded in the SRMS and assigned a Complaints Handling Officer to manage the complaint. The Complaints Handling Officer is responsible for ensuring the complaint is adequately investigated, gathering facts and information to inform a recommended course of action and communicating with the complainant. All complainants are responded to verbally and then in writing with an appropriate plan to

address the complaint including remedial action if necessary. Once the complaint has been resolved Santos checks whether the complainant is satisfied. It is only then that the complaint is closed out.

All complaints received by any contractor performing works on behalf of Santos must be referred to the Santos Construction Supervisor and Environmental Advisor as soon as practicable.

5.6. Monitoring, inspections, audits and corrective actions

The Santos *Risk Management, Investigation and Assurance Operating Standard* (Standard) outlines the requirements to provide assurance that EHS systems and processes are effectively implemented, fit for purpose and are meeting relevant statutory requirements. The key assurance levels of the Standard are summarised below:

- **Level one** assurance activities performed by frontline leadership, must be conducted to ensure that front-line controls are in place and operating effectively for the management of risk; and compliance with controls is monitored and maintained.
- **Level two** assurance must be performed by management and senior management on planned basis and within defined timeframe must occur to confirm effectiveness of level one assurance and must also establish an escalation mechanism to receive reports on any material or systemic control failures or weaknesses.
- **Level three** assurance must only be conducted by independent internal parties (Functions / Divisions) and external third parties, such as the statutory financial external audit or other independent audits commissioned by Santos. This includes annual internal audit plans approved by the Audit & Risk Committee of the Board.

Assurance must be built into processes, including Core Business Processes, at appropriate intervals rather than leaving to the end of the process. Control improvement actions arising from assurance activities must be recorded, monitored, and tracked to completion. Lookbacks must be conducted for transactions approved by the Board as identified by the Managing Director and CEO.

Monitoring will be carried out in accordance with relevant EA conditions and EPBC Act approval conditions (once granted), and other relevant environmental approvals / permits.

5.6.1. Environmental inspections

Inspections will be documented on a checklist that will record whether the performance requirement for each item was achieved, and corrective actions required to achieve the performance requirement. Where the non-conformance does not present a significant risk of environmental harm, and can be corrected promptly, the corrective action will be closed out on the checklist. Where the risk of environmental harm is more significant and / or the corrective action cannot be undertaken promptly, the action will be recorded in the corrective action register.

The corrective action process consists of the following steps:

- identification of a problem (failure or deficiency);
- root cause analysis to identify causes and determine solutions;
- decision as to the appropriate action;
- application and documentation of corrective or preventative action; and
- follow-up and evaluation.

Corrective actions in relation to environmental management may arise from:

- recommendations and outcomes of incident investigation reports, including investigations into incidents, near misses and non-compliances;
- reviews of monitoring results indicating that performance requirements are not being met and / or that trends indicate that environmental degradation may be occurring;
- checks and inspections (note that minor corrective actions identified through checks and inspections will generally be resolved on the spot);
- identification of hazards or improvement opportunities;
- audit recommendations; and
- complaints.

5.6.2. Internal (Santos) assurance inspections

Site inspections will be conducted regularly by Santos during active works. Inspections will be carried out to assess activities against compliance requirements set out in this EMP, EA conditions and EPBC Act approval conditions (once granted), and other relevant environmental approvals / permits.

Additional environmental inspections will be carried out to monitor work practices and conformance to the EMP requirements and any relevant overarching legislative criteria. Non-conformances identified will be issued to the contractor through the relevant contractual communication mechanism for action e.g. Site Instruction.

5.6.3. Contractor and subcontractor inspections

Environmental monitoring and inspections must be undertaken by contractor personnel to ensure compliance against applicable legislation and EMP requirements. All inspection and monitoring data is to be made readily accessible and available to Santos.

Inspections must be conducted, documented and results provided to relevant Santos personnel. Areas identified as requiring corrective and preventive action must be raised within the Contractor's management system and relevant contractor personnel issued corrective actions for close out. This process must be managed by the Contractor.

Inspections must be carried out by the Contractor regularly throughout the construction period to adequately address inherent environmental risks present throughout construction.

5.6.4. Plant and equipment inspections

Prior to mobilising plant to site, a pre-mobilisation plant checklist, including environmental checks is to be completed by the contractor. Prior to arrival at the site, a declaration regarding the weed status of all plant and mechanical equipment is to be made, by completing a Vehicle Hygiene Report. All plant, including tracked or wheeled mechanical equipment is to be inspected on arrival at the site and before commencing construction work.

Additionally, plant operators must conduct their own daily inspections and routine maintenance checks throughout construction.

5.7. Reporting and record keeping

This EMP and all associated, documents and registers will be controlled documents subject to unique document identifiers and version control. Corrective actions will be tracked on a register / database to ensure that updates on the status of corrective actions are available to managers and supervisors.

Other documentation and records to be retained will include:

- incident investigation reports;
- remedial actions taken following incident reports;

- completed site checklists;
- records of training and induction;
- audit reports;
- records of waste removal including waste tracking certificates; and
- all monitoring records.

Reporting will be carried out in accordance with relevant EA conditions and EPBC Act approval conditions (once granted), and other relevant environmental approvals / permits.

All records and data required to be maintained by relevant approval conditions will be retained as specifically required, or for a minimum of 5 years.

6. Environmental Management

6.1. Environmental objectives and performance outcomes

Table 4 identifies environmental objectives and performance indicators (and compliance requirements) for each environmental aspect in the Project Area.

Planning, Objectives and Targets aim to be:

- quantified and measurable;
- realistic and achievable;
- focused on continual improvement;
- consistent with, and related to, Santos's Environment Policy and management standards;
- periodically reviewed and, if required, revised; and
- performance indicators will be reviewed as part of the EMP review.

Table 4: Environmental objectives and performance indicators (and compliance requirements)

Aspect	Objectives	Performance indicators (and compliance requirements)
Water resources	• avoid or minimise impacts to groundwater and surface water values. • avoid or minimise impacts to the physical integrity, fluvial processes and morphology of watercourses and wetlands. • for ephemeral watercourses, undertake works as a priority during periods with no flow to very low flow. • erosion and sediment control devices maintained and fit for purpose as required. • no water contamination by wastes, hydrocarbons or other chemicals used during petroleum activities that result in serious or material environmental harm. • implementation of (as applicable): – Constraints Protocol (Santos, 2025c). – Code of Practice for the construction and abandonment of petroleum wells and associated bores in Queensland Version 2 QLD, Australia (DNRME, 2019) (The Code). – Roma Phase 7-7B-SD20 EPBC Act Water Resource Impact Assessment Report (WRA) (KCB, 2025). – relevant EA and EPBC Act decision conditions (once granted) – Roma Phase 7-7B-SD20 CRAF (Santos). – EOW Irrigation of Associated Water (including coal seam gas water) (ENEW07546918); and – no production wells installed within 90m of a landholder bore.	• erosion and sediment controls are implemented. • no release of produced water to surface waters. • turbidity monitoring undertaken in accordance with relevant EA conditions. • works involving significant disturbance near watercourses and wetlands are in accordance with relevant EA conditions. • impacts to existing groundwater bores are managed in accordance with 'make good' provisions in the *Water Act 2000*. • produced water utilised onsite in accordance with relevant EA conditions / EOW ENEW07546918. • compliance with (as applicable): – Constraints Protocol. – The Code. – WRA. – EA and EPBC Act decision conditions (once granted). – CRAF. – EOW ENEW07546918; and – no production wells installed within 90m of a landholder bore.

Aspect	Objectives	Performance indicators (and compliance requirements)
Soil and land resources	• avoid or minimise adverse impacts to the quality and stability of soils. • reinstate and rehabilitate authorised disturbances to a safe, stable and non-polluting landform suitable for its intended ongoing land use. • avoid or minimise adverse impacts to the quality and stability of soils. • ground disturbance minimised as far as practicable. • no soil contamination by wastes, hydrocarbons or other chemicals used during petroleum activities that result in serious or material environmental harm. • implementation of: – RMP. – Constraints Protocol. – The Code. – WRA. – EA and EPBC Act decision conditions (once granted); and – this EMP.	• erosion and sediment controls are implemented. • release of contaminants to land (including treated sewage effluent and RDM) is in accordance with EA conditions. • fuels and chemicals are stored in accordance with relevant Australian Standards. • produced water utilised onsite in accordance with EA conditions / EOW ENEW07546918. • significantly disturbed land is rehabilitated to a safe, stable and non-polluting landform suitable for its intended ongoing land use. • compliance with: – RMP. – Constraints Protocol. – WRA. – The Code. – WRA. – EA and EPBC Act decision conditions (once granted); and – this EMP.
Flora and fauna	• avoid or minimise impacts to terrestrial and aquatic ecosystems and associated flora, fauna and habitat of state (Matters of State Environmental Significance) and national significance (MNES). • avoid or minimise habitat loss and fauna mortality. • a suitably qualified Fauna Spotter / Catcher will be present during vegetation clearing activities where required; and fauna found to be present within areas to be cleared shall be managed, removed and / or relocated by the Fauna Spotter / Catcher where appropriate, and in accordance with the requirements of this EMP and the SSMP. • hollow logs (located on ground) within disturbance areas retained and shifted to adjacent undisturbed areas where practicable. • measures implemented to reduce risks to fauna from earthworks, vegetation clearing, and entrapment in excavations in accordance with the SSMP. For example, checking open trenches for trapped fauna, use of hessian bags, trench ladders, ramps, sticks, ropes (or similar) to assist trapped fauna escape / survive until they are removed by a Fauna Spotter / Catcher.	• compliance with: – EA and EPBC Act decision conditions (once granted). – Constraints Protocol (including post-EPBC Act approval authorised disturbance limits); and – SSMP.

Aspect	Objectives	Performance indicators (and compliance requirements)
	• active work areas, pits, and other areas hazardous to fauna and stock must be fenced or covered to prevent access. • implementation of: – EA and EPBC Act decision conditions (once granted). – Constraints Protocol (including post-EPBC Act approval authorised disturbance limits); and – SSMP (Santos, 2025d).	
Weeds and pests	• to prevent the introduction, and spread, of invasive weeds and pest animals to the Project Area. • all reasonable and practicable measures will be taken to prevent the introduction, and spread, of invasive weeds and pest animals to the Project Area. • implementation of: – EA and EPBC Act decision conditions (once granted); and – this EMP.	• no introduction of invasive weeds or animals that are classified as Prohibited or Restricted Matter by the Biosecurity Act to the Project Area as a result of authorised activities. • valid weed hygiene certification maintained at all times for vehicles, plant, machinery and equipment. • compliance with: – EA and EPBC Act decision conditions (once granted); and – this EMP.
Rehabilitation	• all significantly disturbed areas caused by petroleum activities are to be rehabilitated to be non-polluting, stable, re-profiled to have contours consistent with surrounding land, surface drainage lines re-established, topsoil reinstated, and groundcover and vegetation is to be consistent with surrounding vegetation cover and species richness. • significantly disturbed areas that may be of value as an asset to the underlying landholder (i.e. access tracks) will be offered to the landholder prior to rehabilitation commencing. Any significantly disturbed areas unwanted by the landholder will be rehabilitated.	• significantly disturbed land is rehabilitated to a safe, stable and non-polluting landform suitable for its intended ongoing land use. • significantly disturbed land is rehabilitated to meet the final rehabilitation criteria specified in the Project's RMP and EA, or otherwise be handed over to the landholder.
Noise	• protect noise environmental values within and around the Project Area.	• noise emissions are avoided, reduced and mitigated wherever practicable. • noise emissions generated by petroleum activities do not exceed relevant noise nuisance limits stipulated by the EA, other than where an alternative arrangement is in place. • noise emissions do not cause environmental nuisance at a sensitive place, other than where an alternative arrangement is in place. • noise complaints are investigated, monitored and resolved in accordance with environmental nuisance monitoring requirements of the EA. • compliance with:

Aspect	Objectives	Performance indicators (and compliance requirements)
		– EA and EPBC Act decision conditions (once granted).
Air	• protect air environmental values and around the Project Area.	• air emissions are avoided and reduced wherever practicable. • dust emissions are adequately suppressed i.e. via road watering. • air quality complaints are investigated, monitored and resolved in accordance with the environmental nuisance monitoring requirements of the EA. • compliance with: – EA and EPBC Act decision conditions (once granted). – Air quality objectives (measured at a sensitive receptor) prescribed by Schedule 1 of the Environmental Protection (Air) Policy 2019.
Hazardous Substances	• to minimise the risk of environmental contamination or harm by correctly storing, handling, using, recycling and disposing of hazardous substances.	• all chemicals, oil and fuel must be labelled, handled, stored and effectively contained, and transported in accordance with relevant Australian Standards and Australian Dangerous Goods Code (ADG Code). • register and SDS for all hazardous substances available on site. • spill kits available on site and maintained. • no uncontrolled release of chemicals, oil or fuel is to occur to the environment.
Liquid and solid waste	• minimise generation of waste and avoid or minimise impacts associated with waste generation and storage. • apply the waste management hierarchy and principles based on waste avoidance, reduction, reuse, recycling, treatment and disposal. • implementation of: – CRAF. – EOW ENEW07546918. – EA and EPBC Act decision conditions (once granted). – waste transport and tracking requirements under the EP Act.	• produced water used in accordance with EA conditions and EOW ENEW07546918. • produced water that cannot be beneficially reused in the Project Area is transferred to existing waste management facilities on adjoining tenures for management and beneficial reuse in accordance with the EA conditions and EOW ENEW07546918. • general and regulated waste is separated and managed in accordance with the requirements of the EP Act. • land application of RDM is in accordance with EA conditions. • regulated waste is transported by a person who holds the appropriate authority under the EP Act. • waste tracking certificates and / or log books are maintained as required under the EP Act. • odour or other complaints relating to waste management are investigated, monitored and resolved in accordance with the relevant nuisance monitoring requirements of the EA.

Aspect	Objectives	Performance indicators (and compliance requirements)
Plant and equipment	• ensure plant and equipment are operated and maintained to minimise environmental impacts / noise and air emissions/ incidents. • ensure plant and equipment are cleaned to minimise weed spread and comply with landholder agreement requirements.	• plant and equipment maintained in accordance with the manufacturer's recommendations. • daily pre-start checks completed for all plant and equipment. • weed hygiene certificates available for all applicable plant and equipment. • all access to private property must be in accordance with landholder agreements.
Stimulation activities	• avoid or minimise impacts to groundwater, surface water and aquatic ecology environmental values. • manage stimulation activities to minimise the risk of adverse environmental impacts. • implementation of a stimulation impact monitoring program in accordance with EA conditions.	• stimulation activities do not negatively affect water quality, other than that within the stimulation impact zone of the target gas producing formation. • a stimulation impact monitoring program is implemented in accordance with the EA conditions. • stimulation activities do not cause a connection of the target gas producing formation and another aquifer. • a stimulation risk assessment is carried out for wells prior to stimulation in accordance with relevant EA conditions.
Community and social	• avoid or minimise adverse impacts on community and social values. • implementation of: – Santos Social Impact Management Plan (SIMP) (Santos, 2012).	• consultation with directly and indirectly affected stakeholders is undertaken. • minimal community complaints are made and those received are effectively resolved. • emergencies and other incidents are infrequent and managed effectively to ensure limited impacts on the community. • implementation of relevant initiatives and actions in the SIMP.
Cultural heritage	• avoid impacts to known places of cultural heritage value. • avoid or minimise impacts to unknown places of unknown heritage value. • no unauthorised harm to areas or items of cultural heritage value at the site. This includes both indigenous and non-indigenous cultural heritage values. • implementation of: – Santos Cultural Heritage Management Plan (CHMP) (Santos, 2009).	• comply with requirements of the CHMP. • correct procedures are followed in event an item of cultural heritage significance is found. • no avoidable loss or disturbance of items or areas of cultural value due to Santos' activities. • no valid complaints related to impacts on cultural heritage from the local community or traditional owners.
Traffic	• minimise impacts on the road network and infrastructure. • ensure safe operation of vehicles and machinery by Santos and maintain road user safety for all.	• Santos safe driving programs are implemented (including training and use of In Vehicle Monitoring Systems (IVMS)).

Aspect	Objectives	Performance indicators (and compliance requirements)
		• comply with Queensland Department of Transport and Main Roads (DTMR) and Maranoa Council road construction, use and permit notification requirements i.e. road corridor permit, road works approval.
Environmental emergency preparedness and response	• minimise the potential for environmental emergencies and be able to respond effectively in the event of an environmental emergency.	• spill kits available and maintained. • daily pre-start checks completed for all plant and equipment. • plant and equipment maintained in accordance with the manufacturer's recommendations. • undertaking of regular inspections, maintenance and integrity checks. • regular monitoring of weather and fire conditions. • fire controls in place for hot works. • no burning of wastes on site. • site tidy and maintained at all times. • smoking only in designated areas. • emergency response procedures in place. • compliance with: – EA and EPBC Act decision conditions (once granted).

6.2. Environmental control plans

The following section comprises the ECPs, which have been developed to document site-specific environmental management measures to be implemented throughout development of the Project.

The ECPs have been developed to achieve ongoing environmental compliance with regulatory requirements and ensure implementation of best practice environmental management strategies.

A brief summary of each ECP is available in Table 5.

Table 5: Environmental Control Plans

ECP	Key Content
1. Construction site management	Measures for general construction site management to minimise risks to environmental values from site establishment through to demobilisation and handover
2. Soil resource management	Management measures to minimise the risk of degrading soil resources during construction works. Includes consideration of erosion and sediment control, contaminated land and acid sulfate soils
3. Water resource management	Management measures to minimise the risk of degrading the quantity and quality of water (surface water and groundwater) resources during construction works
4. Flora and fauna management	Measures to protect the flora and fauna of the local area during construction works
5. Weed and pest management	Measures to reduce the risk of invasive plant and animal introduction and spread at the site or onto surrounding lands
6. Air, vibration, light and noise management	Measures to reduce the risk of environmental harm from air, light, vibration and noise emissions during construction works
7. Liquid and solid waste management	Measures to manage regulated, general and recyclable wastes from the construction works in accordance with the waste management hierarchy
8. Cultural heritage management	Measures to protect the cultural heritage values of the site and surrounding area
9. Hazardous substances use and management	Measures for hazardous substance storage, handling, use and disposal to minimise the risks of environmental contamination
10. Plant and equipment management	Measures for the maintenance and operation of plant and equipment during construction to minimise the risk of environmental harm
11. Environmental emergency preparedness and response	Measures to minimise the impacts of the three environmental emergencies that could reasonably be expected to occur at the site at some time: major chemical spill (fuel), dangerous weather events (heavy rainfall / flooding / cyclone) and bushfire.

Table 6: ECP 1 – Construction site management

ECP 1 – Construction Site Management		
Aspect		
The development has the potential to have an adverse impact on environmental values.		
Key References		
• *Environmental Protection Act 1994.*		
Potential Impacts		
• adverse impact to surrounding environmental values from construction activities.		
Management Actions	**Responsibility**	**Timing**
General		
Works will not be undertaken outside the limits of the approved plans of development.	Construction Manager	At all times
The limits of works will be clearly marked or communicated to all personnel to minimise the potential for disturbance to environmental values outside the approved development area.	Construction Manager / Environment Advisor	Prior to starting works in each area
All personnel will receive training in project-related environmental awareness as part of site induction.	Construction Manager	Prior to starting on site
Environmental exclusion zones established where necessary prior to works commencing in the surrounding area to ensure environmental or cultural heritage values (including MNES values) are protected.	Environment Advisor	As required
No unauthorised entry or works by personnel, vehicles, plant or equipment in environmental exclusion zones.	All personnel	At all times
No stockpiling or storage of any materials, plant or equipment in environmental exclusion zones.	All personnel	At all times
Environmental controls will be installed prior to the relevant activity / task commencing and maintained for the duration of its use.	Construction Manager	As required
All environmental plans, policies, procedures and other relevant information will be communicated, implemented and made available to all personnel.	Construction Manager	As required
Fuel and oil storage tanks will be self-bunded and not stored adjacent to watercourse.	Construction Manager	During site planning
Refuelling will not occur in close proximity of a watercourse	Construction Manager	During site planning
Monitoring	**Responsibility**	**Timing**
Routine site inspections.	Construction Manager	Dependent on activity levels / work schedules
Rainfall based site inspections.	Construction Manager	Prior to and following significant rainfall
All monitoring, inspection and audit data will be managed in accordance with Section 5.6 of the EMP.	Environment Advisor / Construction Manager	At all times
Reporting	**Responsibility**	**Timing**
Near misses or non-compliances with Performance Targets will be reported and managed in accordance with Section 5.4 of the EMP.	All personnel	As required
Corrective Action		
Near misses and incidents in relation to construction site management will be investigated in accordance with Section 5.4 of the EMP to identify necessary corrective actions for implementation.		

Table 7: ECP 2 – Soil resource management

ECP 2 – Soil Resource Management		
Aspect		
Construction activities have the potential to impact soil resources on or adjoining the construction site.		
Key References		
• *Environmental Protection Act 1994.* • *National Environmental Protection (Assessment of Site Contamination) Measure 1999 (amended in 2013).* • International Erosion Control Association (IECA) *Best Practice Erosion and Sediment Control 2008.*		
Potential Impacts		
• soil contamination from poor waste management, use of chemicals (namely hydrocarbons) and plant and equipment maintenance (spills and leaks of hydrocarbons). • erosion (loss of soil resource). • altered geological setting. • change to landform. • degradation of soil resources. • unauthorised / accidental release to land. • temporary reduction in land available for agriculture.		
Management Actions	**Responsibility**	**Timing**
Erosion and Sediment Control		
Erosion and sediment control will be managed so as to: • erosion: minimise the area and duration of soil exposure. • sediment: sediment controls to be suited to soils, climate and catchment size. • drainage: divert clean runoff around disturbed areas and convey drainage in a non-erosion manner.	Construction Manager	As required
Erosion and sediment controls will be installed prior to the start of ground disturbing works and maintained until the area of disturbance has been stabilised.	Construction Manager	As required
Progressive rehabilitation / reinstatement of significant disturbances in accordance with relevant EA conditions.	Construction Manager	As required.
Soil Contamination Prevention and Management		
Notify DETSI of any Notifiable Activities that are to be undertaken at the site.	Environment Advisor	Prior to undertaking a Notifiable Activity
Works will be excluded from areas where soil contamination is encountered that presents a risk of actual or potential material or serious environmental.	Environment Advisor	As required
The construction will be managed and designed in accordance with ECP 1: Construction Site Management to minimise the risk of soil contamination.	Construction Manager	At all times
Liquid and solid wastes will be managed in accordance with ECP 7: *Liquid and Solid Waste Management* to minimise the risk of soil contamination.	Construction Manager / Environment Advisor	At all times
Hazardous substances (including fuel) will be used and managed in accordance with ECP 9: *Hazardous Substances Use and Management* to minimise the risk of soil contamination.	Construction Manager / Environment Advisor	At all times
Plant and equipment maintenance will be undertaken in accordance with ECP 10: *Plant and Equipment Management* to minimise the risk of soil or water contamination.	Construction Manager	At all times

ECP 2 – Soil Resource Management		
Soil and water contamination from emergency situations will be minimised by implementing ECP 11: *Environmental Emergency Preparedness and Response*.	Environment Advisor	At all times
If soil contamination presenting a risk of material or serious environmental harm is encountered at the site or occurs during construction, it will be investigated, and appropriate management / remediation strategies and notification requirements developed and implemented.	Construction Manager / Environment Advisor	At all times
The Project's RMP will be implemented to meet the final rehabilitation requirements required under the EA. This Plan may be updated when the EA is issued or amended from time to time.	Construction Manager / Environment Advisor	During and post construction activities
Monitoring	**Responsibility**	**Timing**
Site inspections.	Environment Advisor	Dependent on activity levels / work schedules
Rainfall based site inspections.	Environment Advisor	Prior to and following significant rainfall
Soil contamination testing (if required).	Environment Advisor	As required
Reporting	**Responsibility**	**Timing**
Near misses or non-compliances with Performance Targets for soil resource management will be reported and managed in accordance with Section 5.4 of the EMP.	All personnel	As required
Damage to or maintenance required by ESC measures will be reported to the Construction Manager.	All personnel	Within 24 hours
Corrective Action		
Near misses and incidents in relation to soil resource management will be investigated in accordance with Section 5.4 of the EMP to identify necessary corrective actions for implementation.		

Table 8: ECP 3 – Water resource management

ECP 3 – Water Resource Management		
Aspect		
Construction activities have the potential to impact water resources (surface water or groundwater) on or adjoining the construction site.		
Key References		
• *National Environmental Protection (Assessment of Site Contamination) Measure 1999 (amended in 2013).* • IECA *Best Practice Erosion and Sediment Control* (IECA, 2008). • *Monitoring and Sampling Manual Environmental Protection (Water) Policy 2009* (DESI, 2018). • *Environmental Protection Act 1994.*		
Potential Impacts		
• aquifer depressurisation resulting in change in groundwater flow paths and storage, decline in groundwater levels / pressure in bores and reduced supply to groundwater users, and reduced stream baseflow for groundwater dependent watercourses or springs. • subsidence altering groundwater flow paths and aquifer storage or causing ground surface displacement and altering surface water flow paths. • changes to groundwater quality resulting in degradation of groundwater supply value for beneficial use or groundwater dependent ecosystems. • increased sedimentation (effects on water quality and geomorphology). • erosion of stream banks. • surface water quality impacts. • altered surface water flow regime (risk to overland flow paths, riparian vegetation, terrestrial ecosystems and environmental flow regime).		
Management Actions	**Responsibility**	**Timing**
Surface Water Flow		
Based on the assigned risk, adopt standard crossing designs for low, medium and high-risk crossings (refer to Appendix 2).	Construction Manager	As required
Pipelines will be buried and preferentially built during periods of no flow to very low flow.	Construction Manager	As required
Erosion and Sediment Control		
Erosion and sediment control will be managed so as to: • erosion: minimise the area and duration of soil exposure. • sediment: sediment controls to be suited to soils, climate and catchment size. • drainage: divert clean runoff around disturbed areas and convey drainage in a non-erosion manner.	Construction Manager	As required
Erosion and sediment controls will be staged in line with ground disturbing works and maintained until the area of disturbance has been stabilised.	Construction Manager	As required
Erosion and sediment controls and works undertaken onsite will reference the IECA Best Practice Erosion and Sediment Control principles.	Construction Manager	As required
Minimise area of land disturbed or compacted. Minimise disturbance to instream bed and banks e.g. use geofabric as a work base.	Construction Manager	As required
Limit use of machinery in waterways.	Construction Manager	As required
Progressively reinstating / rehabilitating significant disturbances in accordance with the EA.	Construction Manager	As required

ECP 3 – Water Resource Management		
For any part of the waterway bed or banks adjacent to the works that has been altered by the waterway barrier works, the site is restored and / or rehabilitated so that as a minimum: • stability and profiles of the bed and banks are re-instated to natural stream profiles and stability. • the waterway bed is retained with natural substrate or reconstructed with substrate comparable to the natural substrate size and consistency. • site conditions allow the rapid re-establishment of native vegetation and cover or native species are replanted to re-establish the natural plant community.	Construction Manager	As required
Water Contamination Prevention and Management		
Notify DETSI of any Notifiable Activities that are to be undertaken at the site.	Environment Advisor	Prior to undertaking a Notifiable Activity
The construction will be managed and designed in accordance with ECP 1: *Construction Site Management* to minimise the risk of soil contamination.	Environment Advisor	At all times
Liquid and solid wastes will be managed in accordance with ECP 7: *Liquid and Solid Waste Management* to minimise the risk of water contamination.	Environment Advisor	At all times
Hazardous substances (including fuel) will be used and managed in accordance with ECP 9: *Hazardous Substance Uses and Management* to minimise the risk of water contamination.	Environment Advisor	At all times
Plant and equipment maintenance will be undertaken in accordance with ECP 10: *Plant and Equipment Management* to minimise the risk of water contamination.	Environment Advisor	At all times
Water contamination from emergency situations will be minimised by implementing ECP 11: *Environmental Emergency Preparedness and Response*.	Environment Advisor	At all times
If water contamination that presents a risk of material or serious environmental harm, is encountered at the site or occurs during construction, it will be investigated, and appropriate management / remediation strategies and notification requirements developed and implemented.	Environment Advisor	As required
Where minor volumes of produced water are to be beneficially reused on site, it will be stored in manufactured tanks, that are designed, constructed and operated in accordance with relevant Australian Standards and State regulations.	Construction Manager	As required
No production wells will be installed within 90 m of a landholder bore unless a site-specific assessment determines that a closer distance is appropriate.	Construction Manager	At all times
Well integrity to be verified prior to stimulation to ensure that there is no significant leakage in the casing, tubing or packer and there is no significant movement into another aquifer through vertical channels adjacent to the well bore hole.	Drilling and Completions Manager	Prior to stimulation
Authorised releases in a manner that ensures (unless otherwise authorised): • no damage to vegetation. • no adverse impact to soil quality and structure. • no ponding or runoff to surface waters. • no aerosols or odours. • deep drainage below root zone is minimised. • no adverse impact to the quality of shallow aquifers.	Construction Manager / Environment Advisor	As required

ECP 3 – Water Resource Management		
A 50 m buffer will be maintained between sewage effluent irrigation areas and watercourses, wetlands or significant vegetation and a 100 m buffer from potable water supply or stock drinking water.	Construction Manager / Environment Advisor	At all times
Use of Water Resources		
Preference will be given to the use of non-potable water supplies for washdown, dust suppression and construction activities where economically and practically feasible.	Environment Advisor	During construction planning
Only extract water from constructed wetland and other farm dams for construction purposes with the permission from the landholder and when water supplies are abundant.	Construction Manager / Environment Advisor	As required
Road watering will only be undertaken when necessary to control dust emissions.	Construction Manager / Environment Advisor	As required
Water use for dust suppression and vehicle washing will be minimised as far as practicable.	Construction Manager / Environment Advisor	At all times
Monitoring	**Responsibility**	**Timing**
Routine site inspections.	Construction Manager / Environment Advisor	Dependent on activity levels / work schedules
Rainfall based site inspections.	Construction Manager / Environment Advisor	Prior to and following significant rainfall
Water quality monitoring downstream of works in watercourses to confirm compliance with release limits specified under the EA.	Construction Manager / Environment Advisor	As specified under EA
Water quality testing of contaminated water (if required).	Environment Advisor	As required
Water use in the vehicle wash and for dust suppression will be monitored and recorded.	Construction Manager / Environment Advisor	At all times
Regular inspections, maintenance and integrity checks on produced water storage tanks will be undertaken.	Construction Manager / Environment Advisor	As required
All monitoring, inspection and audit data will be managed in accordance with Section 5.6 of the EMP.	Construction Manager / Environment Advisor	At all times
Reporting	**Responsibility**	**Timing**
Near misses or non-compliances with Performance Targets or for water management will be reported and managed in accordance with Section 5.4 of the EMP.	All personnel	As required
Damage to or maintenance required by ESC measures will be reported to the relevant Project Engineer.	All personnel	Within 24 hours
Corrective Action		
Near misses and incidents in relation to water resource management will be investigated in accordance with Section 5.4 of the EMP to identify necessary corrective actions for implementation.		

Table 9: ECP 4 – Flora and fauna management

Santos has developed a Significant Species Management Plan (SSMP) (Santos, 2025d) for the Project to guide the management of potential impacts to MNES values located in the Project Area. This SSMP in conjunction with the Constraints Protocol (Santos, 2025c) provides Santos with the tools to systematically identify relevant significant species and implement management measures during the course of conducting petroleum activities in the Project Area. Refer to the SSMP for further information.

ECP 4 – Flora and Fauna Management		
Aspect		
Construction works near or within environmentally sensitive areas		
Key References		
• *Animal Care and Protection Act 2001.* • *Environmental Protection Regulation 2018.* • *Stock Route Management Act 2002.* • *Nature Conservation Act 1992.* • *Nature Conservation (Animals) Regulation 2020 (NCA Regulation).*		
Potential Impacts		
• unnecessary loss of vegetation and habitats. • temporary changes in hydrology which result in vegetation loss. • accidental entrapment of fauna in open voids i.e. excavations and trenches. • mortality from moving vehicles and machinery. • erosion and sedimentation. • light disturbance.		
Mitigation Strategy / Action	**Responsibility**	**Timing**
All clearing must be internally approved and undertaken as per the requirements of the Constraints Protocol and the SSMP.	Principal Contractor / Environment Advisor	Prior to the commencement of any construction activity
Clearing areas should be clearly delineated.[2]	Principal Contractor / Environment Advisor	Prior to the commencement and during any construction activity
Reinforce need to conduct activity in designated and approved areas during site toolbox / induction meetings.	Principal Contractor / Environment Advisor	Prior to the commencement and during any construction activity
A suitably qualified Fauna Spotter / Catcher will be present during vegetation clearing activities where required; and fauna found to be present within areas to be cleared shall be managed, removed and / or relocated by the Fauna Spotter / Catcher where appropriate, and in accordance with the requirements of this EMP and the SSMP.	Principal Contractor / Environment Advisor	Prior to the commencement of and during any construction activity
Hollow logs (located on ground) / potential habitat features within disturbance areas will be retained and shifted to adjacent undisturbed areas where practicable	Principal Contractor / Environment Advisor	Prior to the commencement of any construction activity

[2] Areas can be delineated spatially using GPS technology or physically using visual markers / tape.

ECP 4 – Flora and Fauna Management		
Measures implemented to reduce risks to fauna from earthworks, vegetation clearing, and entrapment in voids. For example, checking on open trench for trapped fauna, use of hessian bags, trench ladders, ramps, sticks, ropes (or similar) to assist trapped fauna escape / survive until removed	Principal Contractor / Environment Advisor	Prior to the commencement of and during any construction activity
Open voids must be fenced or covered where practicable to prevent access or harm to the fauna. Where this is not practicable, the focus should be on regularly checking open voids for entrapped fauna and installing measures to reduce risks to potentially entrapped fauna.	Principal Contractor / Environment Advisor	During construction activities that require open voids
During construction, work areas and open voids will be regularly checked for potentially entrapped fauna.	Principal Contractor / Environment Advisor	During construction activities that require open voids
Open voids will be backfilled as soon as practicable following completion of works.	Principal Contractor / Environment Advisor	As required
Avoid providing artificial food and water sources or shelter within the construction footprint that may attract fauna.	Principal Contractor / Environment Advisor	At all times
Monitoring and Reporting	**Responsibility**	**Timing**
Unauthorised clearing will be immediately communicated to the Site Supervisor and Environmental Advisor.	Principal Contractor	As required
Fauna and stock deaths will be reported in accordance with the Santos SMS reporting procedure.	Principal Contractor	As required
Fauna Spotter / Catcher updates on interactions and reporting will be regularly provided to the Site Supervisor and Environmental Advisor.	Principal Contractor	As required

Table 10: ECP 5 – Weed and pest management

ECP 5 – Weed and Pest Management		
Aspect		
Vehicles, plant, equipment and materials required for construction may introduce invasive weeds or animals to the site.		
Key References		
• *Biosecurity Act 2014.* • DAF (2019) *Vehicle and machinery cleandown procedures.*		
Potential Impacts		
• introduction or spread of invasive weeds or pest animal species.		
Management Actions	**Responsibility**	**Timing**
All site-based personnel will receive General Biosecurity Obligation (under the *Biosecurity Act 2014*) and weed hygiene awareness training. This allows the site-based personnel to be considered a competent and trained person.	Principal Contractor / Environment Advisor	Induction

• all work vehicles, plant and equipment will be inspected and certified as clean by a competent and trained person prior to first entry to the site. This does not apply to road-only vehicles that only use well-formed and maintained tracks and roads on the site that are clear and free of vegetation, have not been contact with invasive plants and only visit the site to deliver materials or perform a particular service (e.g. septic pump out truck).
• if wash down is required, this will be undertaken by a competent and trained person in accordance with DAF (2019) *Vehicle and machinery cleandown procedures*.
• records of weed washdown and certification will be kept in the vehicle at all times and made available to landholders on request and presented to the Santos Site Supervisor upon initial entry to site.
• the certification will remain valid as long as the vehicle/equipment:
  ○ has a current weed hygiene declaration dated within the last 30 days.
  ○ does not travel off sealed roads and well-maintained unsealed roads (other than within the site).
  ○ does not come into direct contact with invasive plants.
  ○ does not operate after coming into direct contact with invasive plants.
  ○ if operating off-road, stays within the designated work area and does not cross a property boundary or other designated boundary.
	Principal Contractor / Environment Advisor	Prior to first entry to site. To be repeated as required

A Weed Hygiene Declaration will be provided by the supplier of all organic materials (soil, sand, mulch, gravel, road base, ballast etc.) brought to site.	Principal Contractor	At the time of delivery
Only registered herbicides to be used in accordance with the *Agricultural Chemicals Distribution Control Act 1966* and regulations.	Principal Contractor	As required
All personnel managing and using pesticides will be appropriately trained and licensed in accordance with the *Agricultural Chemicals Distribution Control Act 1966* and regulations.	Principal Contractor	As required
Should spraying near water be required, only pesticides registered for use near water will be used.	Principal Contractor	As required

ECP 5 – Weed and Pest Management		
Prior to the commencement of activities, personnel undertaking spraying activities will consider the potential impacts of the activities to adjoining properties, livestock, flora, fauna, and sensitive vegetation communities. Personnel will ensure there is confirmation that adjacent land users / holders have been notified of the activity, the appropriate choice of pesticide for the application, wind factor on the day, appropriate methods of targeted spraying, and access to treated plants by livestock.	Principal Contractor	As required
No domestic animals or pets will be brought to site.	All persons	At all times
Putrescible wastes (e.g. food wastes) will be covered to prevent access by vermin and removed regularly from site.	Principal Contractor	At all times
Feeding of wild animals is prohibited.	All persons.	At all times
Pest animal control will only be undertaken by contractors with appropriate permits and licenses.	Principal Contractor	As required
Mud or debris from wheels and bodies of vehicles and equipment will be removed prior to entering public roads or other sealed pavements (by means of vehicle washdown bays).	Site Supervisors	As required
Vehicles will not drive in vegetated areas that are a high risk for weed occurrence if they do not have to, stay on established tracks and roads.	All personnel	At all times
Monitoring	**Responsibility**	**Timing**
Site inspections will include identifying evidence of significant infestations of invasive plants or animals.	Principal Contractor / Environment Advisor	Dependent on activity levels / work schedules
All monitoring, inspection and audit data will be managed in accordance with Section 5.6 of the EMP.	Environment Advisor / Construction Manager	At all times
Reporting	**Responsibility**	**Timing**
Records of all weed and pest inspections and certification to be kept.	Environment Advisor and drivers and operators.	At all times
Application of any pesticide will be recorded and kept.	Environment Advisor	Within 24-hours of application of pesticide
Near misses or non-compliances with Performance Targets will be reported and managed in accordance with Section 5.4 of the EMP.	All personnel	As required
Copies of all weed hygiene certifications and declarations will be kept on the electronic record management system.	Environment Advisor and drivers and operators	At all times
If Class 1 or 2 restricted matter invasive plants or animals listed under the *Biosecurity Act 2014* are identified as present on site these will be reported to the administrating authority.	Environment Advisor	Within 2 hours of becoming aware of the matter
Corrective Action		
Near misses and incidents in relation to biosecurity will be investigated in accordance with Section 5.4 of the EMP to identify necessary corrective actions for implementation.		

Table 11: ECP 6 – Air, vibration, light and noise management

ECP 6 – Air, Vibration, Light and Noise Management		
Aspect		
Air emissions (dust), vibration emissions, light emissions and noise emissions resulting from construction activities may impact amenity at sensitive receptors.		
Key References		
• *Environmental Protection (Air) Policy 2019.* • *Environmental Protection (Noise) Policy 2019.* • *AS 2436-2010 Guide to Noise and Vibration Control on Construction, Demolition and Maintenance Sites.* • *Noise Measurement Manual* (Department of Environment and Science, 2020). • *AS 1055:2018 Acoustics - Description and Measurement of Environmental Noise.* • *Monitoring and Sampling Manual* (DES, 2018) • *AS/NZS 3580.10.1:2016 Methods for Sampling and Analysis of Ambient Air: Determination of Particulate Matter - Deposited Matter - Gravimetric Method.* • *AS/NZS 4282-2023 Control of the Obtrusive Effects of Outdoor Lighting/*		
Potential Impacts		
• reduction in noise amenity. • noise nuisance to sensitive receptors. • reduction in air quality. • generation of dust and fine particulates causing nuisance to sensitive receptors. • light nuisance to sensitive receptors.		
Management Actions	**Responsibility**	**Timing**
Dust, vibration, light and noise management awareness training will be provided as part of the site induction.	Construction Manager / Environment Advisor	Induction
No unnecessary use of horns or other audible signals on mobile plant or equipment.	All personnel	At all times
No unnecessary revving or idling of engines on mobile and stationary machines and shut down any equipment not in use.		
Use of manually adjustable or ambient noise sensitive or ‘squawker’ type reversing alarms on plant and vehicles.		
Use silenced generators where possible.	Construction Manager	At all times
Maintain all vehicles, plant and equipment to reduce the potential for noise emissions.	Drivers and operators	Manufacturer specifications
Ensure trucks, trailers and loads are secured to minimise dust (from load), rattling and other noise emissions when on public roads.	Drivers and operators	At all times
Site speed limits to be implemented and monitored through the IVMS.	All personnel	At all times
Vehicles limited to a reduced speed limit on unsealed roads and haulage routes to reduce dust impacts.	Construction Manager	At all times
Suppress dust emissions from road surfaces with water or chemical dust suppressants.	Environment Advisor	As required
All outdoor lighting designed, built and operated in accordance with *AS/NZS 4282 – 2023 Control of the Obtrusive Effects of Outdoor Lighting*.	Construction Manager	At all times
Do not direct high-beam lighting on vehicles into sensitive receptors.	All personnel	At all times
Progressively rehabilitating significant disturbances where possible.	Construction Manager	As required
Design and operation of flares and vents to be in accordance with petroleum legislation and Australian Standards.	Construction Manager	As required
Landholders or residents of any adjacent sensitive places will be advised of planned works prior to the commencement of activities.	Environment Advisor	As required
Comply with noise nuisance limits stipulated by the EA.	All personnel	At all times
Monitoring	**Responsibility**	**Timing**

ECP 6 – Air, Vibration, Light and Noise Management		
Where required: • noise monitoring will be undertaken by a Suitably Qualified Person (SQP) in accordance with the *Noise Measurement Manual* (D) and *AS 1055:2018 Acoustics – Description and Measurement of Environmental Noise*. • vibration monitoring will be undertaken by SQP in accordance with *AS 2436-2010 Guide to Noise and Vibration Control on Construction, Demolition and Maintenance Sites*. • dust monitoring will be undertaken by SQP in accordance with the *Monitoring and Sampling Manual (*DES, 2018*)* and *AS/NZS 3580.10.1:2016 Methods for Sampling and Analysis of Ambient Air: Determination of Particulate Matter – Deposited Matter – Gravimetric Method*. • illumination (light) monitoring will be undertaken by SQP in accordance with the *AS/NZS 4282-2023 Control of the Obtrusive Effects of Outdoor Lighting*.	SQP and Environment Advisor	Monitoring will be conducted if a written request is made by a regulatory authority or investigate a complaint of nuisance
Site inspections will include inspection of noise, dust, light and vibration controls.	Construction Manager / Environment Advisor	Dependent on activity levels/ work schedules
All monitoring, inspection and audit data will be managed in accordance with Section 5.6 of the EMP.	Environment Advisor	At all times
Reporting	**Responsibility**	**Timing**
Monitoring results will be provided to the regulatory authority within 10 business days of the completion of nuisance-based monitoring.	Environment Advisor	As required
Near misses or non-compliances with Performance Targets will be reported and managed in accordance with Section 5.6 of the EMP.	All personnel	As required
Corrective Action		
Near misses and incidents in relation to noise, dust, light and vibration management will be investigated in accordance with Section 5.4 of the EMP to identify necessary corrective actions for implementation.		

Table 12: ECP 7 – Liquid and solid waste management

ECP 7 – Liquid and Solid Waste Management		
Aspect		
Management of solid and liquid wastes generated by Santos's construction activities.		
Objective		
• to minimise environmental harm to environmental values (land, air quality, surface water and groundwater) by managing all wastes correctly and minimising waste disposal where practicable. • minimise generation of waste and avoid or minimise impacts associated with waste generation. • apply the waste management hierarchy and principles based on waste avoidance, reduction, reuse, recycling, treatment and disposal.		
Performance Targets		
• wastes correctly segregated and stored. • no onsite waste disposal or burning of wastes. • all wastes transported by appropriately licensed waste transporters to licensed waste facilities. • all waste tracking documents and receipts retained for 5 years. • concrete washout restricted to designated areas. • monthly waste statistics recorded and reported. • produced water will be beneficially reused in accordance with EA conditions and the EOW *Irrigation of Associated Water (including coal seam gas water)* (ENEW07546918). • produced water that cannot be beneficially reused will be transferred to existing water / waste management facilities located on adjoining tenures for management and beneficial reuse in accordance with EA conditions or EOW *Irrigation of Associated Water (including coal seam gas water) (ENEW07546918).* • general and regulated waste is separated and managed in accordance with the requirements of the EP Act. • land application of RDM is in accordance with the EA conditions. • regulated waste is transported by a person who holds the appropriate authority under the EP Act. • waste tracking certificates and / or log books are maintained as required under the EP Act. • odour or other complaints relating to waste management are investigated, monitored and resolved in accordance with the environmental nuisance monitoring requirements of the EA.		
Key References		
• *Waste Reduction and Recycling Act 2011* (and Regulation). • *Environmental Protection Regulation 2019.*		
Potential Impacts		
• generation of variety of waste types. • excessive waste generation from inefficient use of resources, and improper management or storage of wastes generated by petroleum activities. • associated environmental impacts of waste generation and management.		
Management Actions	**Responsibility**	**Timing**
The site will be kept in a clean and tidy state at all times.	All personnel	At all times
All personnel will receive waste management awareness training as part of the site induction.	Environment Advisor	Induction
No wastes will be disposed of or burnt at the site.	All personnel	At all times
Wastes will not be stored in environmental exclusion zones.	All personnel	At all times
Wastes will be segregated correctly.	All personnel	At all times
General waste and recycling bins (with lids) will be provided within and near amenities.	Environment Advisor	At all times
Covered bins / skips will be provided for general and recyclable wastes to prevent windblown litter, access by birds / vermin, odour emissions and rainfall ingress.	Environment Advisor	At all times
Regulated Waste (e.g. waste oil, washbay wastewater and blackwater from amenities) will only be removed from site by a Regulated Waste contractor.	Environment Advisor	As required
Wastes will only be transported by appropriately licensed waste transporters to licensed waste facilities.	Environment Advisor	At all times

ECP 7 – Liquid and Solid Waste Management		
Excess batched concrete and concrete washout wastes will be managed in accordance with the relevant SWMS.	Construction Manager	As required
All waste or excess materials (e.g. ballast, sleepers etc), other than waste that has been or will be lawfully reused onsite in accordance with the waste management hierarchy, will be removed from site at the completion of works.	Construction Manager	Prior to demobilisation
Soil or water that is contaminated by an emergency will be managed in accordance with ECP 2: *Soil Resource Management* and ECP 3: *Water Resource Management.*	Environment Advisor	As required
Stimulation flow back fluids will be managed, contained and recycled / reused in accordance with regulatory requirements.	Drilling and Completions Team / Construction Manager	As required
When applying RDM to land: • select suitable locations. • design and control application area size and rates to avoid run-off. • visual monitoring to avoid run-off. • apply adaptive management of application rates and RDM quality.	Drilling and Completions Manager	As required.
All sites will be kept free from litter.	All personnel	At all times
Green waste may be used on site for both rehabilitation and sediment and erosion control.	Environment Advisor	As required
Monitoring	**Responsibility**	**Timing**
Site inspections will include assessment of waste management practices.	Construction Manager / Environment Advisor	Dependent on activity levels / work schedules
All monitoring, inspection and audit data will be managed in accordance with Section 5.6 of the EMP.	Construction Manager / Environment Advisor	At all times
Implementation of a stimulation impact monitoring program, in accordance with EA conditions, which will require monitoring of stimulation fluids and flow back waters.	Drilling and Completion Manager / Environmental Advisor	As required
All waste records will be provided to the Environment Advisor on a monthly basis or upon request.	Construction Manager / Environment Advisor	As required
Reporting	**Responsibility**	**Timing**
Near misses or non-compliances with Performance Targets will be reported and managed in accordance with Section 5.4 of the EMP.	All personnel	As required
All waste-tracking forms and waste disposal receipts will be managed in accordance with Section 5.7 of the EMP and recorded in the Waste Management Register.	Construction Manager / Environment Advisor	Duration of project
Records of all wastes generated will be retained and the quantities and management strategy reported in the monthly environmental report.	Construction Manager / Environment Advisor	Monthly
Corrective Action		
Near misses and incidents in relation to waste management will be investigated in accordance with Section 5.6 of the EMP to identify necessary corrective actions for implementation.		

Table 13: ECP 8 – Cultural heritage management

ECP 8 – Cultural Heritage Management		
Aspect		
Construction works near or within areas of cultural heritage value.		
Key References		
• *Cultural Heritage Act 2003* Duty of Care Guidelines. • *Aboriginal Cultural Heritage Act 2003 and Torres Strait Islander Cultural Heritage Act 2003* Guidelines for the discovery, handling, and management of human remains. • Santos *Cultural Heritage Management Plan* (CHMP) (Santos, 2009).		
Mitigation Strategy / Action	**Responsibility**	**Timing**
Cultural heritage awareness and duty of care training provided to all personnel in the site induction and as required by the CHMP.	Construction Manager / Cultural Heritage Advisor	Induction
Undertake all works with a cultural heritage duty of care.	All personnel	At all times
Environmental exclusion zones established where necessary prior to works commencing in the surrounding area to ensure cultural heritage values are protected on site.	Construction Manager / Cultural Heritage Advisor	As required
No unauthorised entry or works by personnel, vehicles, plant or equipment in environmental exclusion zones.	Construction Manager / All personnel	At all times
No stockpiling or storage of any materials, plant or equipment in environmental exclusion zones.	All personnel	At all times
In the event that an item of cultural heritage significance is found, works in the immediate vicinity would cease and further action would be taken in accordance with the CHMP.	Construction Manager / Cultural Heritage Advisor	Immediately in response to a find
If human remains are found: • immediately cease all works on site • notify in accordance with relevant procedure and CHMP.	Construction Manager / Cultural Heritage Advisor	Immediately in response to a find
Monitoring	**Responsibility**	**Timing**
Site inspections will include inspection of cultural heritage management measures.	Construction Manager / Cultural Heritage Advisor	Monthly
All monitoring, inspection and audit data will be managed in accordance with Section 5.6 of the EMP.	Construction Manager / Cultural Heritage Advisor	At all times
Reporting	**Responsibility**	**Timing**
All cultural heritage reporting, and monitoring data will be recorded and kept.	Construction Manager / Cultural Heritage Advisor	Dependent on activity levels / work schedules
Near misses or non-compliances with Performance Targets for cultural heritage will be reported and managed in accordance with Section 5.4 of the EMP.	All personnel	As required
If any items that are suspected of being of cultural heritage value are found or if human remains are found, the find will be reported in accordance with Section 5.6 of the EMP.	Construction Manager / Cultural Heritage Advisor	Immediately in response to a find
Corrective Action		
Near misses and incidents in relation to cultural heritage will be investigated in accordance with Section 5.4 of the EMP to identify necessary corrective actions for implementation.		

Table 14: ECP 9 – Hazardous substances use and management

ECP 9 – Hazardous Substances Use and Management		
Aspect		
Storage, handling, use and disposal of hazardous substances during construction activities.		
Key References		
• *AS1940-2017 The Storage and Handling of Flammable and Combustible Liquids* • Workplace Health and Safety Queensland's *Managing risks of hazardous chemicals in the workplace Code of Practice* (WHSQ, 2021)		
Management Actions	**Responsibility**	**Frequency**
General		
Hazardous substances awareness training will be provided to all personnel as part of the site induction. This will include a component on spill response and clean-up.	Construction Manager / Environment Advisor	Induction
All SDS will be kept on the intranet and in the chemical storage for all hazardous substances at the site.	Environment Advisor	At all times
A register of hazardous substances will be kept on the electronic record management system.	Construction Manager / Environment Advisor	At all times
All hazardous substances will be stored, handled, used and disposed in accordance with the SDS, manufacturer recommendations and applicable regulatory requirements including AS 1940-2004 The storage and handling of flammable and combustible liquids.	All personnel	At all times
Hazardous substances will only be stored with compatible products (with exceptions where segmentation and distance separation requirements are met).	All personnel	At all times
Hazardous substances will be stored undercover in a bunded area or container. The bund will have the capacity of 110% of the largest container.	All personnel	At all times
Water accumulated in bunds will be removed by a Regulated Waste contractor.	Construction Manager / Environment Advisor	As required
Appropriate fire extinguishers will be provided on site for flammable and combustible chemicals.	Construction Manager	At all times
Appropriate spill kits for the type and quantity of chemicals will be provided and maintained wherever chemicals are stored and used.	Construction Manager / Environment Advisor	At all times
No onsite disposal of chemical wastes.	All personnel	At all times
Spills will be cleaned up immediately using dry methods (not hosing)	All personnel	As required
Only registered herbicides will be used by a licensed weed sprayer in accordance with the *Agricultural Chemicals Distribution Control Act 1966.*	Construction Manager / Environment Advisor	As required
The construction will be managed and design in accordance with ECP 1: Construction Site Management to minimise the risk of contamination associated with hazardous substances.	Construction Manager / Environment Advisor	At all times
Pressure testing of well casing and cement to confirm well integrity and determine the presence / absence of leak potential or significant fluid movement.	Drilling and Completions Team / Construction Manager	As required
Stimulation flow back fluids will be managed, contained and recycled/reused in accordance with regulatory requirements.	Drilling and Completions Team / Construction Manager	As required
Monitoring	**Responsibility**	**Frequency**
Site inspections will include inspection of hazardous substance management measures.	Construction Manager / Environment Advisor	Dependent on activity levels / work schedules
All monitoring, inspection and audit data will be managed in accordance with Section 5.6 of the EMP.	Environment Advisor	At all times

ECP 9 – Hazardous Substances Use and Management		
Reporting	**Responsibility**	**Frequency**
Near misses or non-compliances with Performance Targets will be reported and managed in accordance with Section 5.4 of the EMP.	All personnel	As required
Corrective Action		
Near misses and incidents in relation for hazardous substance use and management will be investigated in accordance with Section 5.4 of the EMP to identify necessary corrective actions for implementation.		

Table 15: ECP 10 – Plant and equipment management

ECP 10 – Plant and Equipment Management		
Aspect		
Incorrect operation of plant and equipment has the potential to adversely impact the environment.		
Management Strategies		
Proactive management strategies to reduce the impacts of plant and equipment include daily pre-start checks, routine maintenance, covering loads of trucks where appropriate, and implementation of weed and pest hygiene measures such as cleaning, inspections and certifications.		
Key References		
• regulatory approval requirements for plant and equipment (Section 2.4)		
Management Actions	**Responsibility**	**Timing**
Daily pre-start checks will be completed on all plant and equipment.	Operators	Daily
Plant and equipment will be maintained in accordance with the manufacturer's recommendations.	Operators	As required
Maintenance and repair works to plant and / or equipment will be undertaken at the workshop. In-field repairs will only occur if the plant or equipment cannot be moved under its own power.	Construction Manager	As required
Spill kits and drip trays and any other necessary controls will be used during maintenance works or repairs to plant and equipment. This applies to the workshop and in-field repairs.	All personnel	As required
Wastes from plant and equipment maintenance undertaken in the workshop or in-field will be in accordance with ECP 7 – Liquid and Solid Waste Management.	All personnel	As required
Refuelling plant and equipment will be in accordance with the relevant SWMS. Suitable containment devices to be in place for refuelling activities involving volumes greater than 50 L.	Refuelling personnel	At all times
No unnecessary revving or idling of engines on mobile and stationary machines and shut down any equipment not in use.	All personnel	At all times
Weed and pest hygiene requirements for plant and equipment (i.e. washdown and certification requirements) are outlined in ECP 5 – Weed and Pest Management.	All personnel	At all times
Ensure trucks, trailers and loads are secured to minimise rattling and other noise emissions when on public roads.	Operators / drivers	At all times
Cover loads of organic materials (soil, gravel, sand, mulch) in trucks and trailers travelling on public roads to and from the site.	Operators / drivers	At all times
Clean tyres of mud before driving on public roads.	Operators / drivers	As required
Monitoring	**Responsibility**	**Timing**
Daily pre-start checks will monitor plant and equipment condition.	Operators	Daily
Plant and equipment management will be monitored as part of monthly site inspections	Environment Advisor	Dependent on activity levels / work schedules
All monitoring, inspection and audit data will be managed in accordance with Section 5.6 of the EMP.	Environment Advisor	At all times
Reporting	**Responsibility**	**Timing**
Daily pre-start forms will be kept with the plant and equipment.	Operators	At all times
Service records will be retained and made available upon request.	Sub-contractors	At all times
Near misses or non-compliances with Performance Targets will be reported and managed in accordance with Section 5.4 of the EMP.	All personnel	As required
Corrective Action		
Near misses and incidents in relation to plant and equipment management will be investigated in accordance with Section 5.4 of the EMP to identify necessary corrective actions for implementation.		

Table 16: ECP 11 – Environmental emergency preparedness and response

ECP 11 – Environmental Emergency Preparedness and Response		
Aspect		
Environmental emergencies at the site may cause harm to people and the natural environment.		
Key References		
• n/a		
Important Information		
The triggers for a spill emergency event are more than 50 litres to ground or any amount of spillage to a watercourse or drain. The region in which the site is located experiences heavy rain and flooding (mainly during the summer months). The area is a low-medium risk for bushfire.		
Management Actions	**Responsibility**	**Timing**
Spills		
All personnel will receive emergency response awareness training as part of the site induction. This will include spill clean-up and fire extinguisher use.	Environment Advisor	Duration of project
Hazardous substances will be managed in accordance with ECP 9: *Hazardous Substance Use and Management*.	All personnel	At all times
Refuelling and servicing of plant and equipment will be managed in accordance with ECP 10: *Plant and Equipment Management*.	Refuelling personnel / Construction Manager	At all times
Appropriate spill kits for the type and quantity of chemicals will be provided and maintained wherever chemicals are stored and used.	Environment Advisor	At all times
Immediately cease any hot works within 30 m of the spill and evacuate all personnel from the area.	All personnel / Construction Manager	Immediately after spill
Spills will be cleaned up immediately (isolate / stop, absorb / clean, dispose of contaminated materials).	All personnel	Immediately after spill if safe
Soil or water that is contaminated by an emergency will be managed in accordance with ECP 2: *Soil Resource Management* and ECP 3: *Water Resource Management.*	Environment Advisor	As required
Heavy Rain, Storms and Flooding		
If heavy rainfall or flooding is forecast, the site will be prepared by: • relocating any mobile plant or equipment to higher parts of the site or away from the site (as required). • removing potential contaminants such as wastes or chemicals from site or ensuring that potential contaminants are protected from rainfall or stormwater flows. • securing loose equipment and materials, ensure bin covers are secure. • ensuring all erosion and sediment control measures have been maintained and are in place.	Construction Manager Advisor	Prior to the event
Bushfire		
Plant and equipment will be maintained to minimise the risk of presenting an ignition source.	Plant operators	As required
Hot works will be undertaken in accordance with the relevant hot work permit requirements and SWMS.	All personnel	During hot works
Fire extinguishers will be provided at the site office, crib rooms, where flammable and combustible liquids are stored and in all vehicles.	Construction Manager / Environment Advisor	At all times
No burning of wastes on site.	All personnel	At all times
Smoking will only be allowed in designated smoking areas. Cigarette bins will be provided at designated smoking areas.	Construction Manager / Environment Advisor	At all times
Monitoring	**Responsibility**	**Timing**
Daily monitoring of forecast weather and fire hazard ratings provided by Bureau of Meteorology. This will be discussed in the daily pre-work brief meeting.	Construction Manager / Environment Advisor	Daily

ECP 11 – Environmental Emergency Preparedness and Response		
Routine and rainfall-based site inspections will determine if hazards are present at the site that could cause an environmental emergency.	Construction Manager / Environment Advisor	Prior to and following significant rainfall
All monitoring, inspection and audit data will be managed in accordance with Section 5.6 of the EMP.	Construction Manager / Environment Advisor	At all times
Reporting	**Responsibility**	**Timing**
Emergencies, near misses or non-compliances with Performance Targets will be reported and managed in accordance with Section 5.4 of the EMP.	All personnel	As required
Corrective Action		
Near misses and incidents will be investigated in accordance with Section 5.4 of the EMP to identify necessary corrective actions for implementation.		

7. EMP Review and Update

This EMP will be reviewed and updated as required by Santos following granting of the new EA and EPBC Act decision and approval conditions.

Updates will reflect changes to processes and procedures, new and / or amended approval conditions, updates to legislation, guidelines and standards, and / or changes to Santos requirements.

Reviews may also be more regularly scheduled (i.e. every 1 to 5 years) or occur in response to matters that affect environmental management (such as incidents, emergencies, changes in site conditions etc).

8. Key References

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Appendix 1: Santos EHS Policy

Santos

Environment, Health and Safety



Policy

Our Commitment

Santos is committed to being the safest gas company wherever we have a presence and preventing harm to people and the environment.

Our Actions

We will:

1. Integrate environment, health and safety management requirements into the way we work
2. Comply with all relevant environmental, health and safety laws and continuously improve our management systems
3. Include environmental, health and safety considerations in business planning, decision making and asset management processes
4. Identify, control and monitor risks that have the potential for harm to people and the environment, so far as is reasonably practicable
5. Report, investigate and learn from our incidents
6. Consult and communicate with, and promote the participation of all workers to maintain a strong environment, health and safety culture
7. Empower our people, regardless of position, to "Stop the Job" when they feel it necessary to prevent harm to themselves, others or the environment
8. Work proactively and collaboratively with our stakeholders and the communities in which we operate
9. Set, measure, review and monitor objectives and targets to demonstrate proactive processes are in place to reduce the risk of harm to people and the environment
10. Report publicly on our environmental, health and safety performance

Governance

The Environment Health Safety and Sustainability Committee is responsible for reviewing the effectiveness of this policy.

This policy will be reviewed at appropriate intervals and revised when necessary to keep it current.

Kevin Gallagher

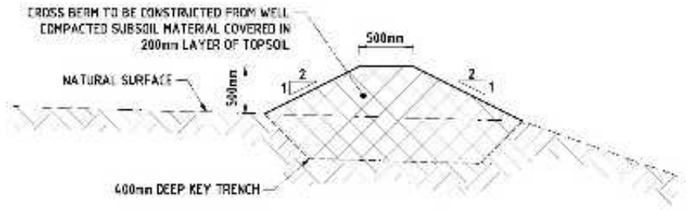
Managing Director and CEO

Document Owner:	David Hanks, Chief Operating Officer		
Approved by:	The Board		
Date Approved:	16 August 2022	Version:	3

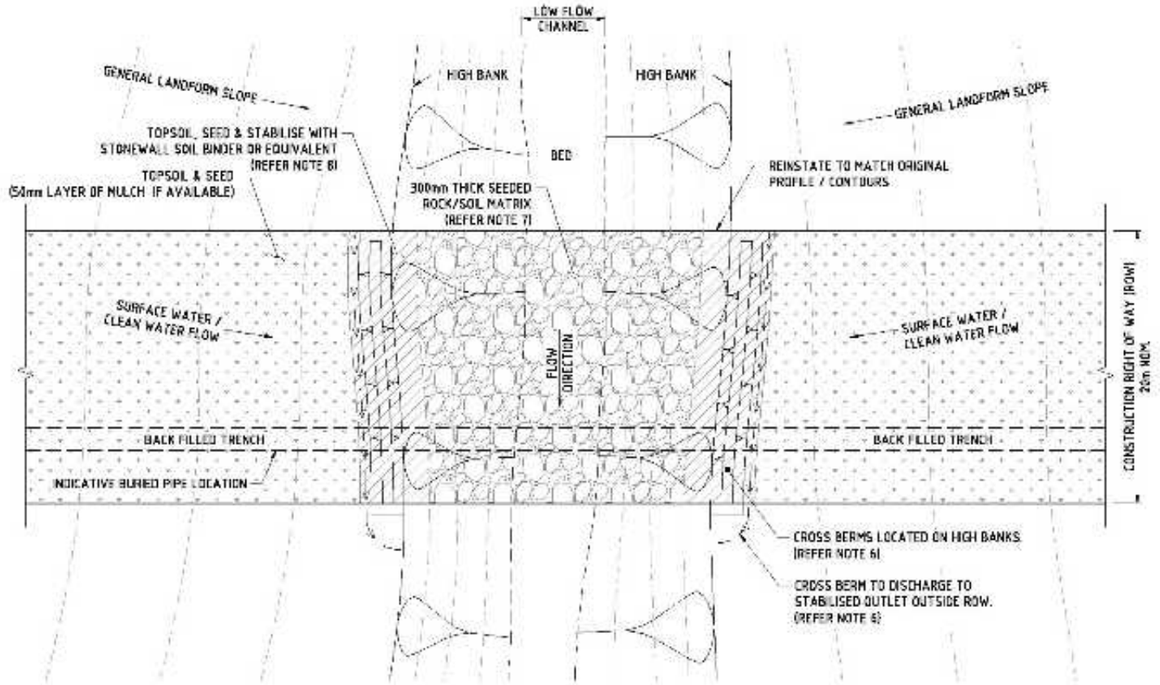
Appendix 2: Standard crossing designs

NOTES:

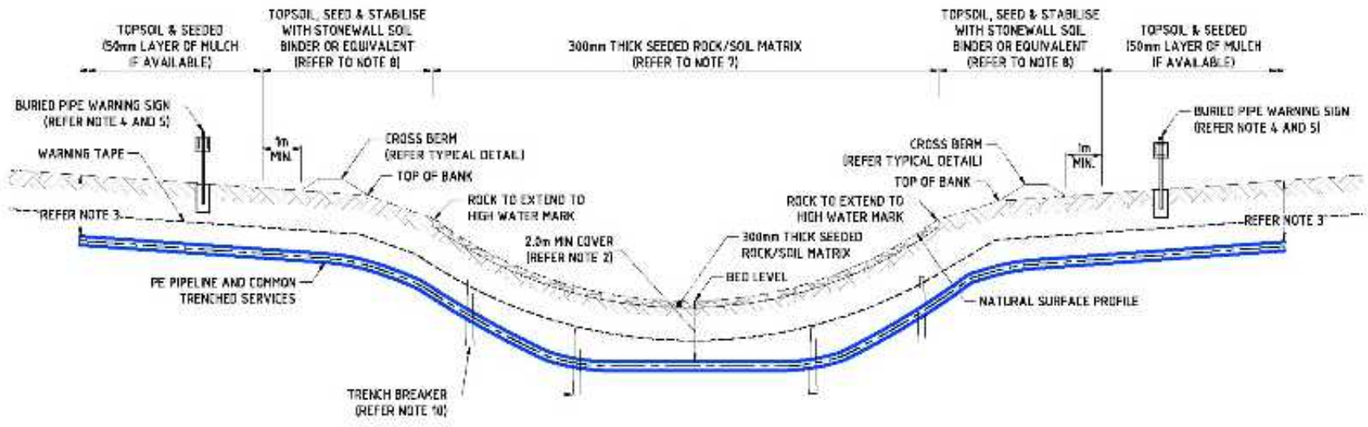
1. REFER TO DWG 0007-650-PLA-0097 FOR GENERAL NOTES.
2. MINIMUM COVER TO BE TAKEN FROM BELOW LOOSE MATERIAL IN DRAINAGE FEATURE BED LIKELY TO BE SCOURED AWAY DURING HIGH FLOW EVENTS.
3. RETURN TO NORMAL DEPTH OF COVER AS PER PROJECT SPECIFIC PIPELINE DETAILED DESIGN.
4. FOR WARNING SIGN REFER TO DWG 1500-050-GAR-0012 AND 1500-050-GAR-0013.
5. BURIED PIPE WARNING SIGNS TO BE LOCATED A MINIMUM OF 3.0m FROM THE TOP OF BANK.
6. INSTALL FINAL BERM ACROSS ROW AT TOP OF THE BANKS. INSTALL ON A MAXIMUM GRADE OF 1.0%. ALL FINAL BERMS TO BE COVERED IN 200mm TOPSOIL. ENSURE BERMS DISCHARGE TO A STABLE LOCATION DOWNSTREAM OF THE WORK SITE (IE. GRASS OR ROCK AREA).
7. FOR FINAL DRAINAGE FEATURE TO HIGH WATER MARK:
   - 7.1 APPLY 300mm THICK LAYER OF SEEDED ROCK/SOIL MATRIX AS PER ORIGINAL SITE CONTOURS. ROCK/SOIL MATRIX TO BE 50% ORIGINAL BED MATERIAL (MIXED WITH SEED) & 50% 200mm RIP RAP ROCK. OR;
   - 7.2 WHERE INSUFFICIENT OR UNSUITABLE ORIGINAL BED MATERIAL EXISTS APPLY SOIL AMELIORANTS (GYPSUM, LIME, DOLOMITE, COMPOST ETC) TO PROVIDE SUITABLE GROWING MEDIUM AS PER SOIL AMENDMENT ADVICE. APPLY 300mm THICK LAYER OF SEEDED ROCK/SOIL MATRIX AS PER ORIGINAL SITE CONTOURS. ROCK/SOIL MATRIX TO BE 50% ORIGINAL BED MATERIAL (MIXED WITH SEED) & 50% 200mm RIP RAP ROCK.
8. FOR FINAL DRAINAGE FEATURE ABOVE HIGH WATER MARK:
   - 8.1 RESPREAD TOPSOIL AS PER ORIGINAL SITE CONTOURS. PROVIDE A MINIMUM OF 200mm TOPSOIL DEPTH. WHERE POSSIBLE, PLACE THE BALANCE OF TOPSOIL FOLLOWED BY THE TOP 50mm OF STRIPPED TOPSOIL. ADD REQUIRED FERTILISER AND SEED. STABILISE WITH STONEWALL SOIL BINDER OR EQUIVALENT. OR;
   - 8.2 WHERE INSUFFICIENT OR UNSUITABLE TOPSOIL EXISTS, APPLY SOIL AMELIORANTS (GYPSUM, LIME, DOLOMITE, COMPOST ETC) TO PROVIDE SUITABLE GROWING MEDIUM AS PER SOIL AMENDMENT ADVICE. RESPREAD AS PER ORIGINAL SITE CONTOURS. ADD FERTILISER AND SEED. STABILISE WITH STONEWALL SOIL BINDER OR EQUIVALENT.
9. SEED TO BE BROADCAST WITHIN TOP 50mm TOPSOIL OR ROCK/SOIL MATRIX. SEED MIX TO TO BE IN ACCORDANCE WITH SEEDING RECOMMENDATIONS.
10. TRENCH BREAKERS SHALL BE INSTALLED AS REQUIRED BY SANTOS SPECIFICATION 'CONSTRUCTION OF POLYETHYLENE GATHERING SYSTEMS' 1515-120-SPC-0008 AND IN ACCORDANCE WITH DRAWING 1500-040-GAR-0001.



TYPICAL CROSS BERM DETAIL
NOT TO SCALE



HIGH RISK DRAINAGE FEATURE CROSSING - PLAN
NOT TO SCALE



HIGH RISK DRAINAGE FEATURE CROSSING - PROFILE
NOT TO SCALE

REV	BY	DATE	REVISION DESCRIPTION	APPROVED
3	MT	19.10.20	REVISED AS PER SANTOS COMMENTS	AH
2	MT	19.03.20	ISSUED FOR USE	AH
1	MT	19.03.20	ISSUED FOR USE	AH

DRG NO.	DRG TITLE
0007-650-PLA-0097	General Notes
1500-050-GAR-0001	Trench Breaker Details
1515-120-SPC-0008	Construction of Polyethylene Gathering Systems
1500-050-GAR-0012	Warning Sign Details
1500-050-GAR-0013	Warning Sign Details
0007-650-PLA-0018	HIGH RISK DRAINAGE FEATURE CROSSING - OPEN CUT

Santos

ENGENY WATER MANAGEMENT

ISSUED FOR USE

PM:	DESIGNED:	AH	CHECKED:	MT
Level 3	DRAWN:	LT	APPROVED:	MT
520 Queen St	PETER KEY	AH	PETER KEY	19.03.20
Brisbane QLD	PROJ:	N/A	SCALE:	N/A

SANTOS LIMITED

AREA 0007 - STANDARD DRAWINGS
HIGH RISK DRAINAGE FEATURE
PE PIPELINE CROSSING-OPEN CUT

DRAWING SIZE:	DWG NO.	REV.
A1	0007-650-PLA-0018	1

Appendix F: Risk Assessment

The environmental risk assessment contained in Section 4.0 was undertaken in accordance with the Santos Management System (SMS) Risk Management Standard. The SMS Risk Management Standard is based on accepted principles and applicable Australian standards. The risk assessment process involves:

- identifying the potential hazards or threats posed by the proposed activities;
- categorising the potential consequences and their likelihood of occurring; and
- using a risk matrix to characterise the level of risk.

Environmental risk assessment is used to differentiate minor acceptable risks from major risks, and to provide a basis for further evaluation and management of major risks. Risks are generally considered acceptable if they fall into the low category without any further mitigation measures, and 'tolerable' if they fall into the medium risk category and are managed to reduce the risk to a level 'So Far As Is Reasonably Practicable' (SFAIRP). Risk reduction measures must be applied to reduce high risks to tolerable levels (see Operational Risk Requirements in Figure 7).

SFAIRP essentially involves making a judgement about whether all reasonably practicable measures are in place to control a potential risk or impact considering the level of consequence and cost, time and resources involved to mitigate it.

Control Measure Identification

Based on identified potential impacts, and the ranking of their unmitigated risk, 'Management Practices' ('Control Strategies') were identified to eliminate, prevent, reduce or mitigate consequences associated with each of the identified potential impacts. Appropriate control strategies were identified from previous activities, current Santos management practices, and through review of best practice techniques across the industry.

Determination of Severity of Consequence

The potential level of impact (consequence) was assessed and assigned in line with potential hazards and receptors, using the 'Santos Environmental Consequence Classification' (see Figure 7) from the Santos Risk Matrix. The consequence level for each risk source is documented in the risk assessment tables in Section 4.0. To describe the severity, scale and duration of potential impacts, six categories of consequence are used (as displayed in Figure 7).

Determination of Likelihood

Likelihood relates to the potential for a consequence to occur. This includes the likelihood of an event occurring and the subsequent potential consequence. This is defined using the Santos Risk Matrix (See Figure 7). To describe the likelihood of a potential environmental consequence occurring, six categories of likelihood are used. The Santos Risk Matrix is then used to characterise the resultant risk into one of five levels.

Determination of Residual Risk

Risk is expressed in terms of a combination of the consequence of an impact and the likelihood of the impact occurring. Santos uses a risk matrix (see Figure 7) to plot the consequence and likelihood to determine the level of risk.

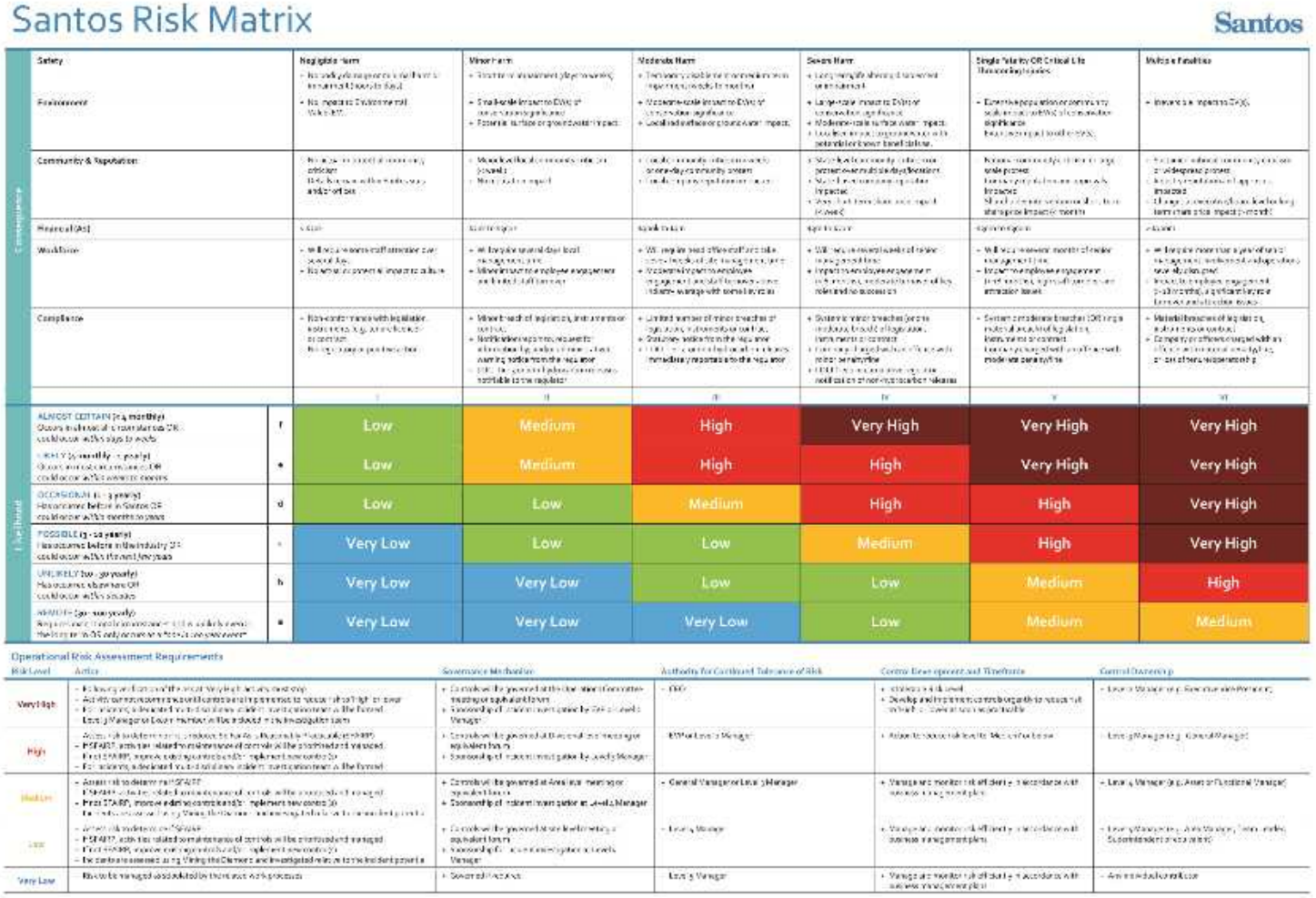


Figure 7: Santos Risk Matrix

Table 33: Environmental Risk Assessment

Identification				Unmitigated Risk			Control Strategies	Residual Risk		
Risk Event / Activity	Relevant EV	Potential Impact	Risk Source	Consequence	Likelihood	Risk		Consequence	Likelihood	Risk
Construction and operation of proposed infrastructure	Land Resources Waste Rehabilitation	Reduction in visual amenity Soil erosion, topsoil loss, inversion and compaction Disturbance to land use and suitability changes Reduction in agricultural productivity Contamination of soil	Infrastructure construction (earthworks activities, including grading and trenching) Vehicle and plant movements Minor spills or leaks of fuels and chemicals from vehicles and equipment Loss of containment Bushfire and flood (natural event) Fire (ignition sources resulting from activities)	III	d	Medium	**General** • Compliance with relevant EA conditions, and all relevant internal and external approvals are in place before work is undertaken. • All disturbance undertaken in accordance with Santos standards. • Industry standards and good industry practices are followed. • Appropriate emergency response plans in place. **Land Resources** • The proposed infrastructure has been designed to be located in pre-disturbed, non-remnant areas or co-located to minimise the area of new disturbance to land and vegetation as much as is reasonably possible (given safety and engineering restrictions). • Surface disturbance will be restricted to the minimum area required to safely carry out activities. • Infrastructure will be located to minimise impacts to drainage patterns, soil, and vegetation. • Sensitive terrain is protected through appropriate construction and maintenance practices. • Management of sensitive areas (e.g. sloped areas) is detailed in scope of works, approval documents and company procedures. • Erosion and sediment control measures in place where appropriate (refer to additional Control Strategies listed under Surface Water). • Following gathering line installation, groundcover will be re-established along the operational RoW. • Any short-term reduction in the availability of existing land use would be offset by commercial agreements between proponents and the property owner. • Vehicle and plant movements: - No unauthorised driving outside of the approved construction area. - Watering of disturbed areas and/or access tracks carried out as required / permitted to reduce dust generation. - Active promotion of appropriate road use behaviours, and the setting of appropriate speed limits for Santos personnel and contractors. - Work scheduled to fit in with landholder's property management activities. • Fire and flood: - Activity planning will consider seasonal conditions and risk of fire and flood. - Water crossings scheduled to take into account seasonal conditions and rainfall / flood likelihood. - Construction activity not undertaken during or immediately prior to flooding. - Personnel are informed on the fire danger season and associated restrictions, and ignition sources are controlled via permit to work. - Measures undertaken to reduce potential impacts of fire and flood where appropriate (e.g. removal of fuels/chemicals/equipment prior to arrival of fire or flood event). • Fuel, oil and chemical storage and handling: - Fuel, oil and chemical storage and handling undertaken in accordance with Australian standards / guidelines (i.e. in bunded areas). - Spill leak and drip trays provided to address minor drips and spills resulting from re-fuelling operations. Spill response equipment and materials kept on site and in operational vehicles (where appropriate). - Maintain a register of incidents and implement corrective actions based on outcome of investigations. - Vehicles and equipment are operated and maintained in accordance with specifications to minimise the potential for a spill or leak (e.g. oil leak or hydraulic hose failure). - Any waste generated during spill clean-up operations will be disposed of in accordance with manufacturer's guidelines and legislative / EA waste management requirements. • Production operations: - Plant and equipment designed, constructed and operated in accordance with Santos Engineering Standards and relevant Australian/International standards.	III	c	Low

Identification				Unmitigated Risk			Control Strategies	Residual Risk		
Risk Event / Activity	Relevant EV	Potential Impact	Risk Source	Consequence	Likelihood	Risk		Consequence	Likelihood	Risk
							- Infrastructure design process to address location and non-location specific threats (e.g. pipeline corrosion) and develop adequate controls to mitigate environmental and public/third party safety risk. - Safety, testing, maintenance and inspection procedures implemented. - Prestart-up checklist prior to commissioning and decommissioning activities. - Pipeline construction integrity verification (e.g. hydro test, or pneumatic test). • Loss of containment: - Infrastructure designed, constructed and operated in accordance with Santos Engineering Standards, relevant Australian/International standards, and relevant EA conditions. - Infrastructure design process to address location and non-location specific threats and develop adequate controls to mitigate environmental and public/third party safety risk. Safety, testing, maintenance and inspection procedures implemented. - Gathering lines designed and constructed to comply with Australian Standards AS2885 – Pipelines Gas and Liquid Petroleum and the APGA Code of Practice For Upstream Polyethylene Gathering Networks-CSG Industry – Version 6 (APGA, 2024). - Pipeline construction integrity verification (e.g. hydro test, or pneumatic test). - Regular monitoring of control systems (e.g. emergency shutdown valves) to ensure that protection levels are adequate. Emergency response training for emergency response personnel. - Loss of containment managed via appropriate Santos incident management system (IMS), and implementation of corrective actions is based on incident investigation. **Waste** - Waste managed in accordance with the *Waste Reduction and Recycling Act 2011* and Waste and Resource Management Hierarchy. - Where practicable, Santos would implement the waste and resource management hierarchy, and reduce risks to EVs from waste storage and disposal, by: o designing activities to incorporate less resource-intensive materials and more efficient processes. o designing contracts which encourage waste avoidance and set waste reduction targets. o identifying and separating waste streams for re-use, recycling, treatment or disposal. o storing waste in appropriate receptacles or designated areas prior to their re-use or collection for recycling, treatment or disposal. o ensuring wastes are removed by transporters which are appropriately licensed or authorised to transport that particular waste type. o ensuring all wastes removed from the site are recycled, treated or disposed of at an appropriately licensed waste facility. o reviewing and auditing waste management practice to confirm legal compliance and identify opportunities for improvement. - Covered bins are provided for the collection and storage of wastes. - Rubbish loads are covered during transport to a licensed waste facility. - On site disposal of residual drilling mud (RDM) undertaken in accordance with mix bury cover method, or alternative method and quality criteria as certified by a suitably qualified third party. - Hydraulic fracturing flowback fluid contained in lined pits or tanks, and removed from site for authorised reuse or disposal upon completion of operations. - In the event of expected flooding, waste will be removed from areas at risk of inundation (where appropriate / safe to do so). - Waste materials and non-essential infrastructure removed from operational areas as soon as reasonably practicable following petroleum activities. **Rehabilitation** - Pipeline trenches are backfilled and topsoils reinstated after pipe laying in accordance with relevant EA conditions. - Gathering line RoWs are re-instated and revegetation commenced after completion of petroleum activities for the purpose of pipeline construction in accordance with relevant EA conditions. - Rehabilitation of significantly disturbed areas undertaken in accordance with relevant EA conditions and rehabilitation criteria. - Areas potentially exposed to contamination will be assessed and remediated as in accordance with relevant EA conditions and rehabilitation criteria.			

Identification				Unmitigated Risk			Control Strategies	Residual Risk		
Risk Event / Activity	Relevant EV	Potential Impact	Risk Source	Consequence	Likelihood	Risk		Consequence	Likelihood	Risk
							- Final rehabilitation of disturbed areas would be undertaken to achieve the final rehabilitation acceptance criteria and relevant EA conditions. - Rehabilitation aims to reshape and stabilise disturbed areas to provide appropriate site conditions to facilitate natural revegetation processes, and will include the following activities (where appropriate): ▪ ripping of areas of compacted soil (except on sensitive soils / environments). ▪ respreading of stockpiled topsoil, vegetation and seed stock (where available) to facilitate natural revegetation. ▪ restoration of natural landform contours.			
Construction and operation of proposed infrastructure	Flora, REs, ESAs, and Flora and Fauna	Damage to and/or loss of native riparian vegetation and habitat Damage to and/or loss of high value flora Introduction and/or spread of weeds, pest plants, animals and pathogens Loss of species population, further endangerment and loss in species diversity Disturbance, injury or loss of fauna	Infrastructure construction (earthworks activities, including grading and trenching) Entrapment in voids (trenches / bell holes / pits) Vehicle and plant movements Fire (ignition sources resulting from activities)	III	c	Low	**General** • Compliance with relevant EA conditions, disturbance limits to MSES/MNES, and all relevant internal and external approvals in place before work undertaken. **Flora, REs and ESAs** • Existing areas of disturbance will be utilised wherever practicable to locate proposed disturbances to minimise habitat fragmentation / disturbance. • All clearing and disturbance must be internally approved via internal Santos approval processes prior to commencement of construction activities. • Areas proposed to be disturbed / cleared shall be clearly delineated (via GPS or visual markers), and the need to conduct the proposed activity in designated and approved areas will be reinforced during site toolbox / induction meetings. • Mature trees will be avoided wherever practicable (and tree limbs will be loped in preference to removing entire trees wherever practicable). • Disturbance in and around ephemeral wetlands will be avoided or minimised wherever practicable, or otherwise preferentially scheduled to occur when the areas are dry, and otherwise in accordance with relevant EA conditions and disturbance limits to MSES/MNES. • Maximum clearance widths for linear and non-linear infrastructure will be in accordance with relevant EA conditions. • Introduction and / or spread of weeds, pest plants, animals and pathogens: - Hygiene protocols implemented as appropriate to minimise the introduction, spread and persistence of weeds, pest plants, animals and pathogens. - Access to and from the site via designated access tracks only. - Vehicle and equipment wash-down when operations have been undertaken in areas of known weed infestations. - Monitor for presence of weeds within the construction area, and where necessary implement control measures. - Ensure that imported material is from an area or source considered to be pest plant/disease free. • Refer to Control Strategies listed under ‘Fire and Flood’ and ‘Vehicle and plant movements’ under Land Resources. **Fauna and Livestock** • A suitably qualified Fauna Spotter / Catcher will be present during woody vegetation clearing activities where required. • Prior to construction activities commencing, the Fauna Spotter / Catcher will survey for the presence of fauna located in or near the proposed disturbance area. • Fauna and significant habitat features will be avoided or relocated outside the proposed disturbance area where appropriate to do so. • Clearing and construction activities will be scheduled to avoid breeding periods, where work delivery schedules are sufficiently flexible to do so. • The period of time that trenches and other excavations are open will be minimised, and open voids will be backfilled as soon as practicable following completion of works. • During construction, open trenches and other open voids will be regularly checked for potentially entrapped fauna. • Open voids must also be fenced or covered wherever practicable to prevent access or harm to fauna and stock. Where this is not practicable, the focus should be on regularly checking open voids for entrapped fauna and installing measures such as escape routes to reduce risks to potentially entrapped fauna. • Pipe string ends will be capped nightly to prevent fauna ingress.	II	c	Low

Identification				Unmitigated Risk			Control Strategies	Residual Risk		
Risk Event / Activity	Relevant EV	Potential Impact	Risk Source	Consequence	Likelihood	Risk		Consequence	Likelihood	Risk
							• Prior to backfilling, trenches and voids will be checked for fauna and any found will be removed. • Refer to additional Control Strategies listed under Vehicle and Plant Movements and 'Fire and Flood' under Land Resources.			
Construction and operation of proposed infrastructure	Surface Water and Wetlands	Disturbance to natural drainage patterns Degradation of downstream water quality from sediment releases / minor spills or leaks of fuels and chemicals (PW / hydrotest water) Damage to and/or loss of native riparian vegetation and habitat Reduction in groundwater quantity and/or availability for other users Contamination of soil and/or watercourses	Drilling and hydraulic stimulation / fracturing activities Production operations Infrastructure construction (earthworks activities including grading and trenching) Vehicle and plant movements Minor spills or leaks of fuels and chemicals from vehicles and equipment Loss of containment Flood (natural event)	IV	c	Medium	**General** • Compliance with relevant EA conditions, and all relevant internal and external approvals in place before work undertaken. **Surface Water** • Appropriate erosion and sediment control (ESC) measures will also be implemented where required to mitigate potential sediment impacts to drainage features. More specifically, Santos will develop site-specific erosion and sediment control plans (ESCP) or implement standard ESCPs for each scope of work e.g. gathering line installation. • RoWs will be constructed to ensure sufficient area is available to construct appropriate erosion and ESC structures (where required). • Santos will only construct in ephemeral wetland areas when they are dry, and linear infrastructure RoWs will be reinstated to their natural landform following construction. • Construction of linear infrastructure within a water course would preferentially be carried out in periods of low or no flow. • Where it is necessary to carry out works in a watercourse during periods of flow, these would be carried out in accordance with the relevant Department of Agriculture, Fisheries and Forestry Waterway Barrier Works Code(s). • Watercourse crossings would be selected at locations where the least impact to riparian flora and fauna will occur (i.e. clearing of vegetation and at narrowest and shallowest locations) where practicable. • Construction or maintenance of linear infrastructure activities in watercourses will comply with the turbidity limit of relevant EA conditions, and water quality monitoring would be carried out downstream of watercourse crossing works where necessary to ensure compliance with water quality limits. • Rehabilitation will commence as soon as reasonably practicable following completion of construction activities, including the restoration of natural landform contours to ensure natural surface water flows are maintained. • Appropriate spill kits would be kept on site and in staff vehicles for use in the event of a spill or leak of hydrocarbons or chemicals, and Chemicals, fuels or other hazardous substances would be stored and managed in accordance with relevant Australian Standard. • Refer to Control Strategies listed under Flora, REs and ESAs, Fire and Flood, Fuel, Oil and Chemical Storage and Handling, and Loss of Containment under Land Resources.	IV	b	Low
Construction and operation of proposed infrastructure	Ground water	Decline in groundwater level / pressure at water bores, reducing water availability and potentially impacting groundwater environmental values Reduction in groundwater head resulting in a reduction of groundwater discharge at	Drilling and hydraulic stimulation / fracturing activities Production (gas and water) operations Well control or well head equipment failure Well casing or cement failure (well integrity failure)	IV	c	Medium	**General** • Refer to general control strategies listed under the Land Resources EV. • Compliance with relevant EA conditions, and all relevant internal and external approvals in place before work undertaken. **Groundwater** • Production wells will be designed, constructed and decommissioned in accordance with the *Code of Practice for the construction and abandonment of petroleum wells and associated bores in Queensland Version 2* (DNRME 2019). • Hydraulic fracturing activities will be undertaken in accordance with the requirements of the Code of Practice (DNRME, 2019), Santos Hydraulic Fracturing Risk Assessment – Santos Eastern Queensland (HFRA) (EHS Support 2021), Eastern Queensland Stimulation Impact Monitoring Program (SIMP) (Santos 2021), Chemical Risk Assessment Framework (CRAF) (Santos, 2025), and the WRA (KCB, 2025). • Drilling and hydraulic fracturing fluids and additives will be used in accordance with the mandatory requirements and good practice guidelines outlined in the Code of Practice (DNRME 2019), CRAF (Santos, 2025), as well as the Safety Data Sheets provided with each fluid / additive. • Drilling and hydraulic fracturing fluids will not contain benzene, toluene, ethyl-benzene and xylene above prescribed levels. No chemicals identified as Persistent, Bio-accumulative and Toxic (PBT) will be used. • The use of biodegradable substances in the drilling and hydraulic fracturing fluid would be preferred where practicable. Products would be chosen, stored, and used at concentrations that minimise the risk of causing environmental harm.	IV	b	Low

Identification				Unmitigated Risk			Control Strategies	Residual Risk		
Risk Event / Activity	Relevant EV	Potential Impact	Risk Source	Consequence	Likelihood	Risk		Consequence	Likelihood	Risk
		spring complexes, potentially causing degradation of GDEs Reduction of baseflow to watercourses, potentially resulting in reduced availability of water to GDEs and reduced water availability to potential users downstream	Minor spills or leaks of fuels, chemicals or other produced fluids Loss of containment Storage and disposal of general waste, chemical and process wastes Vehicle and plant movements				• Personnel, including contractors, would be made aware of emergency spill procedures. • Production wells would be constructed a minimum distance of 90 metres from landholder bores. • Baseline Assessment Plan to consider new landholder bores as required (if applicable depending on bore status). • Refer to Control Strategies listed under Flora, REs and ESAs, Fire and Flood, Fuel, Oil and Chemical Storage and Handling, and Loss of Containment under Land Resources.			
Construction and operation of proposed infrastructure	Air Quality and Noise	Air pollution and localised reduction in air quality Nuisance caused by vibration, noise and dust generation Disturbance to fauna and livestock	Infrastructure construction (earthworks activities including grading and trenching) Vehicle and plant movements Fire (ignition sources resulting from activities) Minor air emissions generated from vehicles and equipment	III	c	Low	**General** • Refer to general control strategies listed under the Land Resources EV. • Fit for purpose equipment. • Conduct regular testing, inspections and maintenance of site equipment. **Air Quality and Noise** • Air and noise emissions will be managed in accordance with controls outlined in Section 4.6.2, including the following processes: – Identification of sensitive receptors during planning. – Landholders consulted as required where activities may affect sensitive receptors and/or agricultural operations. – Systems in place for logging stakeholder / landholder complaints to ensure issues are recorded and addressed as appropriate. – Noise managed in accordance with ‘management hierarchy for noise’ set out in the *Environmental Protection (Noise) Policy 2019* (Noise). – Vehicles, engines and equipment operated and maintained in accordance with manufacturer specifications and planned maintenance systems. – Use of attenuation / suppression devices where required e.g. silencing equipment – Majority of vehicle movements will be limited to daylight hours. – Dust suppression measures carried out where required e.g. road watering. – Refer to control strategies for ‘vehicle and plant movements’ under the Land Resources EV.	II	c	Low

Appendix G: Environmental Objective Assessment and Performance Outcomes

Environmental objectives

The environmental objectives in Schedule 8, Part 3, Division 1 of the EP Reg are based on EVs to be protected, with the exception of the waste objective.

An application should demonstrate how the proposed activity will be managed in a way to achieve these environmental objectives.

Performance outcomes

The assessment tables in Divisions 1 and 2 of the EP Reg also provide performance outcomes to give applicants guidance on how to demonstrate they are meeting the environmental objective. There are usually two performance outcomes.

The first performance outcome is usually the ‘no impact’ option, which makes it clear that if there is to be no impact on an environmental value, then the environmental objective is achieved.

The second performance outcome should be considered when the first is not met. The second performance outcome specifies a series of measures or actions that can be taken to adequately manage the risks the activity poses to the relevant EVs. If an application does not meet either performance outcome for an environmental objective, the application may meet the performance outcome through alternative measures.

Assessment against Schedule 8 (Parts 1 and 2) of the EP Reg (Environmental Objective Assessment and Performance Outcomes) is provided in Table 34 below.

Table 34: Environmental objective assessment

Value / Objective	Performance Outcome - Santos Response
Air	
Environmental objective	
The activity will be operated in a way that protects the environmental values of air.	The intention of this environmental objective is to ensure that any discharges to air, including contaminant releases from point sources, fugitive emissions, and wind borne dust, do not impact on EVs. Consideration should be given to the values as defined in the *Environmental Protection (Air) Policy 2019*. Schedule 8 part 3 of the EP Reg sets identifies the performance outcomes to be achieved that will achieve the Environmental Objective of operating the activity in a way that protects the EVs of air. The Performance Outcomes are: 1. The is no discharge to air of contaminants that may cause an adverse effect on the environment from the operation of the activity; or. 2. All of the following: a. fugitive emissions of contaminants from storage, handling and processing of materials and transporting materials within the site are prevented or minimised b. contingency measures will prevent or minimise adverse effects on the environment from unplanned emissions and shut down and start up emissions of contaminants to air c. releases of contaminants to the atmosphere for dispersion will be managed to prevent or minimise adverse effects on EVs. Schedule 1 of the EPP Air, sets the air quality objectives and indicators to be achieved for each EV. Under the EPP Air, the EVs likely to be affected by the proposed activities includes: • Protecting human health and wellbeing from emissions such as nitrogen dioxide (NO_2) and carbon monoxide (CO)

Value / Objective	Performance Outcome - Santos Response
	• Protecting aesthetic environment from visibility reducing particles such as dust and smoke. Section 4.7 provides an assessment of potential Impacts, mitigation measures and environmental risk assessment of the proposed activities with regard to potential impacts to air EVs (as described in Section 3.9). The proposed activities may result in impacts to air values primarily as a result of: • infrastructure construction; • vehicle and plant movements; • fire (ignition sources resulting from activities); and • minor exhaust emissions generated from vehicles, equipment and machinery. The activity will be operated in a way that protects the EVs of air. Fugitive emissions and releases of contaminants from storage, handling and processing of materials and transporting materials within the site to the atmosphere will be minimised in accordance with mitigation and management measures identified in Appendix F, Table 33 to prevent or minimise adverse effects on EVs. Further, contingency measures will prevent or minimise adverse effects on the environment from unplanned emissions and shut down and start up emissions of contaminants to air. Primary air pollutants generated during the proposed activities would be minor dust and exhaust emissions from operating vehicles, plant and machinery. These sources will be predominantly temporary, occurring only during the construction period. These relatively minor dust and exhaust emissions would remain local to the source, and are unlikely to affect air quality EVs of the broader Project Area provided that mitigation and management measures identified in Appendix F, Table 33 are implemented. There are eleven potential sensitive receptors, including five residences located within the Project Area, and six residences located within approximately 1km of the Project Area boundary. Management (control) strategies, risk sources, potential impacts and the level of risk associated with the proposed activities are summarised in Appendix F, Table 33. The results of the risk assessment indicate that residual risks to air EVs as a result of the proposed activities are

Value / Objective	Performance Outcome - Santos Response
	classified as 'Low'.
Water	
Environmental objective	
The activity will be operated in a way that protects environmental values of waters.	The intention of this environmental objective is to ensure that any discharges to water do not impact on EVs. Consideration should be given to the values as defined in the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019.* The Performance Outcomes are: 1. There is no actual or potential discharge to waters of contaminants that may cause an adverse effect on an environmental value from the operation of the activity. 2. All of the following— a. the storage and handling of contaminants will include effective means of secondary containment to prevent or minimise releases to the environment from spillage or leaks; b. contingency measures will prevent or minimise adverse effects on the environment due to unplanned releases or discharges of contaminants to water; c. the activity will be managed so that stormwater contaminated by the activity that may cause an adverse effect on an environmental value will not leave the site without prior treatment; d. the disturbance of any acid sulfate soil, or potential acid sulphate soil, will be managed to prevent or minimise adverse effects on EVs; e. acid producing rock will be managed to ensure that the production and release of acidic waste is prevented or minimised, including impacts during operation and after the environmental authority has been surrendered; f. any discharge to water or a watercourse or wetland will be managed so that there will be no adverse effects due to the altering of existing flow regimes for water or a watercourse or wetland; g. for a petroleum activity, the activity will be managed in a way that is consistent with the coal seam gas water management policy, including the prioritisation hierarchy for

Value / Objective	Performance Outcome - Santos Response

	managing and using coal seam gas water and the prioritisation hierarchy for managing saline waste;
	h. the activity will be managed so that adverse effects on EVs are prevented or minimised.
	
	Section 4.5 provides an assessment of potential impacts, mitigation measures and environmental risk assessment of the proposed activities with regard to potential impacts to surface water EVs (as described in Section 3.7).The proposed activities have potential to result in direct and indirect impacts to surface water EVs primarily as a result of:
	
	• drilling and hydraulic stimulation / fracturing activities;
	• production operations;
	• infrastructure construction (earthworks activities including grading and trenching);
	• vehicle and plant movements;
	• minor spills or leaks of fuels and chemicals from vehicles and equipment;
	• loss of containment; and
	• flood (natural event).
	
	Refer to Section 4.5 for a detailed discussion of mitigation measures proposed to be implemented to manage and mitigate potential impacts to water EVs.
	
	Section 14 of the EPP water defines the management hierarchy for surface or groundwater. To the extent it is reasonable to do so, release of wastewater or contaminants to waters must be dealt with in the following order of preference:
	
	• firstly—reduce the production of wastewater or contaminants by reducing the use of water;
	• secondly—prevent waste and implement appropriate waste prevention measures;
	• thirdly—evaluate treatment and recycling options and implement appropriate treatment and recycling;
	• fourthly—evaluate the following options for waste water or contaminants in the order in which they are listed –
	  ○ appropriate treatment and release to a waste facility or sewer;
	  ○ appropriate treatment and release to land;

Value / Objective	Performance Outcome - Santos Response
	○ appropriate treatment and release to surface waters or groundwaters. To meet the objectives under EPP Water, the following will be undertaken: • sediment and erosion control measures (e.g., silt fences, diversion drains) will be developed in accordance with the Best Practice Erosion and Sediment Control guidelines; • progressive rehabilitation to re-establish ground cover and minimise run-off; • construction activities occurring within watercourses will be completed in accordance with proposed EA conditions; • all disturbed areas will then be reshaped and stabilised following trenching and revegetated where required to support natural hydrology and ecological recovery; • effluent released to land will be in accordance with MEDLI; • clean up of unauthorised releases as soon as practicable; • appropriate bunding and clean water diversions; • use of sediment ponds to collect any contaminated stormwater; and • CSG water released to land will be in accordance with the release criteria. Further, proposed EA conditions (refer to Appendix A) limit activities within wetlands, lakes, springs and watercourses, and other 'waters' as defined by the EA. For well pads and other permanent infrastructure close to drainage lines and watercourses, areas will be bunded to contain spills and prevent run-off. Spill kits will be kept on-site, and all staff will follow spill response procedures. Cleared areas will be stabilised, and disturbed land will be rehabilitated after works are complete in alignment with proposed EA conditions and Santos internal procedure documents. Management (control) strategies, risk sources, potential impacts and the level of risk associated with the proposed activities are summarised in Appendix F, Table 33. The results of the risk assessment indicate that residual risks to surface water EVs as a result of the proposed activities are classified as 'Low'.
Wetlands	

Value / Objective	Performance Outcome - Santos Response
Environmental objective	
The activity will be operated in a way that protects the environmental values of wetlands.	Wetlands are defined in the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* as an area shown as a wetland on the Map of Queensland wetland EVs. The Map of Queensland wetland EVs is a statewide statutory map under the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019*. It identifies wetlands of high ecological significance (HES) and general ecological significance (GES) across the state. This performance outcome is met if the activity will not potentially or actually impact on a wetland. For example, the activity may be located in an area without any wetlands nearby. The map of referable wetlands, available on the DETSI website may be used to identify proximate referable wetlands. There are no referable wetlands, HES or GES wetlands, spring vents, spring complexes or watercourse springs mapped to be located within the Project Area and there will be no potential or actual adverse effect on a wetland as defined by the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* as part of carrying out the activity. Proposed activities do not include planned direct abstraction from, or discharges to, watercourses. Impacts on surface water users, EVs and spiritual values are not anticipated. Further, proposed EA conditions (refer to Appendix A) limit activities within wetlands, lakes, springs and watercourses, and other 'waters' as defined by the EA, and the activity will be operated in a way that prevents or minimises adverse effects on the EVs of wetlands.
Groundwater	
Environmental objective	
The activity will be operated in a way that protects the environmental values of groundwater and any associated surface ecological systems.	Groundwater is defined in Schedule 19 Dictionary of the EP Reg and means 'underground water'. Surface water is defined in s. 31 of the EP Reg as 'water other than groundwater'. The Performance Outcomes are: 1. Both of the following apply —

Value / Objective	Performance Outcome - Santos Response
	a. there will be no direct or indirect release of contaminants to groundwater from the operation of the activity; b. there will be no actual or potential adverse effect on groundwater from the operation of the activity. 2. The activity will be managed to prevent or minimise adverse effects on groundwater or any associated surface ecological systems. This performance outcome is met if the activity does not involve the intentional injections or release of contaminants to groundwater, and does not involve any activities that might lead to an unintentional release to groundwater, for example, by spillage of contaminants. An activity that could meet performance outcome 1 is an activity that does not involve the handling or storage of any contaminants that may cause an impact on groundwater. If management action or infrastructure is required to manage contaminants, for example secondary containment, then performance outcome 2 is relevant. Section 4.6 provides an assessment of potential Impacts, mitigation measures and environmental risk assessment of the proposed activities with regard to potential impacts to groundwater EVs (as described in Section 3.8). Further, as discussed in Section 3.8, Santos commissioned KCB to undertake a third-party WRA (KCB, 2025) of proposed activities located in the Project Area (attached as Appendix E). Predicted impacts to groundwater as a result of the Project were estimated using the OGIA groundwater model developed for predicting effects on groundwater due to CSG and coal mine development within the Surat Cumulative Management Area (CMA). Refer to Section 4.6 for detailed discussion of mitigation measures proposed to be implemented to manage and mitigate potential impacts to groundwater EVs. Section 14 of the EPP water defines the management hierarchy for surface or groundwater. To the extent it is reasonable to do so, release of wastewater or contaminants to waters must be dealt with in the following order of preference: • firstly—reduce the production of wastewater or contaminants by reducing the use of water; • secondly—prevent waste and implement appropriate waste prevention measures;

Value / Objective	Performance Outcome - Santos Response

	• thirdly—evaluate treatment and recycling options and implement appropriate treatment and recycling;
	• fourthly—evaluate the following options for wastewater or contaminants in the order in which they are listed –
	  ○ appropriate treatment and release to a waste facility or sewer;
	  ○ appropriate treatment and release to land;
	  ○ appropriate treatment and release to surface waters or groundwaters.
	
	All activities with the potential to interact with groundwater will be conducted in line with Santos' internal groundwater management procedures and proposed EA conditions. For linear infrastructure, trenching activities will avoid shallow groundwater areas where practicable. To avoid introducing contaminants to groundwater, fuels, chemical and other hazardous materials will be stored within bunded storage areas and spill kits will be made available. Groundwater monitoring will be undertaken as required by proposed EA conditions and applicable regulatory requirements to verify that groundwater levels and quality are not adversely affected.
	
	For production wells, all well construction will comply with industry standards and Santos' internal design specifications, including casing and cementing to isolate aquifers and prevent inter-aquifer mixing. Permanent infrastructure, including well pads and associated storage areas, will be bunded and designed to contain any spills or leaks, preventing infiltration to underlying groundwater systems. Spill kits and response procedures will be in place at all operational sites.
	
	Management (control) strategies, risk sources, potential impacts and the level of risk associated with the proposed activities are summarised in Appendix F, Table 33. The results of the risk assessment indicate that residual risks to groundwater EVs as a result of the proposed activities are classified as 'Low'.

Noise	
Environmental objective	

Value / Objective	Performance Outcome - Santos Response
The activity will be operated in a way that protects the environmental values of the acoustic environment.	Sensitive receptors for noise issues are specified in the *Environmental Protection (Noise) Policy 2019.* The Performance Outcomes are: 1. Sound from the activity is not audible at a sensitive receptor. The release of sound to the environment from the activity is managed so that adverse effects on EVs including health and wellbeing and sensitive ecosystems are prevented or minimised. Noise emissions associated with CSG activities are regulated under the EP Act and the subordinate legislation being the *Environmental Protection (Noise) Policy 2019* (EPP Noise) and EP Reg. Section 6 the EPP Noise describes the EVs that are to be protected or enhanced are: • The qualities of the acoustic environment that are conducive to protecting the health and biodiversity of ecosystem • The qualities of the acoustic environment that are conducive to human health and wellbeing, including by ensuring a suitable acoustic environment for individuals to do any of the following: ○ sleep ○ study or learn ○ be involved in recreation, including relaxation and conversation • The qualities of the acoustic environment that are conducive to protecting the amenity of the community. Schedule 8 part 3 of the EP Reg sets the performance outcomes that will achieve the Environmental Objective of operating the activity in a way that protects the EVs of the acoustic environment. These are: 1. Sound from the activity is not audible at a sensitive receptor; or 2. The release of sound to the environment from the activity is managed so that adverse effects on EVs, including health and wellbeing and sensitive ecosystems, are prevented or minimised. If not properly managed, the proposed activities have potential to impact on the EVs for noise by causing environmental harm, including nuisance. Section 14 of the EP Act defines environmental harm as any adverse effect, or potential adverse effect (whether temporary or permanent and of

Value / Objective	Performance Outcome - Santos Response
	whatever magnitude, duration or frequency) an EV and includes environmental nuisance. Section 15 of the EP Act defines environmental nuisance as unreasonable interference or likely interference with an EV caused by: • Aerosols, fumes, light, noise, odour, particles or smoke; or • An unhealthy, offensive or unsightly condition because of contamination; or • Another way prescribed by regulation. Schedule 1 of the EPP noise, sets the acoustic quality objectives at sensitive receptors and the EV to be protected. The acoustic EVs identified for the proposed activities include: • Residential receptors (indoor and outdoor) – daytime, evening and night-time • Commercial and retail activity – when the activity is open for business. Section 4.7 provides an assessment of potential Impacts, mitigation measures and environmental risk assessment of the proposed activities with regard to potential impacts to noise EVs (as described in Section 3.9). The proposed activities may result in impacts to noise values primarily as a result of: • infrastructure construction; • vehicle and plant movements; • fire (ignition sources resulting from activities); and • minor exhaust emissions generated from vehicles, equipment and machinery. The majority of potential noise impacts from the proposed activities would be temporary and limited to the initial construction period. The proposed activities (and potential noise and air quality impacts) are also consistent with those associated with existing petroleum activities authorised by the nearby Backbone EA (EPPG04323316), underlying RSGPA (EPPG00898213) and RSGPAE (EPPG00662213) EAs, and existing land use (pastoral / grazing / cropping activities). Impacts from construction activities are expected to be minimal and of short duration. No blasting is proposed. Section 8 of the EPP Noise outlines the management hierarchy for an activity involving noise that affects or may affect an environmental value to be enhanced or protected under the policy. To the

Value / Objective	Performance Outcome - Santos Response

	extent that is reasonable to do so, the EPP Noise requires that noise emissions must be dealt with in the following order of preference:
	• firstly – avoid noise, for example by locating an industrial activity in an area that is not near a sensitive receptor
	• secondly – minimise the noise in the following order
	  ○ firstly – orientate an activity to minimise the noise for example by facing a part of an activity to minimise the noise
	  ○ secondly – use best available technology to minimise the noise
	• thirdly – manage the noise for example by using heavy machinery only during business hours.
	Section 9 of the EPP Noise outlines the management intent for an activity involving noise that affects or may affect an EV to be enhanced or protected under the policy. To the extent it is reasonable to do so, noise must be dealt with in a way that ensures:
	• the noise does not have any adverse effect, or potential adverse effect on an EV
	• background creep (general gradual increase in the total amount of background noise) in an area or place is prevented or minimised.
	All activities will be undertaken in accordance with the operational and monitoring conditions of the proposed EA conditions. Further, alternative arrangements will be in place for a noise scenario where the permissible sound level is exceeded in accordance with proposed EA conditions. The proposed activities are expected to be undertaken with negligible risk of impacts to surrounding sensitive receptors.
	Management (control) strategies, risk sources, potential impacts and the level of risk associated with the proposed activities are summarised in Appendix F, Table 33. The results of the risk assessment indicate that residual risks to noise EVs as a result of the proposed activities are classified as 'Low'.

Waste	
Environmental objective	

Value / Objective	Performance Outcome - Santos Response
Any waste generated, transported, or received as part of carrying out the activity is managed in a way that protects all environmental values.	The intention of this environmental objective is to ensure that waste issues are adequately addressed. The Performance Outcomes are: 1. Both of the following apply: a) waste generated, transported or received is managed in accordance with the waste and resource management hierarchy in the *Waste Reduction and Recycling Act 2011*; b) if waste is disposed of, it is disposed of in a way that prevents or minimises adverse effects on EVs. Performance outcome 1 applies to all activities that generate, transport, receive, or dispose of waste. In Queensland waste associated with CSG activities are regulated under key pieces of legislation including: • *Environmental Protection Act 1994* (EP Act) • Environmental Protection Regulation 2019 (EP Regulation) • *Waste Reduction and Recycling Act 2011* (WRR Act) • Waste Reduction and Recycling Regulation 2023 (WRR Regulation) • Coal seam gas water management policy 2012 • Queensland government's coal seam gas brine action plan 2023-2033 • The National Environment Protection (movement of controlled waste between States and Territories) Measure (NEPM) The EP Act aims to protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (being ecologically sustainable development). The WRR Act aims to promote waste avoidance and reduction and to encourage resource recovery and efficiency. Under section 8AA of the WRR Act; • 'Waste' is defined as anything that ○ is left over, or is unwanted by-product from an industrial, commercial or other activity ○ is surplus to industrial, commercial, domestic or other activity generating the waste,

Value / Objective	Performance Outcome - Santos Response
	• however, waste does not include a resource, or a thing prescribed by regulation not to be a waste • waste can be a gas, liquid, solid or energy, or a combination of any of them. Schedule 8 part 3 of the EP Reg sets the performance outcome that will achieve the Environmental Objective that any waste generated, transported or received as part of an activity is managed in a way that protects all EVs. Under this section, both of the following apply: • waste generated, transported or received is managed in accordance with the waste and resource management hierarchy under the WRR Act; and • if waste is disposed of, it is disposed of in a way that prevents or minimises adverse effects on EVs. The NEPM provides a basis for ensuring that controlled wastes which are to be moved between States and Territories are properly identified, transported, and otherwise handled in ways which are consistent with environmentally-sound practices for the management of these wastes. The proposed EA conditions will appropriately govern waste management for the Project, and Santos will implement measures so that waste is managed in accordance with the waste and resource management hierarchy and the waste and resource management principles. **Waste generation** Waste generation will occur throughout construction, operation and decommissioning of each Project activity. The principal waste generating activities from the proposed activities can be broadly classified as the following: • Project construction activities • CSG well drilling • CSG production/extraction • Sewage treatment • Pipeline waste water from low point drains • Activities incidental to construction and operation such as camps • Asset decommissioning and abandonment activities.

Value / Objective	Performance Outcome - Santos Response

	Each of these activities generate a variety of waste products that can be categorised as being one of the following three categories:
	
	• **Regulated waste** – wastes listed schedule 9[3] of the EP Regulation. Regulated wastes are subject to specific storage, transport and Reporting requirements and require careful on-site management due to the hazards associated with them. Regulated wastes may be recyclable or disposable. The EP Regulation also defines 'limited regulated waste'. Up to 10% of the total amount of waste received at a general waste disposal facility in a year can be limited regulated waste. The definition of limited regulated waste includes the following specific regulated waste types:
	  ○ animal effluent and residues, including abattoir effluent and poultry and fish processing waste
	  ○ asbestos
	  ○ food processing waste
	  ○ quarantine waste that has been rendered non-infectious
	  ○ sewage sludge or residue produced in carrying out an ERA to which an environmental authority for sewage treatment applies
	  ○ tyres
	• **General recyclable waste** – wastes that are not regulated and able to be reused, reconditioned, or reprocessed.
	• **General waste** – wastes that are not regulated and cannot be recycled. General disposal waste is comprised of two main waste streams: putrescible (i.e., something that can decay) and non-putrescible.
	
	The specific waste types expected to be generated as part of the Project are listed in Section 3.10.
	
	EVs to that are to be protected or enhanced that can potentially be impacted by waste from the proposed activities include:
	
	• Water – contamination of surface and groundwater can potentially occur if:

[3] https://www.legislation.qld.gov.au/view/html/inforce/current/sl-2019-0155#sch.9

Value / Objective	Performance Outcome - Santos Response
	○ waste is not stored and contained appropriately ○ unauthorised release of contaminants such as brine and untreated CSG water ○ stormwater is not appropriately managed before release ○ unplanned spills of produced water, hydrocarbons, chemicals are not cleaned appropriately ○ effluent is not appropriately treated before releasing to land • Land – contamination of soils can potentially occur if: ○ waste is not stored and contained properly ○ unauthorised release of contaminants such as brine and untreated CSG water ○ stormwater is not appropriately managed before release ○ effluent is not appropriately treated before releasing to land ○ excessive nutrient loading from the treated effluent ○ irrigation of CSG water that does not comply with the release criteria • Health and wellbeing – health and wellbeing can potentially be impacted where: ○ dust, excessive noise, and other airborne contaminants including offensive odours that can cause nuisance at a sensitive receptor ○ waterborne human disease-causing microorganisms in the treated effluent ○ unauthorised release of contaminants such as brine and CSG water • Flora and fauna – Flora and fauna can potentially be impacted if: ○ waste is not stored and contained properly • General aesthetic and amenity – the general aesthetic of the environment can potentially be impacted where: ○ Waste stockpiles are not covered causing litter and dust emissions ○ Waste stockpiles exceed certain heights • Impact on air quality from emissions including dust, GHG, NOx Section 4.8 provides an assessment of potential Impacts, mitigation measures and environmental risk assessment of the proposed activities with regard to potential impacts associated with waste generation, storage, processing and transport. The proposed activities may result in impacts to EVs (as described in Section 3.9) due to the generation of waste, primarily as a result of the storage and disposal of: • general waste; • waste fuels;

Value / Objective	Performance Outcome - Santos Response
	• oils and other chemicals; and • produced fluids and other process wastes. All chemicals and fuels used for the Project will be stored, transported and handled on-site will be effectively contained and where relevant, meet the relevant Australian Standards (e.g. AS 1940:2017 for the storage and handling of flammable and combustible liquids. Further, management of PW, residual drilling materials, hydraulic fracturing stimulation fluids and hydrostatic test water and water from LPDs are specifically discussed in Sections 4.8.1 to 4.8.5. Impacts associated with the generation of waste, primarily as a result of the storage and disposal of waste, have the potential to impact on EVs including on land and biodiversity, visual amenity, soil and water quality and human health. Santos aims to minimise the operational footprint and significant disturbance associated with its activities as far as reasonably practicable. However, potential direct and indirect impacts to EVs resulting from the generation, storage and disposal of waste may include: • reduction in visual amenity; • disturbance, injury or loss of fauna and livestock (i.e. fauna/livestock access to waste/contaminants); • contamination of soil and water resources (groundwater / surface water); • disturbance to land use and land suitability changes; and • reduction in agricultural productivity. Management (control) strategies, risk sources, potential impacts and the level of risk associated with the proposed activities are summarised in Appendix F, Table 33. The results of the risk assessment indicate that residual risks to EVs due to the generation, storage and disposal of waste as a result of the proposed activities are classified as 'Low'
Land	
Environmental objective	

Value / Objective	Performance Outcome - Santos Response
The activity is operated in a way that protects the environmental values of land including soils, subsoils, landforms and associated flora and fauna.	The intention of this environmental objective includes management of land issues during the operational phase of the activity, as well as rehabilitation of significantly disturbed land once operational activities have ceased. Schedule 8 part 3 of the EP Reg, sets the performance outcomes for achieving the Environmental Objective of carrying out the activity in a way that protects the EVs of land, including soils, subsoils, landforms and associated flora and fauna. The Performance Outcomes are: 1. There is no actual or potential disturbance or adverse effect to the environmental values of land as part of carrying out the activity. 2. All of the following — a. activities that disturb land, soils, subsoils, landforms and associated flora and fauna will be managed in a way that prevents or minimises adverse effects on the environmental values of land; b. areas disturbed will be rehabilitated or restored to achieve sites that are (i) safe to humans and wildlife; and (ii) non-polluting; and (iii) stable; and (iv) able to sustain an appropriate land use after rehabilitation or restoration; c. the activity will be managed to prevent or minimise adverse effects on the environmental values of land due to unplanned releases or discharges, including spills and leaks of contaminants; d. the application of water or waste to the land is sustainable and is managed to prevent or minimise adverse effects on the composition or structure of soils and subsoils. The land EVs of the Project Area are described in detail in Section 3.1, and Sections 4.1 and 4.9 provide an assessment of potential Impacts, mitigation measures, rehabilitation and environmental risk assessment of the proposed activities with regard to potential impacts to land

Value / Objective	Performance Outcome - Santos Response
	EVs. Potential direct and indirect impacts to land resources will be predominantly short-term and associated with the initial limited clearing and construction phases of the project. The proposed activities would result in direct disturbance of land for the construction of well leases, access tracks, gathering infrastructure and other incidental petroleum activities as described in Section 2.2. Proposed disturbance may temporarily reduce the availability of land for agriculture. However, these impacts would be offset by commercial agreements between Santos and relevant property owners. Following completion of the construction phase, large sections of land will begin regenerating to achieve stability and groundcover similar to that of surrounding areas. In accordance with the Land Guideline (ESR/2015/1839), appropriate soil management and rehabilitation practices will be implemented to avoid or mitigate these impacts and to ensure that disturbed land is returned to a stable and non-polluting condition. Section 4.9 provides a detailed description of rehabilitation to be undertaken as part of the proposed activities. Rehabilitation activities should seek to maintain or enhance, and protect the following EVs: • the existing primary land use for agriculture • ecosystem functioning including provision of wildlife habitat and connectivity, and ecosystem services like clean air and water; and • visual amenity of the landscape. Rehabilitation works would aim to meet Rehabilitation Acceptance Criteria under the proposed EA conditions. Rehabilitation and decommissioning of disturbed land areas would occur progressively in accordance with proposed EA conditions. The objective of rehabilitation and decommissioning is to achieve a post development landform that is: • safe for humans, native fauna and livestock • non-polluting; and

Value / Objective	Performance Outcome - Santos Response
	• stable and able to sustain appropriate land use. Disturbed areas such as pipeline RoWs would be stabilised post-construction to ensure the safe and effective operation of assets and to minimise the risk of erosion, soil loss and weed invasion. Stabilisation works would include: • remediating areas of contaminated land resulting from petroleum activities • re-establishing surface drainage lines and re-profiling contours for operational use • establishing a safe landform for humans and livestock in areas of significant cut and fill • reinstating top soil • soil conditioning where required; and • promoting the establishment of groundcover vegetation. Once disturbed areas are no longer required for operations, these would be returned to an appropriate land use in accordance with landholder needs and applicable regulatory requirements. Agricultural land uses and natural areas comprising MSES, ESAs and other forms of vegetation are the two most common pre-disturbance land uses to be rehabilitated. Final rehabilitation of natural areas would be undertaken to achieve the final rehabilitation criteria specified conditions for the proposed EA. Management (control) strategies, risk sources, potential impacts and the level of risk associated with the proposed activities are summarised in Appendix F, Table 33. The results of the risk assessment indicate the residual risk to land resource EVs as a result of the proposed activities is classified as 'Low'.

Appendix H: Eastern Queensland Hydraulic Fracturing Risk Assessment

Statutory Declaration

Resource activities other than mining

Declaration of compliance for written documents

A statutory declaration is a written statement of facts that is sworn or declared under the Oaths Act 1867. *This statutory declaration has been prepared to declare the authority holders compliance with the provisions of the* Environmental Protection Act 1994 *(EP Act) or an environmental authority condition that stipulates the requirement to submit a certified written document to the administering authority.*

Oaths Act 1867

QUEENSLAND
TO WIT

Re: Written documents relating to an environmental authority for a resource activity other than mining under the *Environmental Protection Act 1994.*

Written document: Santos Eastern Queensland Hydraulic Fracturing Risk Assessment – Document # 0007-650-EMP-0044 (7 March 2025)

(Insert type of document, e.g. contingency plan for emergency environmental incidents)

Subject matter: Compliance with Environmental Authorities and conditions as per Section 1.3 for the Environmental Authorities listed in Table 1 of the written document.

(Insert subject matter, e.g. compliance with environmental authority number PEN1001222222)

Authority holder: Santos Ltd

I, Nigel Goulding

(Insert full name of person making this declaration)

of, 3900 Stonewater Drive, Columbus OH 43221

(Insert suburb and city of the person making this declaration)

Declaration of compliance for written documents

in the State of Queensland do solemnly and sincerely declare that:

1. I am a suitably qualified person as defined in the environmental authority; having professional qualifications, training, skills and experience relevant to the subject matter and can give authoritative assessment, advice and analysis relative to the subject matter using the relevant protocols, standards, methods or literature. A copy of my curriculum vitae is Annexure A to this declaration[1];
2. The authority holder has fully complied with the requirements of environmental authority(ies) as per Section 1.0 and conditions of the environmental authority(ies) as per Attachment 1 of the written document.
3. All relevant material has been considered in preparing the Eastern Queensland Stimulation Impact Monitoring Program.
4. The content of the Eastern Queensland Stimulation Impact Monitoring Program is accurate and true.
5. The Eastern Queensland Stimulation Impact Monitoring Program meets the requirements of the environmental authority(ies) as per Section 1.0 and conditions of the environmental authority(ies) as per Attachment 1 of the written document.

And I make this solemn declaration conscientiously believing the same to be true, and by virtue of the provisions of the *Oaths Act 1867*.

Taken and declared before me, at SYDNEY NSW

(Insert name of town or city and suburb)

this 07 MAR 2025 day of _____ in the year _____

(Insert day, e.g. 18th) (Insert month) (Insert year)

_____ _____

Signed Signed

(Person making this declaration) (Cross out whichever is not applicable)

Justice of the Peace / ~~Commissioner for Declarations~~ / ~~Solicitor / Barrister~~ / ~~Notary~~ for the State of New South Wales Australia

JUSTICE OF THE PEACE
John Peter White
Registration 195515
14/38 Gelle Line of Road
NSW Richmond NSW 2754
Ph:

_____

(Print name and registration number, if applicable)

[1] The signatory does need to initial each page of the annexure, but it does need to be marked with the following: "This is the *[insert name of document]* or a copy of the [insert name of document] marked with the letter "A" referred to in the Statutory Declaration [insert sworn/taken/affirmed/solemnly declared] before me at [insert day] of [insert month], [insert year].

Approved By

Signature	Date

Director
Energy Regulation and Implementation Unit
Environmental Protection Act 1994
Department of Environment and Heritage Protection

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Santos

SANTOS EASTERN QUEENSLAND HYDRAULIC FRACTURING RISK ASSESSMENT

0007-650-EMP-0044

Revision	Date	Description	Prepared	Reviewed	Approved
0	07 Nov 2019	Finalised for Use	EHS Support	Santos	Santos
1	15 Sep 2021	Update to include new HF fluid systems	EHS Support	Santos	Santos
2	13 Jun 2023	Update HF fluid system description	EHS Support	Santos	Santos
3	7 March 2025	Administrative Review and Update	EHS Support	Santos	Santos

Santos

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Abbreviations and Units

Abbreviation	Description
>	greater than
<	less than
%	percent
°	degrees
µg/m^3	microgram per cubic metre
µS/cm	microsiemens per centimetre
ADI	acceptable daily intakes
ADWG	Australian Drinking Water Guidelines
AGE	Australian Groundwater and Environmental Consultants Pty Ltd
ANRA	Australian Natural Resources Atlas
ANZECC	Australian and New Zealand Environment Conservation Council
API	American Petroleum Institute
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AT	averaging time (days)
ATP	Authority to Prospect
AVPA	Arcadia Valley Project Area
B	Bioaccumulative
BAF	Bioaccumulation factor
bbl	barrels
BCF	Bioconcentration factor
BIOWIN™	Wastewater treatment process simulator
BMF	Biomagnification factor
BOM	Bureau of Meteorology
BTEX	benzene, toluene, ethylbenzene, xylenes
BW	body weight (kg)
CASRN	Chemical Abstracts Service Registry numbers
CBL	Cement bond log
CCID	Chemical Classification Information Database
CCME	Canadian Council of Ministers of the Environment
CF	correction factor (1 x 10-3 l/cm^3)
CHRIP	Chemical Risk Information Platform
CICAD	Concise International Chemical Assessment Document
cm	centimetre
COPC	chemicals of potential concern
cP	Centipoise
CSF	Cancer slope factors
CSG	Coal seam gas
CW	concentration in water (mg/l)
Cwater	Concentration of COPC in water (mg/l)
CWMMP	Coal Seam Water Monitoring and Management Plan
DPA	Denison Project Area

Abbreviation	Description
dB	Decibels
DAWE	Department of Agriculture, Water and the Environment (Commonwealth)
DEHP	Department of Environment and Heritage Protection (Queensland) (now Department of Environment and Science)
DERM	Department of Environment and Resource Management (Queensland)
DES	Department of Environment and Science (Queensland)
DEWHA	Department of the Environment, Water, Heritage and the Arts (Commonwealth)
DNRME	Department of Natural Resources, Mines and Energy (Queensland)
DO	Dissolved oxygen
DOC	Dissolved organic carbon
DOR	Department of Resources (Queensland)
DotE	Department of the Environment (Commonwealth)
DP	dermal permeability factor (Kp – cm/hr)
DTA	Direct Toxicity Assessment
EA	Environmental Authority
EC	electrical conductivity
EC50	Half maximal effective concentration
ECB	European Chemicals Bureau
ECHA	European Chemicals Agency
ECx	Effective concentration
ED	exposure duration (years)
EDTA	Ethylenediaminetetraacetic acid
E-ESE	East-East Southeast
EF	Exposure frequency (days/year)
EHC	Environmental Health Criteria
EIS	Environmental Impact Statement
EM	Environmental management
EPA	Environment Protection Authority
EPBC Act	*Environmental Protection and Biodiversity Conservation Act 1999*
EPC	Exposure point concentrations
EPISUITE™	Estimation Programs Interface Suite™
EPP	Environmental Protection Policy
EQ	Eastern Queensland
ERA	Ecological Risk Assessment
ESIS	European Chemical Substances Information System
ESP	Electric submersible pump
ET	exposure time (hr/day or hours/hours)
EU	European
EV	Environmental value
foc	Fraction organic carbon content
FPA	Fairview Project Area
g/cm^3	Grams per cubic centimetre
GAB	Great Artesian Basin

Abbreviation	Description
GABCC	Great Artesian Basin Coordinating Committee
GABWRP	GAB Water Resource Plan
GDE	Groundwater Dependant Ecosystem
GDR	Great Dividing Range
GHS	Globalized Harmonized System for Classification and Labelling of Chemical
GIS	Geographic Information System
GLNG	Gladstone Liquefied Natural Gas
GMA	groundwater management area
GMU	Groundwater management unit
HERA	Human and Environmental Risk Assessment
HEV	High ecological environment
HHRA	Human health risk assessment
HI	Hazard index
HPV	High Production Volume
HQ	Hazard quotient
HRIPT	Human Repeat Insult Patch Test
HSDB	Hazardous Substances Databank
HSE	health-safety-environmental
HSNO	Hazardous Substances and New Organisms
IARC	International Agency for Research on Cancer
IC50	Half maximal inhibitory concentration
ICP	The inhibitory concentration to cause a p% effect
IPCS	International Program of Chemical Safety
IR	ingestion rate (l/hr)
IRIS	Integrated risk information system
IRwater	Ingestion rate (litres/day)
ISO	International Standards Organisation
IUCLID	International Uniform Chemical Information Database
J-CHECK	Japan CHEmicals Collaborative Knowledge database
JECDB	Japan Existing Chemical Data Base
JITP	Just In Time Perforating
JRC	Joint Research Centre
Kg	Kilogram
Kh	Henry's law constant
Km	Kilometre
km2	Square kilometre
Koc	Organic carbon partition coefficient
Kow	Octanol-water partition coefficient
L	Litres
LA90 1-hour	The noise level equalled or exceeded for 90% of the measurement period over an hour
LAeq 1-hour	Average energy A-weighted sound pressure level for the time interval of monitoring over an hour
LAmax	The maximum instantaneous noise level during a measurement period
LC50	Lethal concentration, 50%

Abbreviation	Description
LD50	Lethal dose, 50%
LOAEL	Lowest observed adverse effect level
LOEC	Lowest observed effect concentration
LOR	Limits of reporting
m	metres
m/s	Metres per second
MATC	Maximum acceptable tolerable concentration
mbgl	metres below ground level
MDB	Murray-Darling Basin
Mg/L	Milligram per litre
MITI	Ministry of International Trade and Industry
mL	Millilitre
mm	millimetres
mm/s	Millimetres per second
mm/year	Millimetres per year
MSDS	material safety data sheet
NEPC	National Environmental Protection Council
NEPM	National Environment Protection (Site Assessment) Measure
NHMRC	National Health and Medical Research Council
NICNAS	National Industrial Chemicals Notification and Assessment Scheme
NNE	north
N-NNE	North-north northeast
NOAEL	No observed adverse effect level
NOEC	No observed effect concentration
NOHSC	National Occupational Health and Safety Commission
NRM	Department of Natural Resources and Mines
NRMMC	Natural Resource Management Ministerial Council
NTP	National Toxicology Program
NWQMS	National Water Quality Management Strategy
OECD	Organisation for Economic Cooperation and Development
OH&S	Occupational Health and Safety
OSHA	Occupational Safety and Health Administration
OTF	On-the-fly
P	Persistence
PAHs	polycyclic aromatic hydrocarbons
PBT	persistent (P), bioaccumulative (B) and Toxic (T)
PCP	Progressive cavity pump
PEC	Priority Existing Chemical
PL	Petroleum Lease
PNEC	Predicted no-effects concentration
POD	Point of departure
ppm	Parts per million
psi	pounds per square inch

Abbreviation	Description
QRA	quantitative risk assessment
QSAR	Quantitative structure-activity relationship
RAIS	Risk Assessment Information System
REACH	Registration, Evaluation, Authorization and Restriction of Chemical Substances
RfCs	Reference concentrations
RfDs	Reference doses
RHO	Density of soil material
RIVM	National Institute for Public Health and Environmental Protection
ROP	Resource Operation Plan
RSGPA	Roma Shallow Gas Project Area
RSGPAE	Roma Shallow Gas Project Area East
SA	skin surface area available for contact (cm^2/d)
SCA	Scotia Project Area
SCCS	Scientific Committee on Consumer Safety
SIDS	Screening Information Dataset
SILO	SILO is an enhanced climate data bank hosted by The Science Delivery Division of the Department of Science, Information Technology, Innovation and the Arts (DSITIA)
SIMP	Stimulation Impact Monitoring Program
SP	Spontaneous Potential (or Self Potential, Shale Potential log)
SPA	Scotia Project Area
SPL	Sound pressure levels
SWL	Sound power levels
T	Toxicity
TCs	Tolerable concentrations
TDI	Tolerable daily intakes
TDS	total dissolved solids
TI	Total intake of COPC (mg/kg/day)
TRV	Toxicity reference values
UFTotal	Total uncertainty factors
UNECE	United Nations Economic Commission for Europe
URF	Unit risk factors
USEPA	United States Environment Protection Authority
V	Very persistence
vB	Very bioaccumulative
VDL	variable density log
WA	Western Australia
WCM	Walloon Coal Measures
WERD	Water Entitlements Registration Database
WHO	World Health Organisation
WRP	Water Resource Plan
wt%	Weight percent
WTP	Water Treatment Plant

1 Introduction

1.1 Preamble

Santos is undertaking the development of conventional and coal seam gas (CSG) resources in the Surat and Bowen Basins of Queensland.

For the purposes of this assessment, the term 'study area' refers to area applicable to this assessment and includes all of Santos' upstream tenures associated with the Santos upstream development areas in Eastern Queensland (EQ) (hereafter referred to as the Santos EQ Project).

Where required, environmental approvals for Santos' petroleum and gas activities have been obtained from the Queensland Coordinator General (CG) and/or the Department of Environment and Science (DES). Environmental Authorities (EAs), issued by DES for specific project areas and/or individual petroleum leases (PLs) and specific exploration and appraisal areas (authority to prospect (ATP)) have also been obtained. These EAs have typically required the development of a risk assessment, prior to the undertaking stimulation activities, to ensure that stimulation activities are managed to prevent environmental harm.

This Hydraulic Fracturing Risk Assessment (HFRA) has been written as a single overarching risk assessment that covers all relevant and site-specific matters for EQ Project. As all wells have the potential to be hydraulically stimulated at one or more point in time, the single HFRA approach is considered appropriate to cover all wells over the Santos EQ Project time-period.

The HFRA addresses the regulatory requirements contained within the current Santos EQ EAs and synthesises the findings of several hydraulic fracturing risk assessments completed to date. The document includes information and assessment on all the hydraulic fracturing fluids currently used by Santos in EQ and provides a framework for inclusion of new tenure and new fluids systems within the risk assessment document as required. The HFRA also describes the process by which hydraulic fracturing is conducted and monitored.

The framework of this HFRA is such that it can be readily applied to all the wells comprising the Santos EQ Project as there are limited differences in the site-specific characteristics of wells within the study area nor differences in the type of stimulation procedures. Where specific characteristics do differ, additional information relating to respective sub-regions has been provided (e.g., climate, geology).

To facilitate the assessment and compilation of risk assessments completed on multiple fluid systems, this document has been organised with project information associated with the setting, geology and hydrogeology of the areas and the risk assessment methodologies and general findings within the body of the text. Information specific to the individual vendor hydraulic fracturing fluid systems and the associated risk assessment results are summarised in separate Appendices. The reader should identify the specific fluid system being utilised and the reference the appropriate risk assessment summary.

1.2 Project Area

This HFRA documents the environmental conditions relevant to the Santos EQ Project which are pertinent to the assessment of potential risks associated with hydraulic fracturing activities. The Santos EQ Project Area and

primary infrastructure relating to this HFRA are shown on

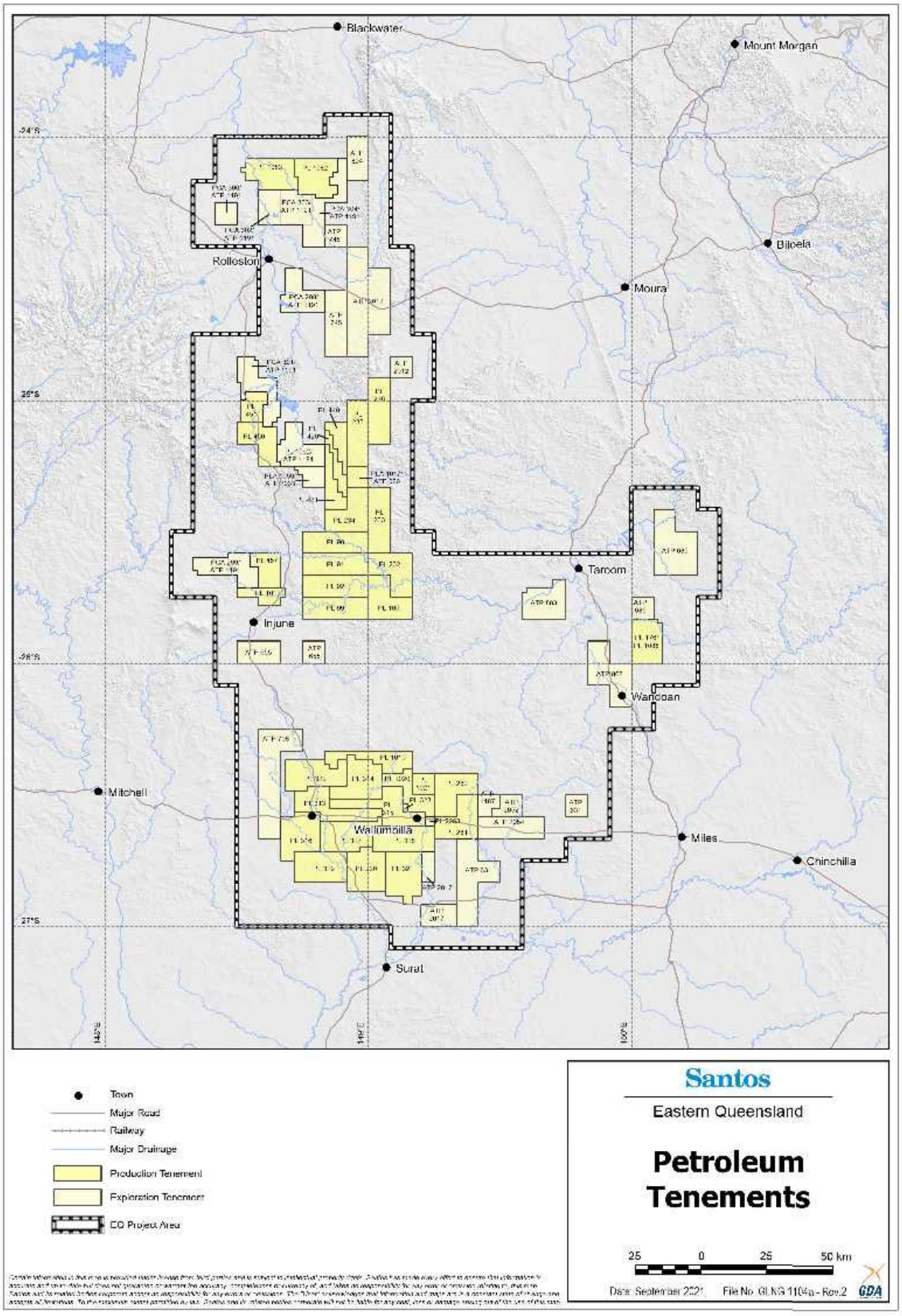


Figure 1, the extent of which is identified as 'Possible Area for Supporting Infrastructure'.

~~The main development areas focus on the Roma Shallow Gas Project Area (RSGPA), Fairview Project Area (FPA), Arcadia Valley Project Area (AVPA), Scotia Project Area (SPA) and Denison Project Area (DPA).~~ These

areas/regions present different geological, hydrological and geomorphological characteristics however the coal sequences and key aquifer units reflect the broader Basin depositional history and geometry. Where specific characteristics do differ, additional information relating to respective sub-regions has been provided. The area lies within the Surat and Bowen Basins, the latter comprising a portion of the Great Artesian Basin (GAB). The area is sparsely developed, and generally comprises rural communities and homesteads that are largely engaged in agriculture, such as livestock grazing.

For the purposes of this assessment, the terms 'study area' and EQ Project Area refer to the areas applicable to this assessment and includes all of the upstream tenures associated with the Santos EQ Project. The EAs (Permit Numbers) and Project Areas covered by this HFRA, include but are not limited to those identified in **Table 1**.

Table 1. Santos EQ Project EAs and Project Areas

Environmental Authority	Project Area
EPPG00928713	Fairview Arcadia Project Area (Fairview Project and Arcadia Valley Project Areas)
EPPG00898213	Roma Shallow Gas Project Area
EPPG00662213	Roma Shallow Gas Project Area East (PL 281 & 282)
EPPG03515915	Scotia Project Area
EA0001210	Maisey
EPPG00872113	Denison
EPPG00872113	ATP 337-1191 Environmental Authority
EPPG03516615	PL 320 Environmental Authority
EPPG04180616	PL 321 Environmental Authority
P-EA-100130995	PL 1059
EPPG00421513	ATP 685 Environmental Authority
EA0001589	ATP 2040 Environmental Authority
EA0001803	ATP 2045 Environmental Authority
EA0002052	ATP 2052-2053 Environmental Authority
EA0002315	ATP 2054 Environmental Authority
EA0002316	ATP 2055, 2056, 2057 Environmental Authority
EPSX01318213	ATP 1087 Environmental Authority

Note – EA numbers and Project Area details are subject to change as EAs are granted or amended.

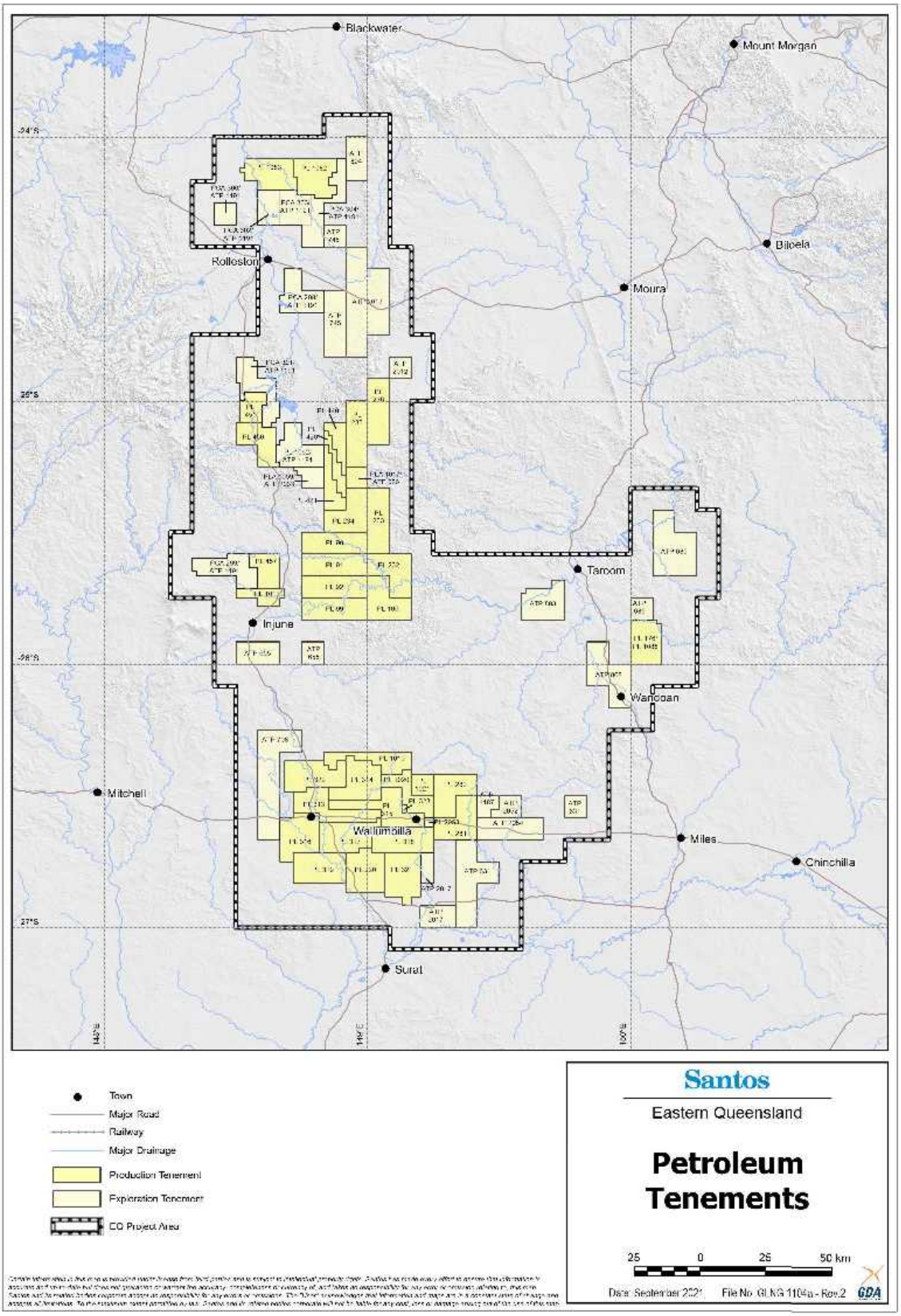


Figure 1. Santos EQ Project Petroleum Tenures

1.3 Environmental Authority Requirements

The EA approval requirements for the Santos EQ Project necessitate the collection and provision of information on hydraulic fracturing. Detailed regulatory requirements contained in these EAs and the sections of this risk assessment where the conditions are met are provided in **Table 2**.

Evaluation of compliance with these requirements must be considered in the context of other approval and regulatory requirements. As described further in **Section 4**, the drilling, completion and hydraulic fracturing is conducted in accordance with the *Code of Practice for the Construction and Abandonment of Petroleum Wells and Associated Bores in Queensland* (version 2 December 2019) [Code of Practice], which is overseen by the Department of Resources (DOR). No well can be drilled or hydraulically fractured without completion of DOR's prescribed process and reporting requirements.

In addition, Santos has key management plans associated with State and Commonwealth Approvals, which determine where wells can be drilled and potentially hydraulically fractured and identify the processes for assessment and management of risk. These key documents include the Environmental Protocol for Constraints Planning and Field Development (Constraints Protocol), which establishes the framework for avoiding or minimising environmental impacts, including the potential for impacts on aquifers, watercourses and springs and other associated management plans to comply with EA requirements.

Further, supporting documents such as the Stimulation Impact Monitoring Plan (SIMP), which is informed by this risk assessment, and associated routine operational monitoring are core components of the risk assessment/management components contained in this document.

Table 2. EA Approval Requirements

Reference[1]	Condition	Section in Risk Assessment
(*)	Prior to undertaking well stimulation activities, a risk assessment must be developed to ensure that stimulation activities are managed to prevent environmental harm	This document.
(*)	The stimulation risk assessment must be carried out for every well to be stimulated prior to stimulation activities being carried out at that well and address issues at a relevant geospatial scale such that changes to features and attributes are adequately described and must include, but not necessarily be limited to	This HFRA has been written as a single overarching risk assessment that covers all relevant and site-specific matters for the Santos EQ Project. As all wells have the potential to be hydraulically stimulated at one or more point in time, the single HFRA approach is considered appropriate to cover all wells over the Santos EQ Project time-period. The framework of this HFRA is such that it can be readily applied to all the wells comprising the Santos EQ Project as there are limited differences in the site-specific characteristics of wells within the study area nor differences in the type of stimulation procedures. Where specific characteristics do differ, additional information relating to respective sub-regions has been provided (e.g., climate, geology).
(a)	a process description of the stimulation activity to be applied, including equipment and a comparison to best international practice	**Section 4** provides a detailed discussion of the processes and monitoring implemented as part of hydraulic fracturing. As documented in **Section 4**, a prescriptive program of requirements for well completion and hydraulic fracturing is provided within the Code of Practice and International Best Practices (American Petroleum Institute Standards) that are used by Santos and Santos' hydraulic fracturing contractors. The ongoing advancements in technology and processes provided by international

Reference[1]	Condition	Section in Risk Assessment
		hydraulic fracturing specialists such as Schlumberger and Halliburton ensure that best practices are continuously being adopted on projects to ensure effective management of potential human health and environmental hazards.
(b)	provide details of where, when and how often stimulation is to be undertaken on the tenures covered by this environmental authority	Hydraulic fracturing can be conducted in any well completed in the Basin to enhance performance. The need for hydraulic fracturing is determined by physical data on the coal sequences, appraisal testing data and the performance data for other wells in the area. As noted in **Section 4.2.1**, a systematic framework of risk assessment must be completed before hydraulic fracturing is proposed and executed in a well. This starts with the siting of wells that are placed away from faults and structures that may be of concern (e.g., areas where fractures do or may have the potential to propagate from the target sequence into overlying aquifers – see **Section 2.5** and **2.6**). Details on how often wells are to be fractured in the area is provided in **Section 4.6** along with the process of notifications and reporting to DNRME (who approves and monitors the proposed activities), which is provided in **Section 4.6.1**.
(c)	a geological model of the field to be stimulated including geological names, descriptions and depths of the target gas producing formation(s)	Information regarding the conceptual geological model is found in the following sections: **Sections 2.5** (Regional and Basin Geology) **Sections 2.6** (Local Geology)
(d)	naturally occurring geological faults	Information regarding the fault systems can be found in the following sections: **Section 2.4.3** **Sections 2.5** (namely: **Section 2.5.4** and **Section 2.5.5**) **Sections 2.6** (namely: **Section 2.6.1.1**, **Section 2.6.2.1**, **Section 2.6.3.1** and **Section 2.6.4.1**) Importantly, information suggests that due to the tectonic setting, the faults and folds are tight and are characteristically not zones of groundwater flow, but rather are hydraulic barriers to flow. They typically compartmentalise the groundwater and restrict free flow across the compartment boundaries. This is generally manifested in water quality and temperature differences between compartments.
(e)	seismic history of the region (e.g., earth tremors, earthquakes)	Seismic history of the region is discussed in **Section 2.4** and **Section 2.5.5**.
(f)	proximity of overlying and underlying aquifers	The proximity of overlying and underlying aquifers to development targets is presented in **Section 3.7**.
(g)	description of the depths that aquifers with environmental values occur, both above and below the target gas producing formation	The description of the depths that aquifers with environmental values occur, both above and below the target gas producing formation is included in **Section 3.7**. This is also visually represented on **Figure 18** to **Figure 20**, **Figure 21** to **Figure 26**, and **Figure 30** to **Figure 35**.
(h)	identification and proximity of landholders' active groundwater bores in the area where stimulation activities are to be carried out	This is presented in **Figure 45** to **Figure 47** and discussed in **Section 3.6**, **Section 3.8** and **Section 3.9**.
(i)	the environmental values of groundwater in the area	**Section 3.6** Presents the Environmental Values of Groundwater **Section 3.8** Proximity to Environmental Values
(j)	an assessment of the appropriate limits of	The hazard and quantitative risk assessments demonstrated that the risk from hydraulic fracturing activities is limited with the implementation of standard

Reference[1]	Condition	Section in Risk Assessment
	reporting for all water quality indicators relevant to stimulation monitoring in order to accurately assess the risks to environmental values of groundwater	management and administrative controls. The fencing of sites (precluding the entry of unauthorised personnel and livestock) and management of initial flow back and produced water limit the potential for any unacceptable impacts within the receiving environment. In this context standard reporting limits for water quality parameters are considered sufficient for stimulation impact monitoring with baseline bore sampling including low level polycyclic aromatic hydrocarbon (PAH) analysis to ensure that the water quality in landholder bores is suitable for potable uses.
(k)	description of overlying and underlying formations in respect of porosity, permeability, hydraulic conductivity, faulting and fracture propensity	**Section 2.6** Faults and geological controls **Section 3.2.2** Aquifer and aquitard hydraulic properties **Section 3.5** Description of formation as well as some local formation properties
(l)	consideration of barriers or known direct connections (between the target gas producing formation and the overlying and underlying aquifers	**Section 3.7** Proximity to overlying and underlying aquifers and coal seams **Section 3.8** Proximity to Environmental Values
(m)	a description of the well mechanical integrity testing program	In accordance with the Code of Practice and International Best Practices, a comprehensive well design, well construction validation and mechanical testing program is implemented to ensure that the wells meet the project requirements and are not subject to mechanical failures that could result in human health or environmental hazards. **Section 4.3** provides a detailed discussion of the well integrity program, including selection of casing materials, logging of the boreholes, well completions, casing and cementing design, and validation testing of the casing and cement.
(n)	process control and assessment techniques to be applied for determining extent of stimulation activities (e.g., microseismic measurements, modelling)	This includes down hole pressure, flow rates and hydraulic fracturing fluid viscosity (if gel based systems are being used), which are described in **Section 4.4.2** and **Section 4.4.3**. This allows the hydraulic fracturing contractor to optimise the performance of the hydraulic fracturing process, and to rapidly identify unexpected pressure changes that could indicate a loss of well or confining layer integrity, and hence trigger a hold point for the hydraulic fracturing operation. Site-specific data are used in combination with models to predict the performance of each hydraulic fracturing event. The use of models as part of the design process (**Section 4.4.1**) is a critical component of the process as actual pressures and flows are compared to the model to determine the performance of the hydraulic fracturing event (including extent). Anomalies are identified as part of the monitoring program and subject to further evaluation and supplemental assessments. Microseismic measurements and testing are rarely used to assess performance.
(o)	practices and procedures to ensure that the stimulation activities are designed to be contained within the target gas producing formation	The practices and procedures for ensuring that stimulation activities are designed and implemented in a manner to contain the fluids to the target formation are discussed in **Section 4.4**. The key components include appropriate design and installation of well casing and cement to ensure effective zonal isolation, robust design practices including modelling using site-specific data to design a safe and effective hydraulic fracturing event (**Section 4.4.1**), extensive monitoring of the hydraulic fracturing event (refer response to (n) above), evaluation of actual versus modelled pressure and flows and assessment of anomalous data . Leveraging the processes contained within the Code of Practice and International Best Practices, Santos and its contractors implement a

Reference[1]	Condition	Section in Risk Assessment
		comprehensive set of procedures to ensure safe implementation of hydraulic fracturing and containment of the fluids within the target formation.
(p)	groundwater transmissivity, flow rate, hydraulic conductivity and direction(s) of flow	**Section 3.3** provides a regional overview and data properties summarised in **Table 6**. **Section 3.5** provides localised data (where available) and these are captured in **Table 8** to **Table 11**. Groundwater flow is captured in **Section 3.2**, **Section 3.3, Section 3.5** and **Figure 42** to **Figure 44**.
(q)	a description of the chemicals used in the stimulation activities (including estimated total mass, estimated composition, chemical abstract service numbers and properties), their mixtures and the resultant compounds that are formed after stimulation	A broad range of fluid systems and chemicals are utilised for hydraulic fracturing activities (see **Appendix A**). Detailed mass balances of the composition of these fluid systems and associated CAS numbers are included in **Appendix C**. In addition, hazard and quantitative risk assessments are included for chemicals and fluid systems in **Appendix C**. The toxicological profiles for individual chemicals consider the resultant breakdown products for each chemical (if relevant) and its associated toxicological properties (**Appendix F** and **Appendix G**).
(r)	a mass balance estimating the concentrations and absolute masses of chemicals (compounds) that will be reacted, returned to the surface or left in the target gas producing formation after stimulation	A mass balance of the chemicals returned to surface is included in **Appendix C** and **Appendix D**. This mass balance, which is supported by Stimulation Impact Monitoring data, indicates that injected chemicals are diluted with formation water and return to surface at concentrations lower than the injected concentrations. High concentrations are initially observed within the first days of pumping but rapidly decline to concentrations less than 10% of the injected concentration. In addition to dilution, other mass loss mechanisms include complexation, bio-decay and hydrolysis. Physical sorption and sorption to the organic carbon of the coals is a major mass loss mechanism for cations and organic molecules with high sorption coefficients. Physical fate and transport modelling (**Section 7.2**) of indicative chemicals has been conducted based on the physical properties of the chemicals and the coal. This has demonstrated that migration of chemicals within the coal sequences is limited.
(s)	an environmental hazard assessment of the chemicals used, including their mixtures and the resultant chemicals that are formed after stimulation including: • toxicological and ecotoxicological information of chemicals used • information on the persistence and bioaccumulation potential of the chemicals used • identification of the stimulation fluid chemicals of potential concern (in stimulation	The approach to the environmental hazard assessment of the chemicals used, including their mixtures and the resultant chemicals that are formed after stimulation is detailed in • **Section 6** (Qualitative Assessment Methodology) • **Section 7** (Exposure Assessment) • **Section 8** (Quantitative Risk Assessment Methodology). The findings of the assessment are discussed in **Appendix C** for each fluid system that has been assessed. In particular: • Toxicological and ecotoxicological information is tabulated for each chemical in the tables provided in **Appendix C** (i.e., see **Appendix C.1**, **Table 1**). • The environmental hazard assessment approach outlined in **Section 6.1** was undertaken to rank the hydraulic fracturing chemicals based on persistence (P), bioaccumulation (B) and toxic (T) potential (hereafter referred to as PBT). PBT findings for each stimulation fluid chemical is provided in **Appendix C** (i.e., see **Appendix C.1**, **Section C2.3**). • Constituents of potential concern based on the findings of the quantitative risk assessment for each fluid system are identified in **Appendix C** (i.e., see **Appendix C.1**, **Section C4**).

Reference[1]	Condition	Section in Risk Assessment
	fluids) derived from the risk assessment	
(t)	an environmental hazard assessment of use, formation of, and detection of polycyclic aromatic hydrocarbons in stimulation activities	As noted in **Section 4.7**, PAHs are not present in any of the chemicals used in hydraulic fracturing and will not be formed from the chemicals used in hydraulic fracturing.
(u)	if used, identification and an environmental hazard assessment of using radioactive tracer beads in stimulation activities	Identification and an environmental hazard assessment of using radioactive tracer beads in simulation activities is discussed in **Section 9.6.**The section summarises the findings of a quantitative risk assessment conducted by EHS Support (2013a) on the use of radiological tracers and perforation balls. The risk assessment is included in **Appendix H**.
(v)	an environmental hazard assessment of leaving stimulation chemicals in the target gas producing formation for extended periods after stimulation	An environmental hazard assessment of leaving stimulation chemicals in the target gas producing formation for extended periods after stimulation is provided in **Section 7.2**.
(w)	human health exposure pathways to operators and regional population	Human health exposure pathways are detailed in **Section 7.1** and **Section 7.3** and tabulated in **Appendix C**.
(x)	risk characterisation of environmental impacts based on the environmental hazard assessment	A quantitative risk assessment was conducted to characterise potential risks of environmental impacts based on the findings of the environmental hazard assessment. The risk characterisation methodology is provided in **Section 8**. The findings of the quantitative risk assessment are detailed for each fluid system in **Appendix C** and summarised in **Section 10**.
(y)	potential impacts to landholder bores as a result of stimulation activities	Fate and transport modelling was conducted to assess the fate and transport of hydraulic fracturing chemicals in the subsurface. Methodology, model assumptions and findings are detailed in **Section 7.2**. Based on groundwater fate and transport modelling, no potentially complete exposure pathways were identified for groundwater.
(z)(1)	the determination of the likelihood of causing interconnectivity and/or negative water quality as a result of stimulation activities undertaken in proximity of each other	It is considered highly unlikely that the activities will cause interconnectivity and/or negative water quality as a result of stimulation activities. The presence of competent aquitards (refer **Section 3**), careful siting of wells (in accordance with the Code of Practice - avoiding areas where fractures or thinning of the aquitards exist), robust casing and cementing design and verification/validation testing (in accordance with the Code of Practice and International Best Practices - as documented in **Section 4.4**) and careful design and execution of hydraulic fracturing prevent the one or multiple hydraulic fractured wells impacting overlying aquifer formations.
(z)(2)	An assessment of cumulative underground impacts, spatially and temporally of the stimulation activities to be carried out on the tenure covered by this environmental authority	An assessment of cumulative underground impacts is provided in **Section 9.7**. Cumulative underground impacts are not anticipated as part of the project based on the controls described within this document. Fracturing will be confined to the target sequences and vertical fracturing into overlying aquifer units will not occur.
(aa)	potential environmental or health impacts which may result from stimulation including but not limited to water quality, air quality	Potential environmental or health impacts which may result from stimulation, including but not limited to water quality, air quality, noise and vibration, are evaluated in **Section 9**. Potential risks associated with noise, vibration and air quality were assessed in the Golder Stage 1 and Stage 2 Hydraulic Fracturing Risk Assessments (2011a). Findings from the assessment are provided in **Section 9.1**, **Section 9.2**, **Section 9.3** and **Section 9.4**.

Reference[1]	Condition	Section in Risk Assessment
	(including suppression of dust and other airborne contaminants) and noise and vibration	Potential environmental or health impacts to water quality are evaluated in **Appendix C**. The assessment concludes that the risks associated with hydraulic fracturing (with implementation of regulatory requirements and Santos controls) is low. Recommendations for risk management consistent with Santos's existing practices have been provided and should be implemented (as required) to ensure potential exposures are incomplete or minimised.

1.4 Risk Assessment Process

Risk assessments provide a systematic approach for characterising the nature and magnitude of the risks associated primarily with environmental hazards and is an important tool for decision-making [Draft guidance for ecological risk assessment provided by the Environment Protection Authority (EPA) Victoria (Gibson et al., 1997) and Environmental Health Risk Assessment, Guidelines for Assessing Human Health Risks from Environmental Hazards (enHealth, 2012)]. It should be emphasised, however, that the risk assessment is only one of the factors that inform decision making in the management of environmental issues.

This report combines qualitative and quantitative risk assessment methodologies to assess the potential risks posed by individual chemicals and the mixtures of chemicals used in hydraulic fracturing. A listing of hydraulic fracturing chemicals assessed by fluid system is provided in **Appendix A**.

The scope of the qualitative risk assessment comprises:

- Issue identification – A description of the current environmental setting (including a description of potential receiving environments and the various factors, which act upon them, including climatic influences), detailed geological and hydrogeological information, gas well integrity and a description of the hydraulic fracturing process, including an identification of the constituents of the hydraulic fracturing fluid.
- Hazard assessment – An evaluation of the environmental hazard of relevant chemical additives in the hydraulic fracturing fluid based on aquatic toxicity, environmental persistence and bioaccumulation.
- Exposure assessment – The exposure assessment comprises of an evaluation of surface and subsurface exposure pathways assessment and mass balance calculation to identify the amount of each chemical additive of the hydraulic fracturing fluid. For the additives selected as chemicals of potential concern (COPCs), fate and transport modelling is used to identify the likely extent of movement from the gas well.
- Risk characterisation – A qualitative evaluation of environmental and human health risk associated with the hydraulic fracturing activities based on the identification of complete exposure pathways and hazard identification.

The quantitative risk assessment builds on the assessment and findings of the qualitative risk assessment, namely quantifying ecological and human health risk for potentially complete exposure pathways.

This risk assessment includes assessments completed over the last eight years for a range of fluid systems and chemicals. The risk assessment approach incorporates revisions to the assessment methodology that have been recommended in national guidance. The initial risk assessment methodology (discussed further in **Section 5**) utilised a risk assessment methodology that aligned with former Australian risk assessment guidelines. This methodology was endorsed in subsequence guidance set forth by the Commonwealth Department of the Environment and Energy (DoEE) (2017).

Subsequent to issuance of this guidance, the Commonwealth developed a more streamlined approach that aligned with other regulatory requirements (Chemical notification, permitting and assessment requirements). These recommendations were incorporated into Categorisation Guidelines (Draft) developed by DoEE, the Northern Territory Hydraulic Fracturing Inquiry and core chemical regulatory guidance developed by the Australian National Industrial Chemicals Notification and Assessment Scheme (NICNAS). The revised approach utilises a tiered assessment framework where quantitative risk assessments are conducted on a chemical-specific basis for higher

hazard chemicals and the risks posed by mixtures evaluated qualitatively. This Hazard and Tiered Risk Assessment approach is discussed further in **Section 5** and is the basis for assessments conducted on chemicals after 1 January 2020.

1.5 Report Structure

Based on the EA requirements and to facilitate the assessment and compilation of multiple fluid systems, the document has been structured with a detailed discussion of the Site setting, hydrogeology and hydraulic fracturing and risk assessment process contained within the body of the report. General findings and recommendations from the risk assessment are also summarised in the document as identified in **Table 3**.

Table 3. Report Structure

Report Section	Content
Section 2	Provides information on the setting and geologic framework within which the hydraulic fracturing activities are being undertaken
Section 3	Evaluates the hydrogeological framework, groundwater resources and the environmental values associated with groundwater and surface water resources in the area
Section 4	Describes the hydraulic fracturing process and documents the integrated nature of well construction and hydraulic fracturing activities. A detailed discussion of the design, implementation and monitoring of hydraulic fracturing activities, in accordance with international best practice, is provided in this section.
Section 5	Describes the risk assessment framework that was implemented by Santos EQ and provides a guide to the process and the remaining chapters
Section 6	Details the methodology, approach and general findings from the Qualitative Risk Assessment
Section 7	Outlines the exposure assessment process and identifies the potentially complete exposure pathways that need to be considered in the Quantitative Risk Assessment
Section 8	Details the methodology, approach and general findings from the Quantitative Risk Assessment
Section9	Assesses the other potential risks associated with hydraulic fracturing including noise and vibration, air quality and the use of alternative proppants and radiological tracers
Section 10	Provides a general overview of the risk assessment findings and guides the reader through the vendor-specific findings, which are provided in **Appendix C** through **Appendix H**.

2 Site Setting and Issue Identification

The information provided in this section addresses the following EA approval requirements: conditions (c), (d), (e) and (k).

2.1 Climate

The climate of the Santos EQ Project Area is inland sub-tropical, with cool a dry winter season (April to September). In general, the year-round climate is dry, with winter months being more arid than summer months (

Table 4). Most of the annual rainfall occurs during the summer months (December and January,

Table 4). Variability in terrain across the project area will contribute to some variability in local climate.

Local climate is described using data observed at eight Bureau of Meteorology (BOM) observation stations. While all available data from the BOM have been considered, not all meteorological variables are recorded at each station; as a result, some data sets are incomplete or different lengths. The Queensland Government provides meteorological variables that are useful for agrometeorological research and modelling called the Data Drill. The meteorological variables in the Data Drill database are derived by interpolating the BOM's station records creating synthetic data calculated for a grid with approximately 5 km surface spatial resolution (http://www.longpaddock.qld.gov.au/silo/).

Based on the Data Drill results, climatic conditions are similar for the development area, although average temperatures and evaporation have a slightly smaller seasonal variability in the Arcadia region, probably reflecting its comparative northern location and proximity to the tropics.

The Denison region experiences the highest average rainfall with approximately 688 millimetres per year (mm/year), then Fairview, Arcadia Valley, Scotia and Roma regions with approximately 630 mm/year, 610 mm/year and 586 mm/year, respectively. While rainfall is similar in winter months across the Santos EQ project area, the regions surrounding Denison, Scotia, Arcadia Valley and Fairview generally experience higher rainfall than the Roma region during summer.

The Santos EQ Project Area is in a portion of Southern Central Queensland where magnitude of rainfall water and evaporation water loss is unbalanced. The Arcadia Valley and Roma regions experience higher evaporation rates, approximately 2,080 mm/year and 2,100 mm/year, respectively, while in Denison and Fairview regions the evaporation rate is approximately 1,930 mm/year and 1,998 mm/year, respectively.

The same spatial distribution can be observed for annual net evaporation, which is lower in the Fairview region (1,370 mm) and higher in the Arcadia valley and Roma regions (1,490 mm and 1,496 mm, respectively). The Roma region experiences the highest variability during the year, with net evaporation ranging between over 190 mm in summer and below 40 mm in winter. Lower seasonal variations occur within the Fairview and Arcadia Valley regions.

Table 4 presents the average minimum and maximum monthly temperatures, the average monthly total rainfall and the total and the average monthly total and net evaporation for the development areas within the Santos EQ Project area. Annual average values are presented for temperature while annual average total amount of rainfall and evaporation are presented in the same table. Maximum values are in red and minimum values in blue.

Table 4. Climate Data within the Santos Eastern Queensland Project Area

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature (C°)	Max	RSGPA	34.4	33.4	31.6	28.0	23.6	20.1	19.6	22.0	26.0	29.7	32.4	34.2	28.5
		FPA	33.8	32.6	31.2	27.9	23.9	20.6	20.3	22.5	26.3	29.7	32.0	33.6	28.4
		AVPA	34.3	33.2	32.2	29.4	25.8	22.8	22.5	24.7	28.1	31.2	33.0	34.3	29.9
		DPA	34.0	32.5	31.6	29.0	25.3	22.3	22.2	24.1	27.6	30.6	32.8	34.0	28.8
	Min	RSGPA	20.4	19.9	17.6	12.9	8.3	5.2	3.8	5.2	9.0	13.7	16.8	19.1	12.9
		FPA	19.9	19.4	17.1	12.6	8.4	5.1	3.8	5.0	8.9	13.4	16.5	18.7	12.6
		AVPA	21.2	20.8	19.1	15.3	11.2	7.8	6.4	7.7	11.4	15.6	18.2	20.2	14.9
		DPA	20.9	20.5	18.9	14.9	10.9	7.3	6.4	7.6	11.3	15.2	17.9	19.8	14.3
Rainfall(mm)		RSGPA	80.1	73.5	61.9	33.4	35.4	34.7	35.1	25.4	28.0	50.9	56.5	71.4	586.3
		FPA	95.9	88.5	63.1	40.3	34.6	35.2	31.0	22.2	25.5	46.1	64.3	82.6	629.3
		AVPA	97.9	87.8	58.3	35.6	33.5	32.8	26.1	20.6	25.2	42.6	60.1	86.8	607.3
		SPA	98	89	63	35	41	36	39	28	31	55	74	89	678
		DPA	110.6	108.7	71.0	39.0	34.5	37.9	28.3	23.9	30.2	48.3	64.1	92.2	688.2
Evaporation (mm)	Tot	RSGPA	272.1	205.0	206.1	149.5	99.4	72.3	80.4	111.2	163.4	214.7	238.9	269.3	2082.3
		FPA	250.3	191.7	194.6	144.0	99.7	74.9	83.0	113.3	162.7	207.4	226.4	249.8	1997.8
		AVPA	242.9	195.1	202.2	155.3	116.1	91.7	100.9	128.8	173.9	214.9	229.2	246.8	2097.8
		DPA	230.7	186.8	169.1	135.0	104.3	77.9	88.6	124.0	159.5	203.1	221.0	232.2	1932.2
	Net	RSGPA	192.0	131.5	144.1	116.1	64.0	37.6	45.3	85.8	135.4	163.9	182.5	197.9	1496.1
		FPA	154.4	103.3	131.5	103.8	65.1	39.7	52.0	91.1	137.2	161.2	162.1	167.2	1368.6
		AVPA	145.0	107.3	143.9	119.7	82.6	58.9	74.8	108.2	148.6	172.3	169.1	160.0	1490.4

2.2 Topography

The general topography of the Santos EQ Project Area is presented on **Figure 2**.

The Great Dividing Range (GDR) traverses the southern part of the Fairview region and the northern part of the Roma region, then trends north north-west to the Buckland Plateau. Notable topographic features within the Santos EQ Project Areas include (URS, 2008):

- Near-level to strongly undulating plateau surface remnants cut by steep-sided ravines and terminating in sandstone escarpments, occurring in the central part of the Santos EQ Project Area including the regions of Denison, Scotia, Fairview and Arcadia Valley.
- Broad areas of low relief undulating terrain and alluvial plains, interrupted by occasional low hills across the southern part of the Roma region.
- Broad alluvial plains and foot slopes of the Arcadia-Comet valley feature extending northward from the northern margin of the Fairview region to the northern limit of the Santos EQ Project Area.

In the northern and central parts of the Fairview and Denison regions, the Precipice Sandstone and Evergreen Formation outcrop resulting in raised plateaus with steep escarpments. The Hutton Sandstone outcrops in the southern parts of the Fairview region with the landscape characterised by rounded hills and in the eastern parts of the SPA. Further south the Orallo Formation and Mooga Sandstone outcrop. The drainage channels have been in-filled with alluvial sediments comprising Quaternary aged sand, gravel and clay.

The topography of the Dension region is dominated by the Taroom Hills geographic region that consists of gently sloping to strongly undulating dissected upland plateau remnants, of mostly broad extent, and that are formed predominantly on sandstone, with very steep ravine slopes and sandstone escarpments (URS, 2008). The area is subject to an array of landforms and soil types, which tend to vary with the different sections of the area.

The Roma region is generally characterised by flat to gently undulating terrain, with a gradual slope towards the southwest. The Bungil and Wallumbilla Formations give rise to typically flat topography in the southern part of the region where large areas of poorly consolidated Tertiary sandstone and conglomerate unconformably overlay the Wallumbilla Formation. The drainage channels have been in-filled with alluvial sediments comprising Quaternary sand, gravel and clay throughout the Santos EQ Project Area.

The eastern portions of the Roma region include gently undulating plains and short segments associated with low hills and ridges; developed on weathered sandstones and shales. The Yuleba area is characterised by undulating plains to scarps and low hills developed mainly on coursed grained, quartzone sandstones and poorly weathered sediments. The Struan Area includes undulating plains to low hills and escarpments developed predominantly on quartzone sandstones. Coogoon includes gently undulating plains and short slopes associated with ridges and crests and developed on weathered sandstones and old sandy alluvia. Maranoa Region contains flat plains, which have been developed on sandy alluvia.

In the far northern reaches of the Santos EQ Project Area, the Arcadia Valley region has been in-filled with Cainozoic sandy sediments, which are overlain by Quaternary aged alluvial deposits along the drainages. Steep cliffs on either side of the valley typically comprise of the Permian aged Clematis Sandstone or Moolayember Formation.

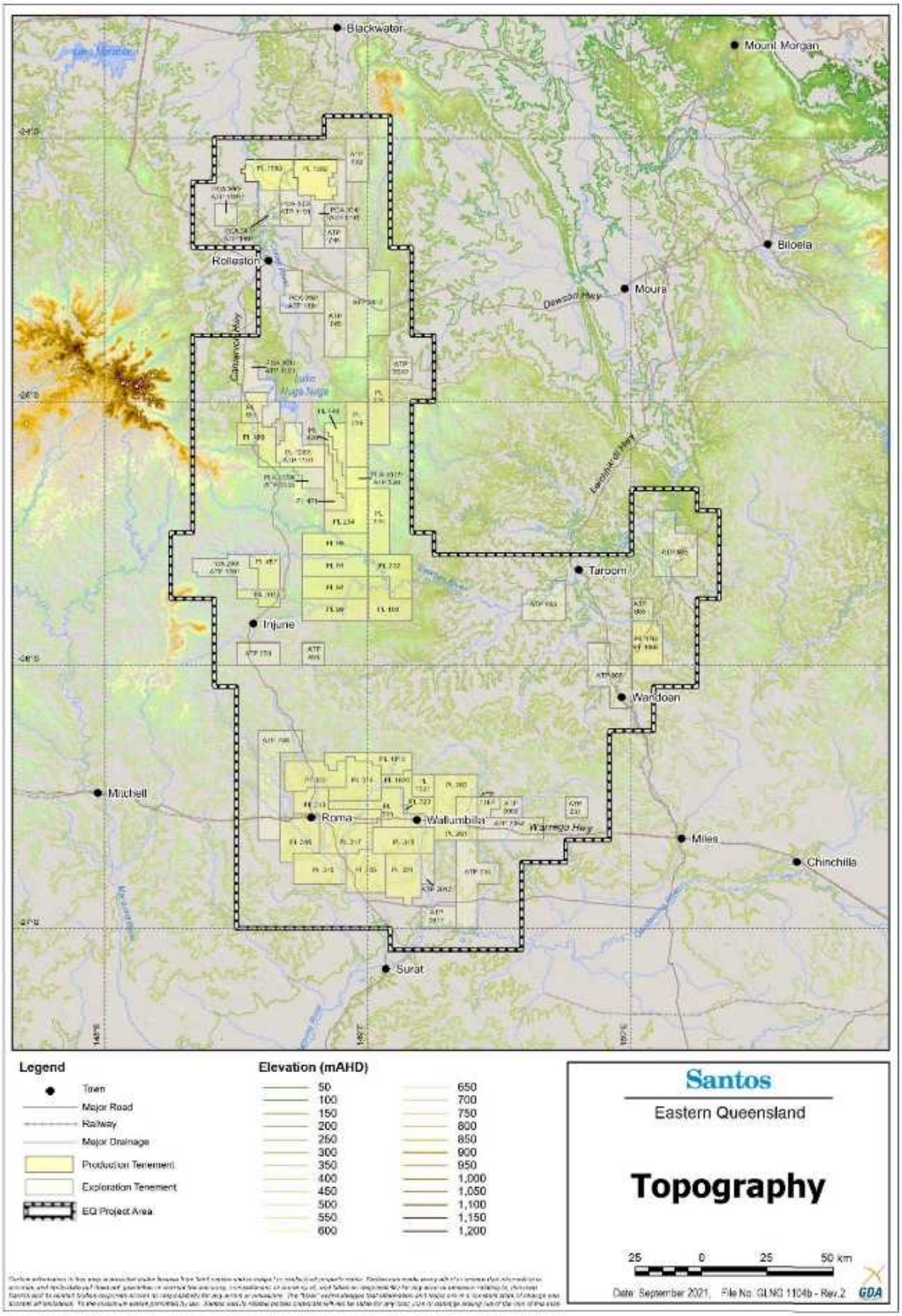


Figure 2. Topography

2.3 Hydrology / Surface Water

Due to the large study area, as well as the relative environmental homogeneity across these extensive basins, the contextual setting for analysis of the existing environment was constrained to six major sub- catchments:

- Fitzroy River Basin
  - Comet River
  - Lower Dawson River
  - Upper Dawson River.
- Condamine-Balonne River Basin
  - Dogwood Creek
  - Upper Balonne River Tributaries
  - Amby Creek (tributary of Maranoa River).

The sub-catchments were delineated based on the catchments depicted in the relevant Water Resource Plan (WRP) Maps (Fitzroy Basin WRP, 2011; Condamine and Balonne WRP, 2004), to enable straightforward identification of environmental values on a sub-catchment scale.

The Condamine-Balonne Catchment is in the Murray Darling Basin, which eventually discharges to the Great Australian Bight in South Australia. The Dawson River and Comet River catchments are located in the Fitzroy Basin, which discharges into the Pacific Ocean near Rockhampton.

The Fitzroy River Basin in Central Queensland is the largest coastal catchment in eastern Australia, covering an area of approximately 142,000 km^2, consisting of six sub-catchments: Nogoa, Comet, Mackenzie, Isaac-Connors, Dawson and Lower Fitzroy.

Many of the rivers and streams in the study area are ephemeral and characterised by high variations in duration and volume of flows due to highly variable rainfall and runoff and high evaporation rates. Prolonged base flow occurs only in wetter years in most streams.

The northern area of the study area (within the Arcadia Valley region) is located in the central-eastern portion of the Comet River catchment (

Figure 3). The Fairview region is located in the southern section of the Fitzroy River Basin in the upper reaches of the Dawson River catchment (

Figure 3). The southern area is located in the upper reaches of the Condamine-Balonne catchment (**Figure 4**). The main surface water system in the Scotia region is Bungaban Creek as well as sections of the Dawson River (

Figure 3). Further detail on each project area (including DPA) is presented in **Section 2.3.1** to **Section 2.3.4**.

2.3.1 Fairview and Arcadia Valley Region

The main plateaus with the Fairview region are referred to as the Fairview and Springwater Plateaus. The entire Springwater Plateau and the south side of the Fairview Plateau drain southward into Hutton Creek, while the northern half of the Fairview Plateau drains north into Baffle Creek and the Dawson River (

Figure 3). The irrigation program is located on those plateaus. In the downstream reaches of Hutton Creek, grazing, forestry and cropping are widespread. A number of water storages and weirs are located on the Dawson River from Taroom downstream and are used for irrigation and recreational purposes, supporting regional industry and urban communities.

The Upper Dawson River catchment area contains extensive but largely ephemeral or intermittent stream networks. The Dawson River downstream of Dawson's Bend is the exception as it is perennial, maintained by significant spring flows arising from the riverbed and adjacent to the stream. A number of springs are located near

the outcrop areas of the Hutton Sandstone, many within the boundaries of the Fairview region (

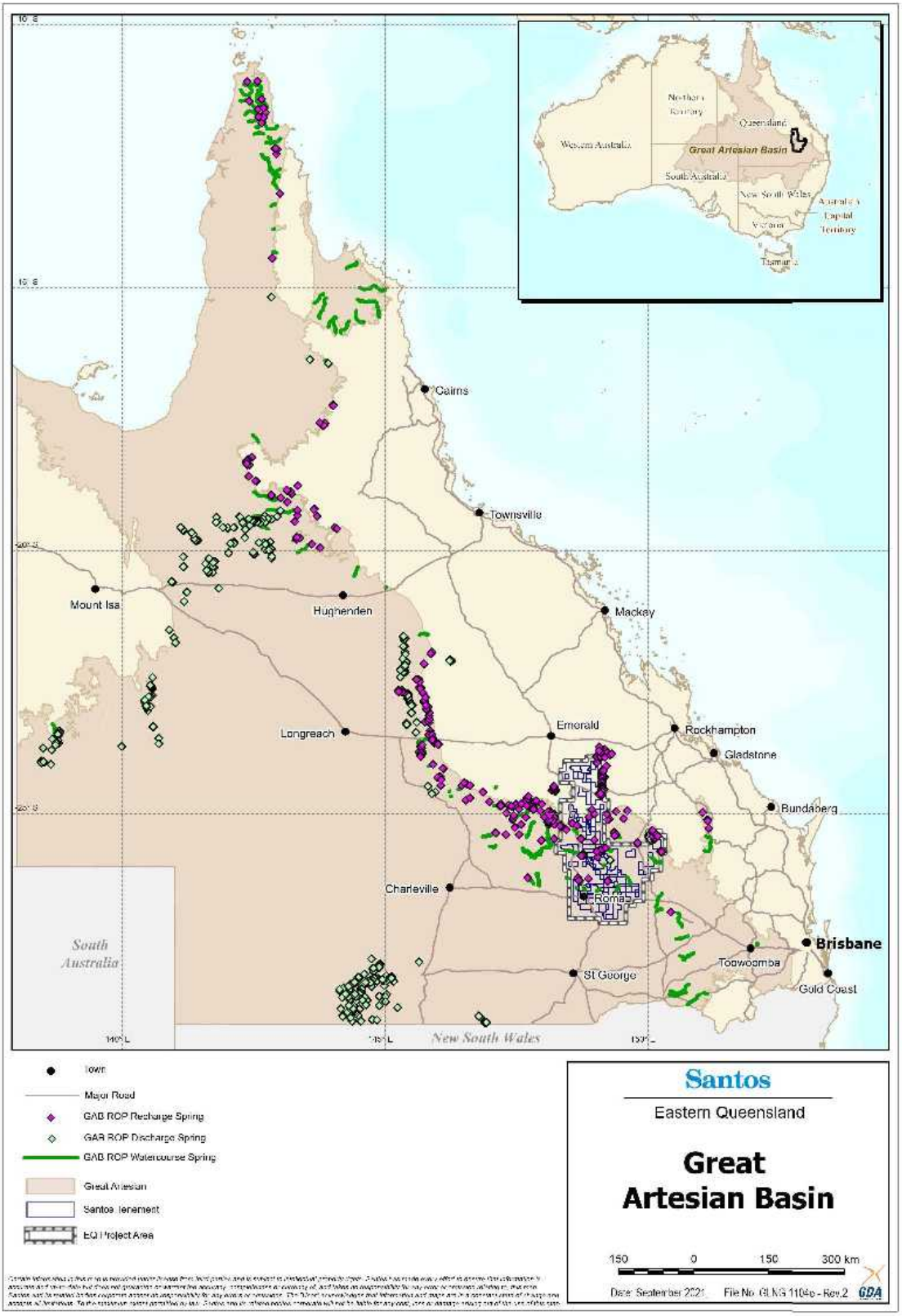


Figure 6). There are several springs located within the Precipice and Gubberamunda Sandstone outcrop areas, also considered to be recharge zones of the GAB.

High ecological environments (HEV) areas identified within the portions of the Upper Dawson River catchment and located inside the Fairview and Arcadia Valley region using the Queensland (EHP) Geographic Information System (GIS) database included:

- Presho Forest Reserve (HEVa2147)
- Presho State Forest (HEVa2146)
- Belington Hut State Forest (HEVa2145)
- Stephenton State Forest (HEVa2144)
- Beilba State Forest (HEVa2142)
- Forrest State Forest
- Doonkuna State Forest (HEVa2141)
- Lake Murphy Conservation Park (HEVa2149) – close to ROB02 monitoring site
- Carraba Conservation Park (HEVm2142)
- Cooaga State Forest (HEVa2159)
- Barakula State Forest (HEVa2159)
- Mundell State Forest (HEVa2160)
- Cherwondah State Forest (HEVa2158)
- Gurulmundi State Forest (HEVa2157)
- Juandah State Forest (HEVa2156)
- Hinchley State Forest (HEVa2155)
- Dinoun State Forest (HEVa2152)
- Mount Organ State Forest (HEVa2154)
- Emu State Forest (HEVa2151)
- Combabula State Forest (HEVa2153)
- Woodduck State Forest (HEVa2150)

A total of 670 wetland areas (encompassing approximately 79,150 ha) were identified within the Upper Dawson River catchment, using the Queensland Wetland Classification Method. The wetlands are predominantly riverine or floodplain swamps with grass, sedge and herb vegetation. Around 30% of the wetlands, classified as lacustrine wetlands, are artificial or modified (e.g., farm dams, irrigation channels). Less than 10% of the identified wetlands consist of swamps containing Melaleuca and Eucalypt tree species. The largest area of wetland appears to be concentrated within the Beilba State Forest (centred on Hutton Creek). There are no nationally or internationally significant wetlands scheduled within this sub-catchment.

The northern and western most portions of the Arcadia Valley region lie within the Comet River Catchment area. The Comet River Catchment area extends west of the Lower Dawson River catchment, encompassing the townships of Springsure and Fernlees in the west and Comet in the northern extent within the larger Fitzroy Basin.

The main tributaries on the Comet River on the western side of the catchment are the Sandhurst, Springsure, Meteor and Minerva Creeks, all flowing south to north. On the eastern side of the Comet River are the Sirius, Humboldt, Rockland, Christmas Creeks and the Brown River. The Comet and Nogoa River confluence forms the Mackenzie River at the township of Comet.

High ecological environment areas identified within the portions of the Comet River catchment using the Queensland Department of Environment and Heritage Protection (DEHP) GIS database included:

- Shotover State Forest (HEVa2127)
- Humboldt National Park (HEVm2126)
- Western portion of Expedition State Forest (HEVa2171)

- Expedition National Park (HEVm2141)
- Nuga National Park (HEVm2124

A total of 127 wetland areas (encompassing approximately 10,557 ha) have been identified within the Comet River catchment, using the Queensland Wetland Classification Method. Whilst the wetlands are predominantly classified as lacustrine, they are also listed as being artificial/modified (features such as dams or irrigation channels). Some sub-coastal floodplain wetlands consisting of grass, sedges and herbs (and occasionally Melaleuca and Eucalypt species), classified as palustrine wetlands, are also present (approximately 13% of identified features). The largest areas of wetland appear to be within Shotover State Forest in the north and Expedition National Park in the south. There are no nationally or internationally significant wetlands scheduled within this sub-catchment.

2.3.2 Denison Region

The Denison region (which includes the DPA) lies wholly within the Fitzroy River Basin. The northern and central sections form part of the catchment area of the Comet River, which is a major tributary of the Fitzroy River.

Several tributaries of the Comet River, as well as the Comet River itself, flow in a northerly direction and include the Brown River, Carnarvon Creek, Arcadia Creek, Meteor Creek and Clematis Creek. The tributaries of the Comet River are ephemeral and typically experience periods of no flow for over 50 percent of time.

The southern section of the Denison region lies within the upper catchment area of the Dawson River, which is also a major tributary of the Fitzroy River. Tributaries of the Dawson River that flow through the southern tenures include Baffle Creek, Hutton Creek and Injune Creek. These creeks rise in the Great Dividing Range that separates this river system from the catchment area of the Maranoa River, which is part of the Balonne-Condamine River Basin. These tributaries of the Dawson River tend to be deeply incised streams flowing through sandstone areas of the Great Dividing Range, and consequently have sustained base flows, unlike the tributaries of the Comet River catchment.

2.3.3 Roma Region

The Roma region (which includes the RSGPA) is located in the upper catchment area of the Murray-Darling Basin (MDB) whereas the Fairview and Arcadia Valley regions are located within the Fitzroy Basin.

The Condamine-Balonne River is a regional river system, which straddles the southern boundary of the southern tenures of the Roma region, generally flowing from east to southwest. This river system contains extensive meandering streams that are largely ephemeral or intermittent. The major streams in the catchment include Yuleba Creek, Wallumbilla Creek, Bungil Creek, Blyth Creek, which discharge to the Balonne River (**Figure 4**), which in turn flows into the MDB.

The Balonne River sub-catchment includes the towns of Toowoomba, Dalby, Roma, Chinchilla and Surat. The topography of the catchment varies from flat near the Balonne River to hilly in the upstream sections. Tributaries include the Maranoa River, which flows southward from the Carnarvon Range into the Beardmore Dam near St George.

Streamflow records are available from two DEHP gauging stations in the Balonne Catchment: Tabers at Bungil Creek (BOM, site 043105, DEHP site 422210) (1966 – Present), and Yuleba Forestry at Yuleba Creek (BOM site: 543008, DEHP site 422219) (1972 – Present). Streamflow records show substantial seasonal variations at each location reflecting their dominant ephemeral nature.

High ecological value (HEV) areas have not yet been scheduled for the Condamine-Balonne River Basin by DEHP.

A total of 476 wetland areas (encompassing around 43,187 ha) have been identified within the across the Upper Balonne Tributaries catchment, using the Queensland Wetland Classification Method. The wetlands are approximately 50% artificial or modified; 20% riverine, and 15% Melaleuca and Eucalypt tree swamps (palustrine wetlands). The remainder of wetland features are generally grass/herb swamps, also classified as palustrine. The largest area of wetland appears to be concentrated along the Balonne River near Yuleba Creek, Bungil Creek, within the Gubberamunda State Forest, and between Bungil Creek and Bungeworgerai Creek. There are no nationally or internationally significant wetlands scheduled within this sub-catchment.

2.3.4 Scotia Region

The Scotia region is located in the upper catchment area of the Dawson River which drains northwards and is a tributary of the Fitzroy River. The main surface water system in the region the Dawson River, Bungaban Creek and Cockatoo Creek. These flow through the northern part of the Scotia block from east to west and onward in a north-westerly direction into the upper catchment of the Dawson River that flows into the Fitzroy River Basin.

The general catchments, streams and rivers in the vicinity of the Scotia region are shown on **Figure 5**.

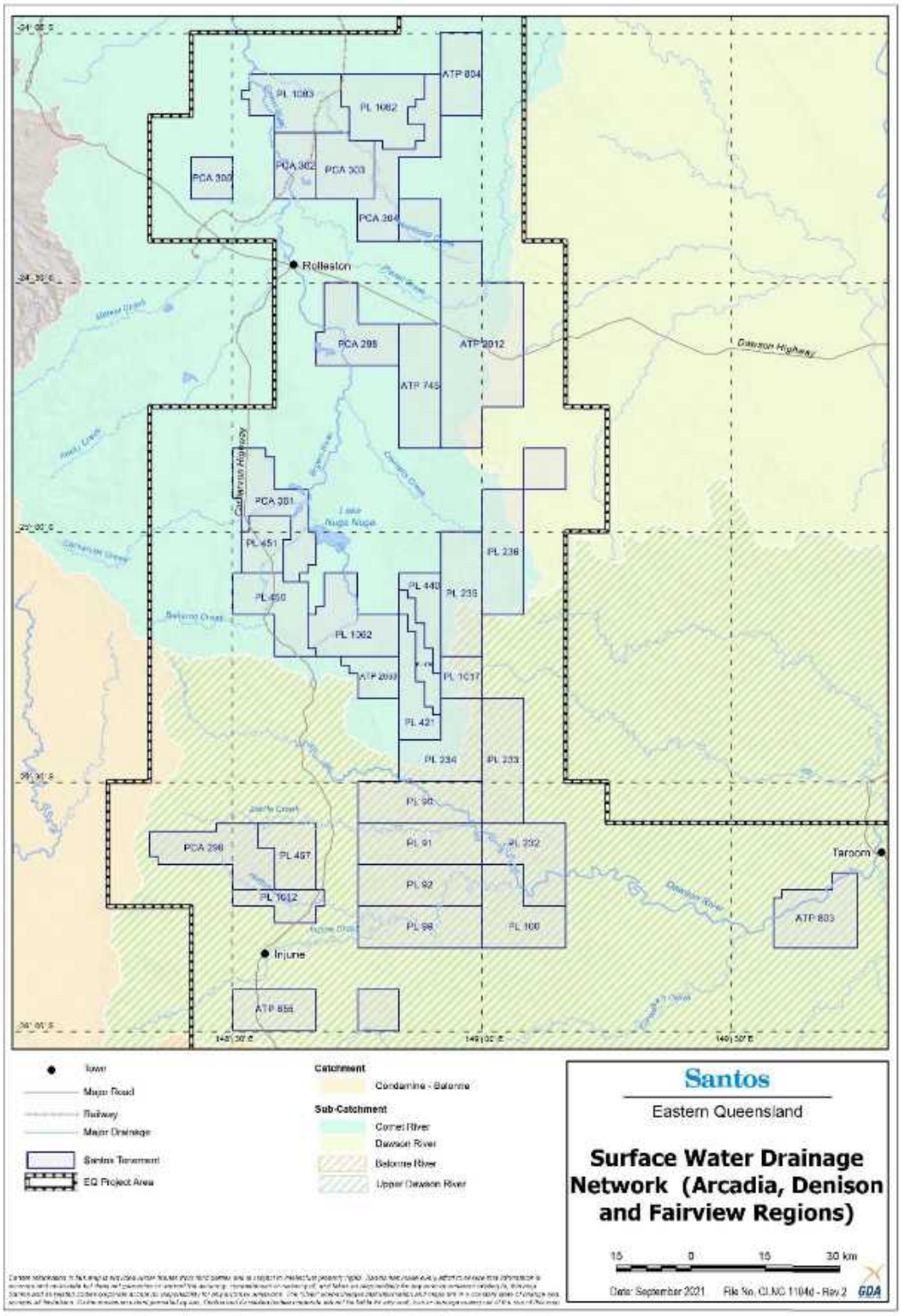


Figure 3. Surface Water Drainage Network (Denison, Fairview, and Arcadia)

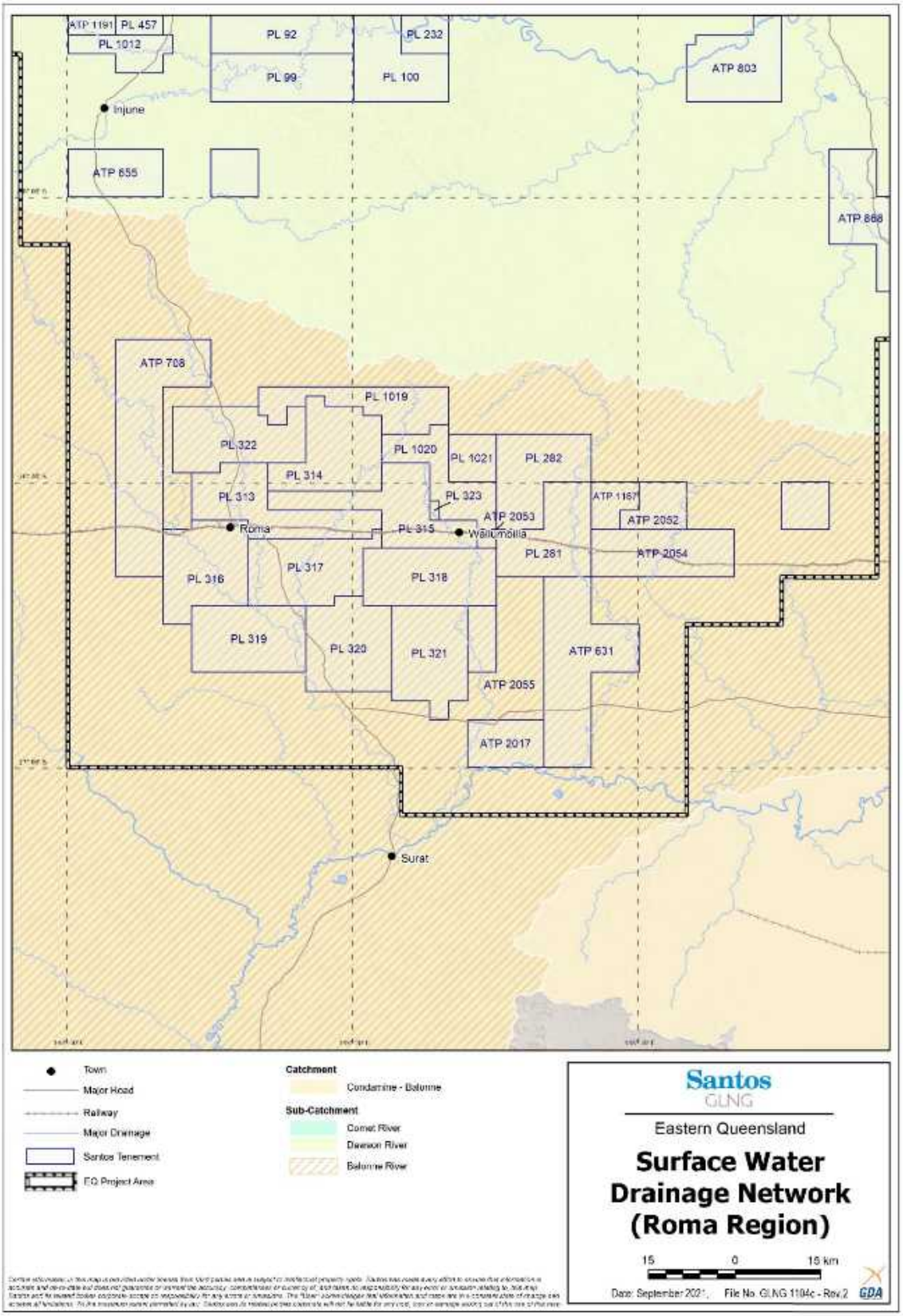


Figure 4. Surface Water Drainage Network (Roma)

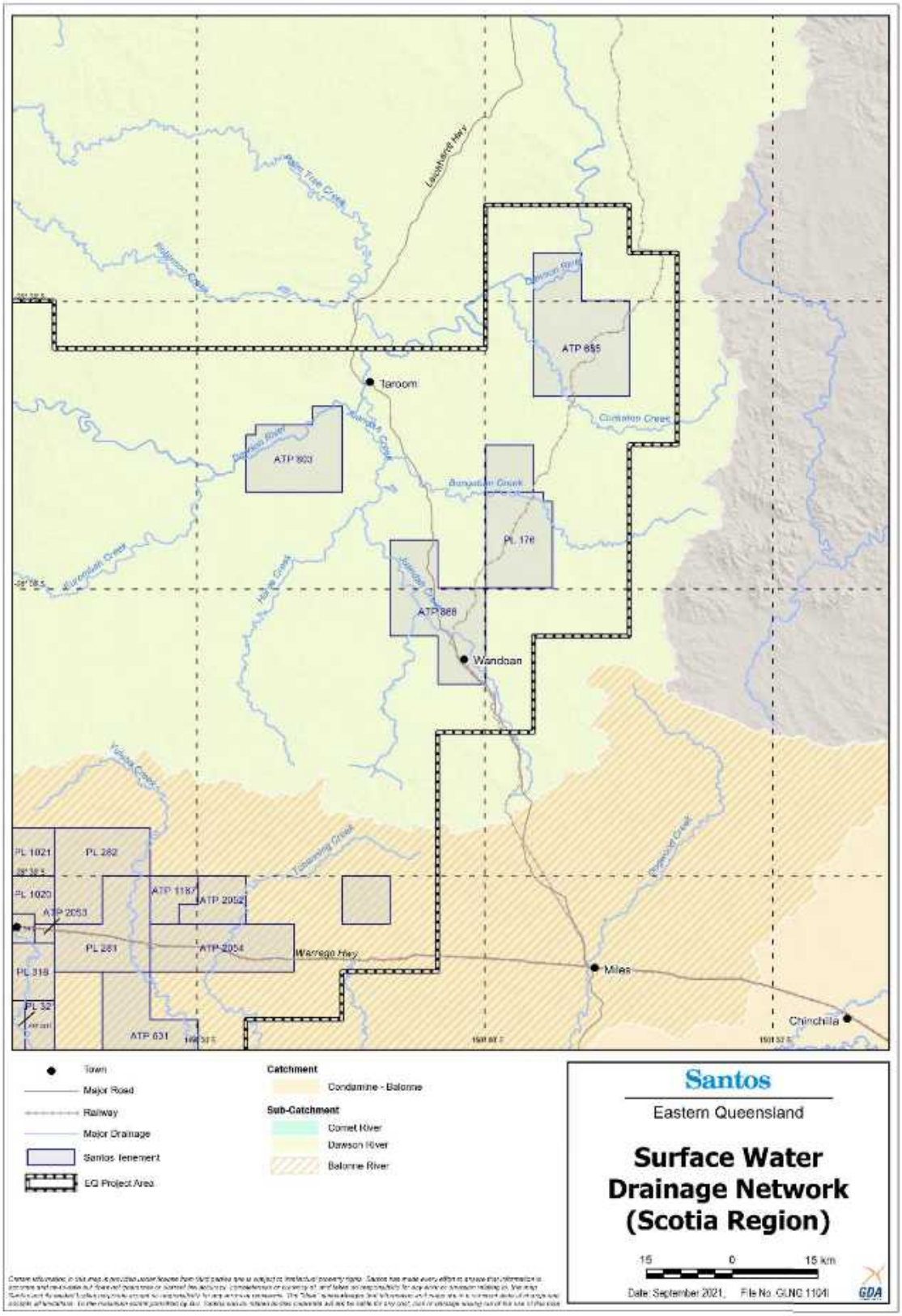


Figure 5. Surface Water Drainage Network (Scotia)

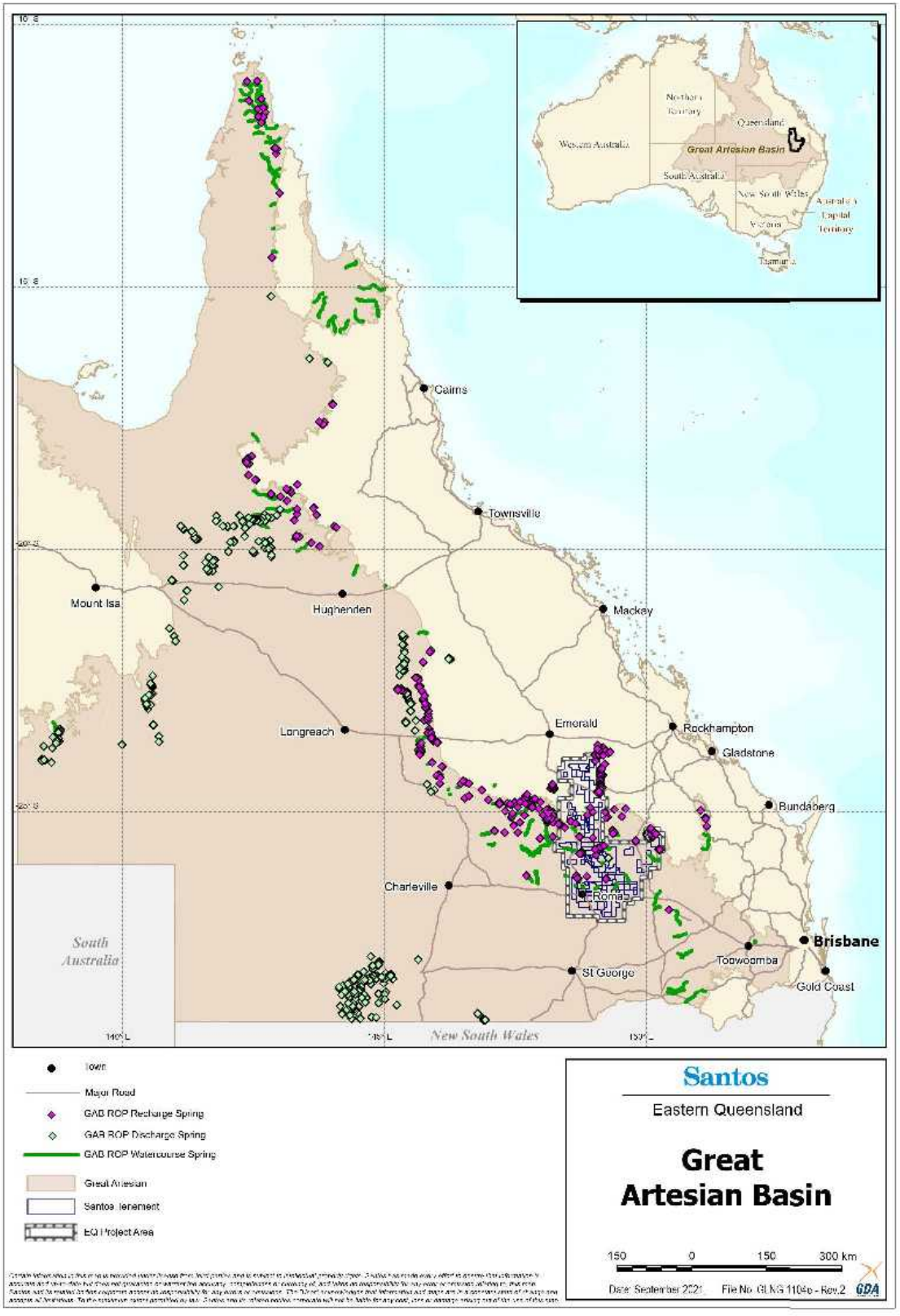


Figure 6. Great Artesian Basin

2.4 Geological Setting

2.4.1 Continental Setting

The Santos EQ Project Area is located entirely within the large, south-dipping Permian to Cretaceous depositional basins of the Bowen Basin and Surat Basin, themselves located within the easternmost location of the GAB extents (

Figure 7).

The GAB is one of the largest artesian groundwater basins in the world. It extends 2,400 km from Cape York in the north to Dubbo in the south. At its widest it is 1,800 km from the Darling Downs to west of Coober Pedy. With an area of over 1.7 million km^2, the GAB underlies approximately one-fifth of the Australian continent.

2.4.2 Stress Field Setting

Australia lies within the Indo-Australian tectonic plate and undergoes an absolute movement of approximately 7 centimetres (cm) per year to the north- north northeast (N-NNE). This is reflected in the N-NNE orientated major horizontal stress field as indicated for the Bowen Basin (**Figure** 8). The minor horizontal stress will be approximately normal (90°) to this, viz. east-east south-east (E-ESE). The horizontal in-situ stress can be relatively high and anisotropic and exceed the vertical stress due to gravity.

The continental geomechanical setting is presented in **Figure 9** and illustrates the tectonic contribution to the regional stress field within continental Australia.

The origin and nature of near surface stress in Australia has been discussed in several publications, for example, Brown and Windsor (1990) and Enever and Lee (2000). The total stress at a point in the Earth's crust (including Australia) is generally considered to be made up of the following components:

- Gravity due to the weight of overburden. Gravity also contributes to the horizontal stress due to the Poisson's effect
- Tectonic component, which could be an active or a remnant tectonic stress, from movement of the earth's plates, and generally impacts the horizontal stress field
- Thermal and physio-chemical effects.

Analysis of stress and rock strength has been undertaken through in-house and contractor (JRS/Helix RDS) services. Borehole studies have utilised image log data, wireline log data, rock strength testing and drilling experience to model the stress variation between geological rock units from surface to the target coal seams, namely, the Walloons and Bandanna Coals of the Surat and Bowens Basins sequences, respectively. The results of these borehole studies are consistent with stress magnitude and orientation produced by broader plate tectonics as indicated on the publicly available Australasian Stress Map (Hillis et al., 1999; Reynolds, 2001).

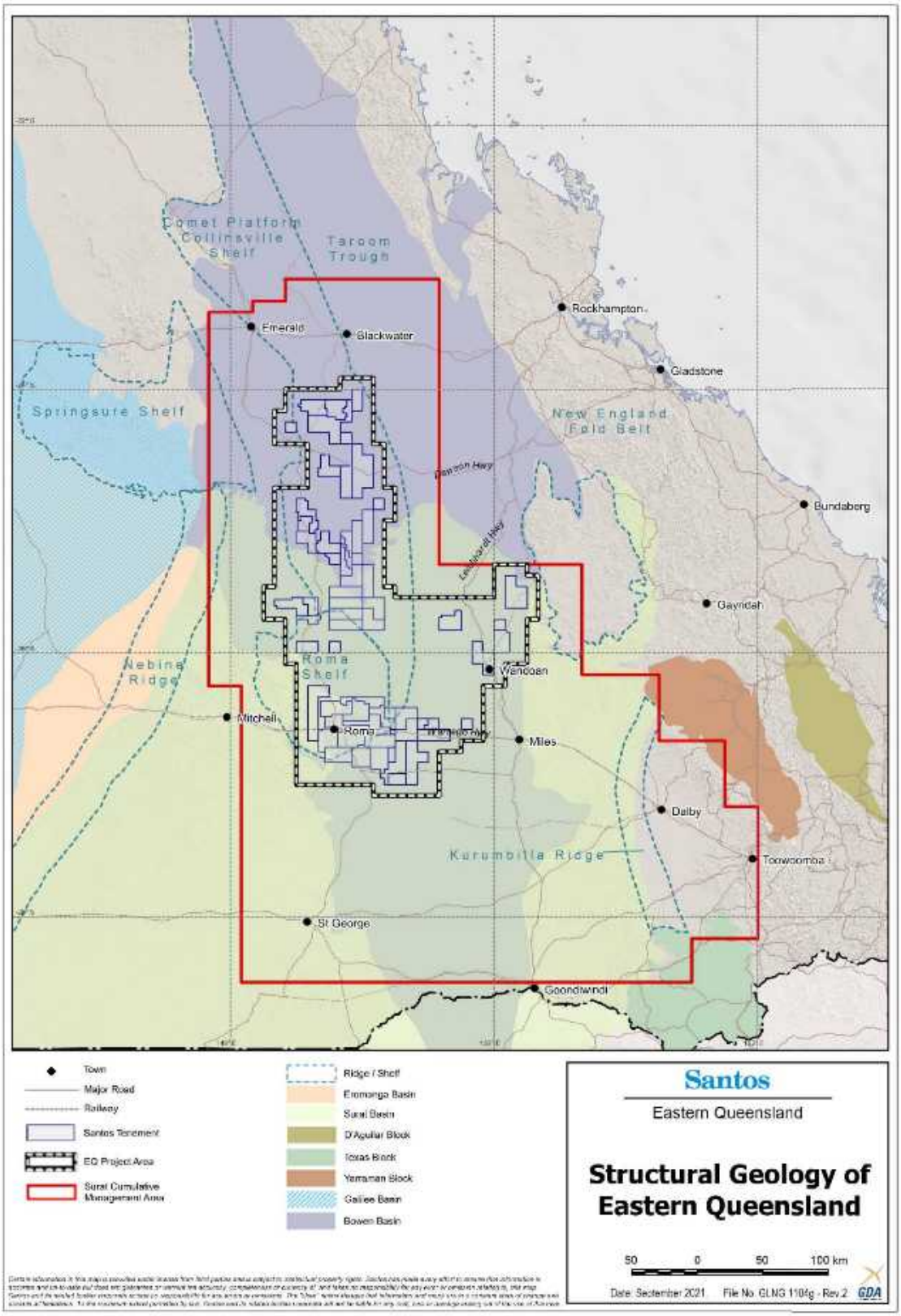

Comet Platform
Collinsville Shelf
Taroom Trough
Springsure Shelf
New England Fold Belt
Nebine Ridge
Roma Shelf
Kurumbilla Ridge
Rockhampton
Emerald
Blackwater
Gladstone
Bundaberg
Gayndah
Wandoan
Mitchell
Roma
Miles
Dalby
Toowoomba
St George
Goondiwindi
Dawson Hwy
Leichhardt Hwy
Town
Major Road
Railway
Santos Tenement
EQ Project Area
Surat Cumulative Management Area
Ridge / Shelf
Eromanga Basin
Surat Basin
D'Aguilar Block
Texas Block
Yarraman Block
Galilee Basin
Bowen Basin
Santos
Eastern Queensland
Structural Geology of Eastern Queensland
50 0 50 100 km
Date: September 2021 File No. GLNG 1104g - Rev.2
GDA

Figure 7. Map of Structural Geology of Eastern Queensland

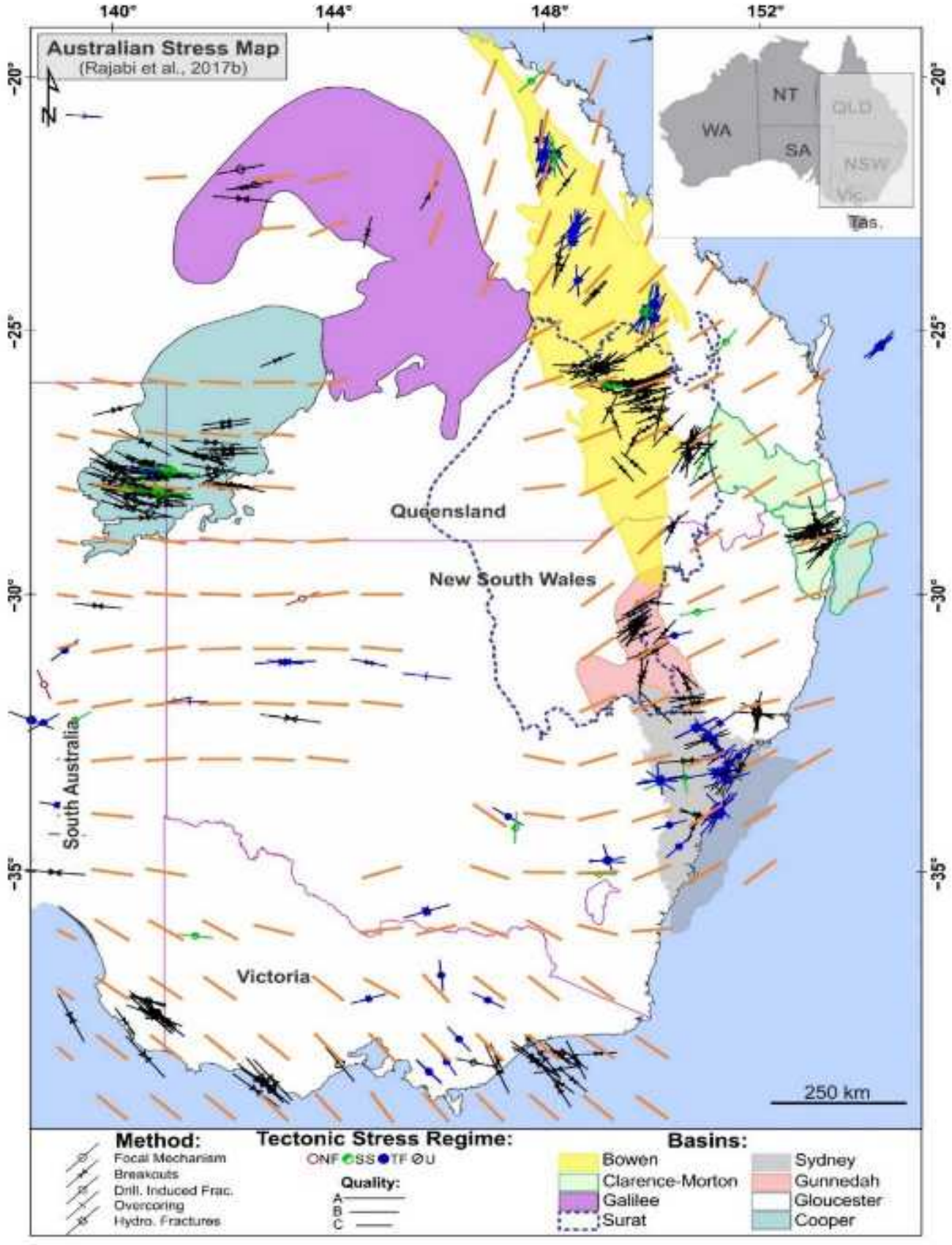


Figure 8. Eastern Australia Stress Map

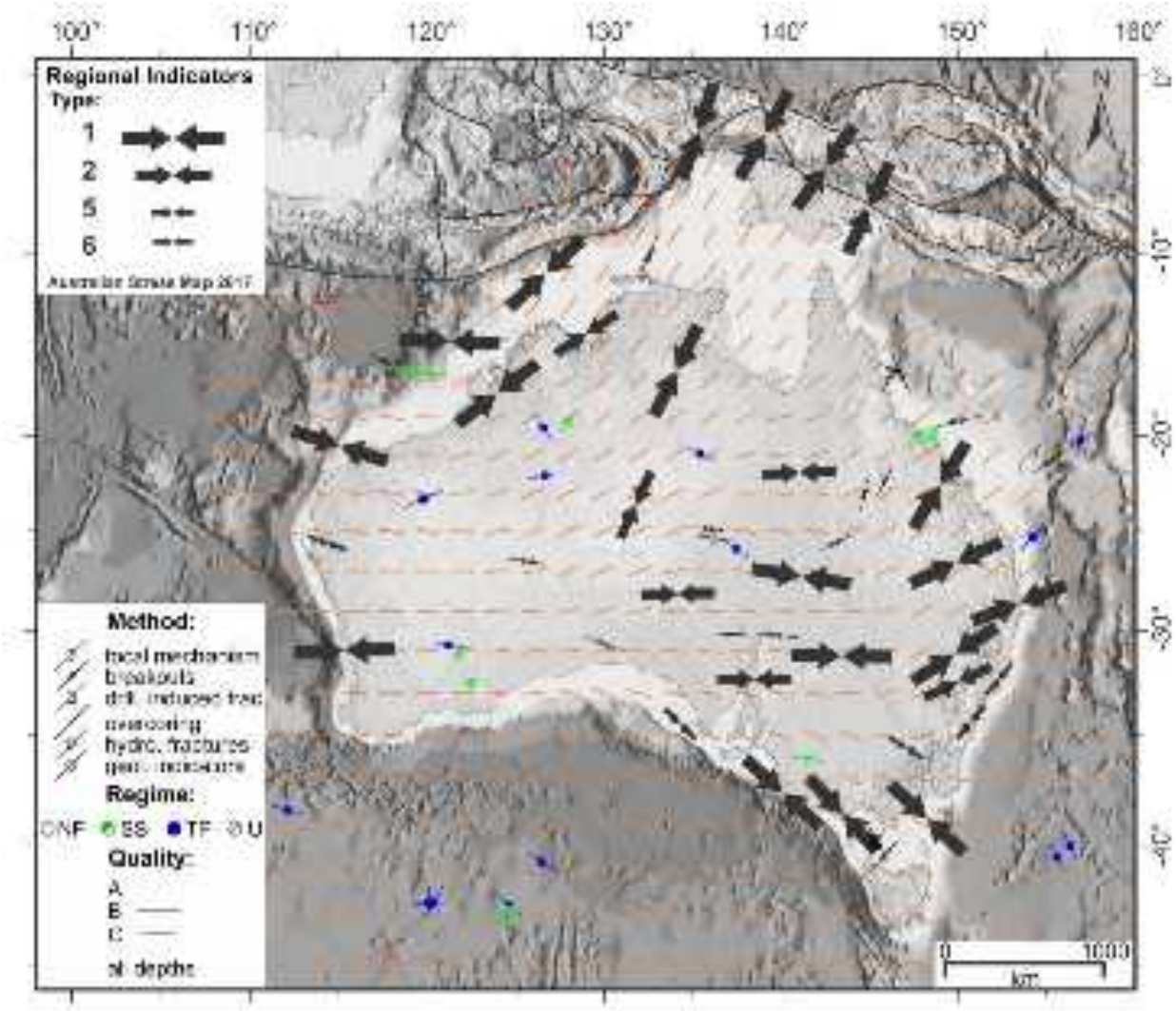


Figure 9. Stress Provinces Across the Australian Continent

Note: The orange lines show the smoothed pattern of maximum horizontal stress (SHmax) that demonstrate the variability of SHmax across the Australian continent
Source: Energies 2021, 14, 2651

2.4.3 Tectonic Setting – Faulting and Folding

The regional tectonic setting described above manifests itself in structural features characteristic of a largely compressive environment, in which thrust faulting and folding are dominant. These features are further detailed in **Section 2.5.4** and **Section 2.5.5**. The key consequence of this tectonic setting is that the faults and folds are tight and characteristically not zones of groundwater flow, but rather are hydraulic barriers to flow. They typically compartmentalise the groundwater and restrict free flow across the compartment boundaries. This is generally manifested in water quality and temperature differences between compartments (OGIA, 2020).

2.5 Regional Geology

The geology of the Santos EQ Project Area includes a Jurassic to Cretaceous age sequence of alternating sandstone and siltstone formations associated with the Surat Basin, which unconformably overlies Triassic to late-Permian sedimentary formations of the Bowen Basin (**Figure 10** and **Figure 11**).

The Bowen and Surat Basins are structurally separate sedimentary depositional centres, however they are stratigraphically and hydraulically interconnected (DME, 1997). The Surat Basin is a sub-basin of the GAB (

Figure 7, **Figure 11** and **Figure 36**) . Both the Surat and the Bowen basins contain sandstones, siltstones and mudstones. The sandstones are permeable and include the major aquifers, and the siltstones and mudstones are impermeable and do not contain aquifers.

The basins generally comprise southward dipping synclines, with the Surat Basin formations outcropping or subcropping in the Project Area and the underlying Bowen Basin formations outcropping in the AVPA to the north. A stratigraphic sequence for the study area is presented in **Figure 11** and **Table 5**.

Localised geological cross-section are presented beginning in **Section 2.6.1**, **Figure 18** to **Figure 20**, **Figure 21** to **Figure 26**, **Figure 30** to **Figure 35**. Their transect location is shown in **Figure 10**.

2.5.1 Bowen Basin Geological Setting and Model

The Bowen Basin is an Early Permian to Middle Triassic age basin, which comprises shallow marine and continental clastic and volcanic rocks (**Figure 11**). The Bowen Basin is comprised of two sedimentary depositional centres, namely, the Denison and Taroom Troughs (**Figure 12**). The main structural feature through the Project area is the Comet Ridge, located along the western margin of the Taroom Trough in the southern extent of the Bowen Basin. The Comet Ridge is comprised of mainly Devonian aged rocks and is covered by a relatively thin sequence of gently folded Permian and Triassic rocks, which make up the Bowen Basin.

The oldest formation included in the Bowen Basin stratigraphic sequence is the Reids Dome Beds, a unit of highly variable thickness. The Reids Dome Beds are unconformably overlain by the Early Permian aged formations of the Back Creek Group, which include the Cattle Creek Formation, the Aldebaran Sandstone and a number of other formations (**Figure 11**). The Aldebaran Sandstone is the deepest formation targeted for water supply within the north-western reaches of the Project area, near the town of Emerald. The other formations within the Back Creek Group are generally of a lower permeability. The Back Creek Group is overlain by shale, siltstone, tuff, bentonite and labile sandstone of the Black Alley Shale.

The Black Alley Shale and the Bandanna Formation are included in the Late Permian Blackwater Group. Gas in the Denison, Fairview and Arcadia Valley region is extracted from the coal seams of the Bandanna Formation, at depths of 200 to 1,500 metres below ground level (mbgl). The thickness of the Bandanna Formation is variable throughout the Project area, from approximately 60 to 100 m thick in the Comet Ridge area. Up to six coal seams are defined within the Bandanna Formation with an average coal thickness of approximately 11 to 12 m in the Fairview region, generally thinning northward. However, to the east of the Fairview region, 15.3 m of net coal has been intersected (McClure S. et al., 2008).

The Bandanna Formation is unconformably overlain by the oldest formation of the Triassic aged Mimosa Group, the Rewan Formation (**Figure 11**). This formation is the oldest formation to outcrop within the Arcadia Valley (**Figure 11**). The Clematis Sandstone is a prominent formation in the Arcadia Valley region, forming the steep cliffs of the Expedition Range, and is overlain by mudstone and sandstone units of the Moolayember Formation. The Arcadia Valley has been in-filled with Cainozoic sandy sediments, which are overlain by Quaternary alluvium deposits along the drainages.

The unconformable contact between the Moolayember Formation and the overlying Precipice Sandstone marks the boundary between the Bowen and Surat Basin sequences.

Geological contour maps illustrating the top and thickness of the Precipice Sandstone and the Bandanna Formation are provided in the ‘Groundwater Impact Study’ (Golder, 2010).

2.5.2 Surat Basin Geological Setting and Model

The Surat Basin comprises a sequence of south dipping consolidated Jurassic and Cretaceous sediments. As previously mentioned, the Surat Basin is a sub-basin of the GAB.

Due to compression and erosional processes, the Precipice Sandstone directly overlies, and is in hydraulic connection with, the Bandanna Formation in a limited area of the southwest Fairview region.

The outcrop region of the Precipice Sandstone crosses through the northern part of the Fairview region (**Figure 10**). The younger Surat Basin formations outcrop progressively south through Roma, including the Evergreen Formation, the Hutton Sandstone and Birkhead Formation, the Springbok Sandstone, WCM, Westbourne Formation, the Gubberamunda Sandstone and Orallo Formation.

The final Surat Basin formations that outcrop within the southern reaches of the Santos EQ Project Area include the Mooga Sandstone, and the Bungil and Wallumbilla Formations (Bureau of Mineral Resources, Geology and Geophysics Surficial Geology, 1967).

The WCM are the main gas bearing units within the Surat Basin and are the target formation for gas operations within the Roma area. The thickness of the coal measures in the Roma area ranges from 100 to 460 m, at depths ranging from 170 to 933 mbgl. The coal seams are separated by silty and tight sandstone, which restricts leakage between seams. There is an unconformable contact between the Springbok Sandstone and the WCM. They are considered to be in hydraulic connection (Scott S. et al., 2004).

Note that the Adori Sandstone (referred to in the CG's comments) is a formation of the Eromanga Basin and is not present within the Santos EQ Project Area, with its equivalent in this area being the Springbok Sandstone.

Geological contour maps illustrating the top and thickness of the main Surat Basin aquifers and key Bowen Basin units have been mapped and assessed by Santos EQ and are presented beginning in **Section 2.6.1**, **Figure 18** to **Figure 20**, **Figure 21** to **Figure 26**, **Figure 30** to **Figure** 35. Their transect location is shown in **Figure 10**.

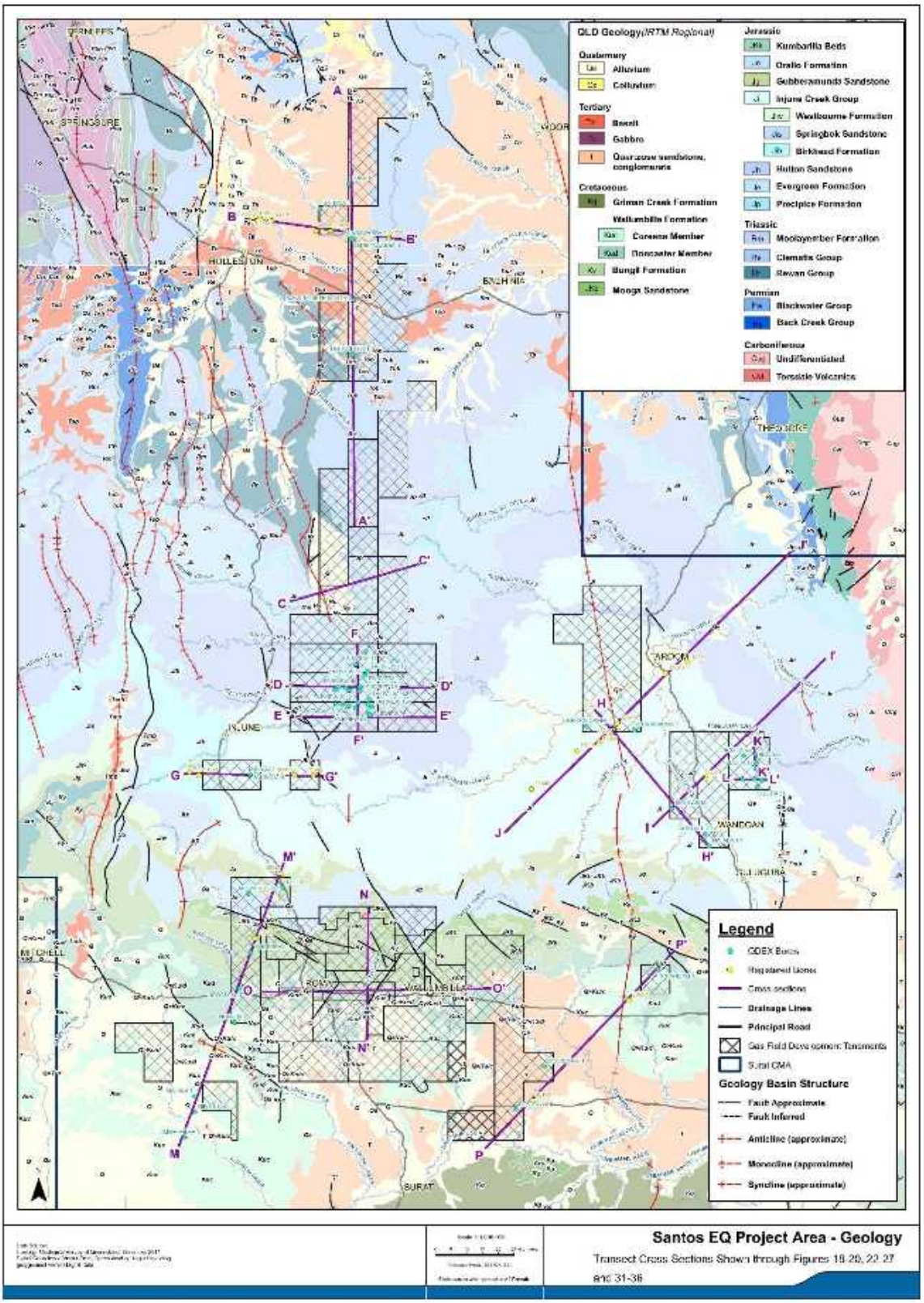


Figure 10. Surface Geology

*Note: Transect Cross-Sections Shown through **Figure 18** to **Figure 20**, **Figure 21** to **Figure 26**, **Figure 30** to **Figure** 35*

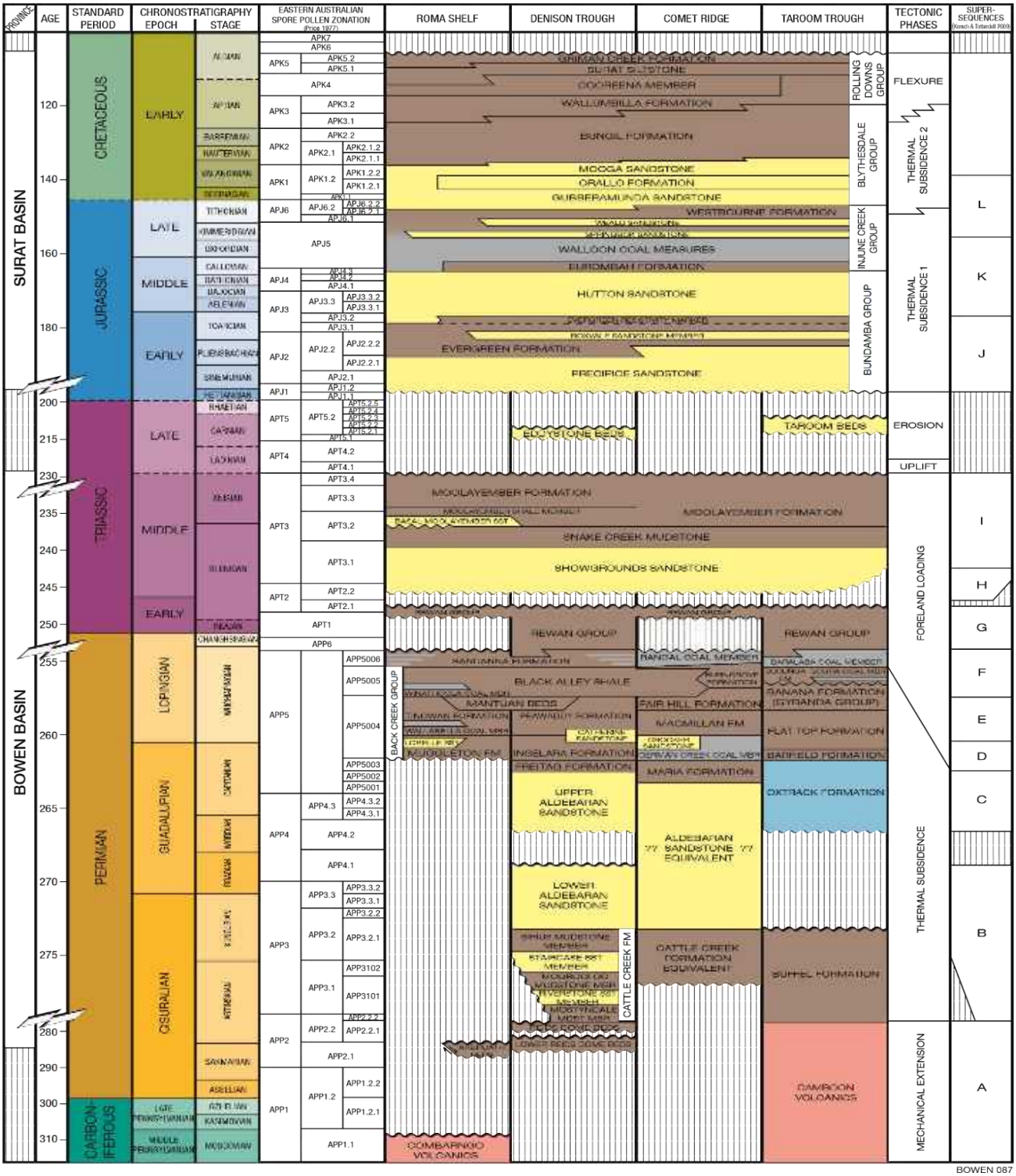


Figure 11. Structural Geology of Eastern Queensland

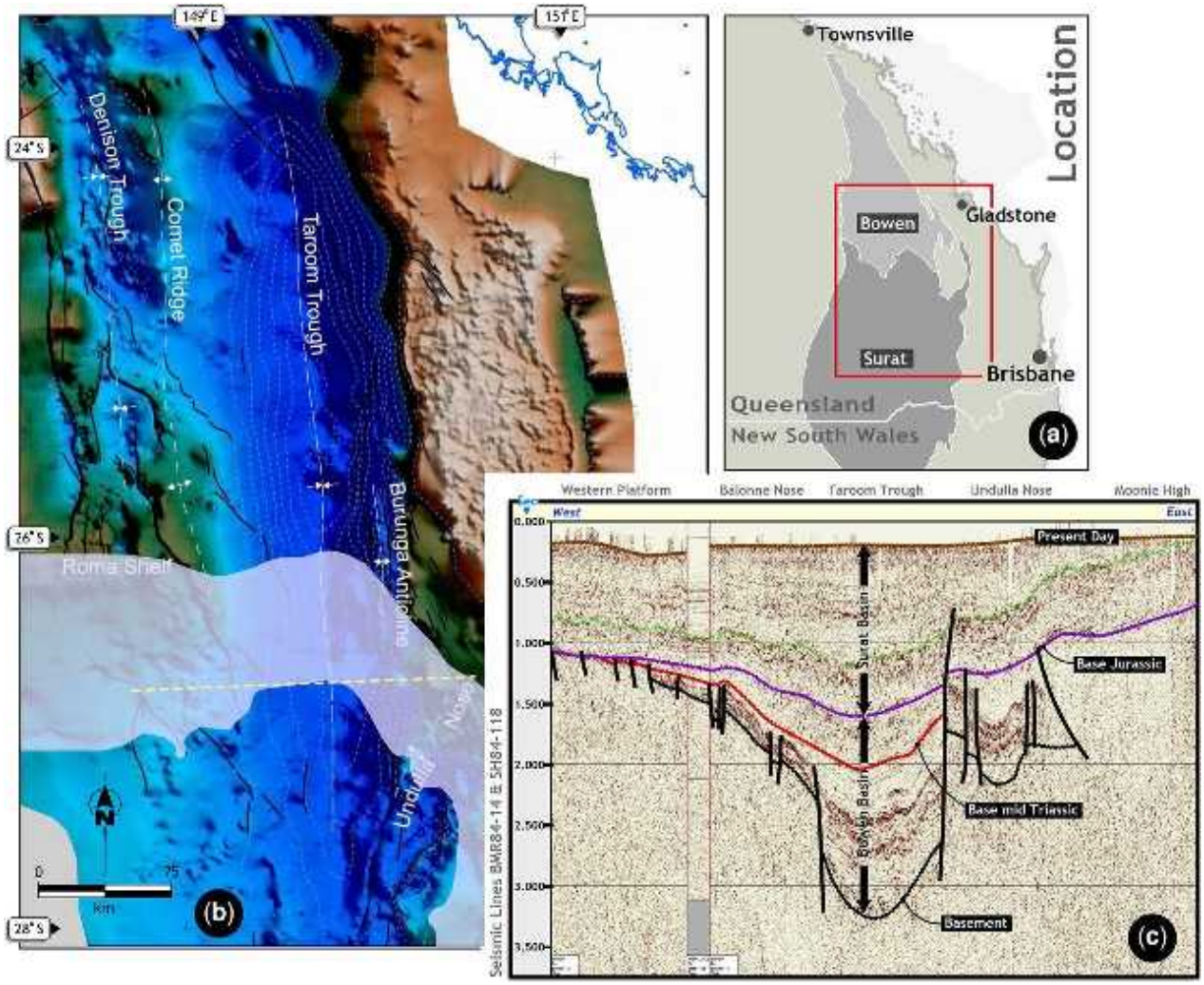


Figure 12. Bowen and Surat Basins in Australia

Notes: (a) Location of Bowen and Surat basins in Australia. (b) SEEBASE map showing the structure of the top basement underlying the Bowen basin and Surat Basin; (c) Seismic line showing basic structural elements of Bowen and Surat basins Source: He et al., 2020

2.5.3 Gas Development Formations

Gas development in the study area targets coal measures within the stratigraphic profiles of both the Surat and Bowen Basins. The Roma area targets the WCM, located within the Surat Basin sequence, while the Bowen Basin coal seams of the Bandanna Formation and Cattle Creek Formation are targeted in the Dension, Scotia, Fairview and Arcadia Valley regions. Descriptions of these formations are provided in the following sections.

2.5.4 Regional Faulting

The southern part of the Santos EQ Project Area is located near the northern margin of the Surat Basin. In this area, the main geological units, including the targeted WCM do not indicate deformation or complex faulted geology. However, the faulting and folding that is recognised in the older subsurface strata is either absent or attenuated in the outcropping Jurassic-Cretaceous sediments. Some features are, however, visible in the outcrop including the Alicker and Eurombah Anticlines, the Hutton- Wallumbilla Fault and several west north-west trending faults.The north-west trending Hutton-Wallumbilla Fault is located west of Roma and is downthrown to the west with a displacement of approximately 450 m in the basement but just 30 m in the overlying sediments. Small north-west

trending faults elsewhere in the Roma region are likely related to the movements that formed the Hutton-Wallumbilla Fault (URS, 2008).

West north-west trending faults also occur in the RSGPA. These faults are likely a result of epeirogenic movements (the gradual uplift or subsidence of the Earth's surface) related to the Surat Basin through the Tertiary period (URS, 2008). These faults have limited or no vertical displacement, but they leave a clearer topographic imprint than the larger faults in the same region due to their younger age.

The major structural feature in the north of the Santos EQ Project Area is Comet Ridge, which comprises mainly Devonian age rocks, and is covered by a relatively thin sequence of Permian and Triassic rocks. The Permian and Triassic sequence of sediments was folded principally during the late Triassic Period, although some of the deformation within the Permian sediments possibly occurred during the period of uplift and emergence in the Lower Permian. Fold axes are generally parallel trending north-west to the Comet Ridge axis. The Permian-Triassic folds are truncated by the erosional unconformity surface on which the Precipice Sandstone was deposited. The overlying Jurassic and Cainozoic rocks are not folded (Golder, 2009).

The central part of the Santos EQ Project Area near Injune is situated between two large reverse fault systems that are oriented approximately north south (**Figure 13**). Immediately to the east of Injune is an anticline, which plunges to the south-southeast and corresponds to a southerly extension of the Comet Ridge in the geological basement. The anticline is complementary to the Mimosa Syncline and runs through the eastern area of the study area near Taroom.

Figure 14 illustrates the structural features in the central and southern part of the Santos EQ Project, which affect the WCM sequence in the Roma Area.

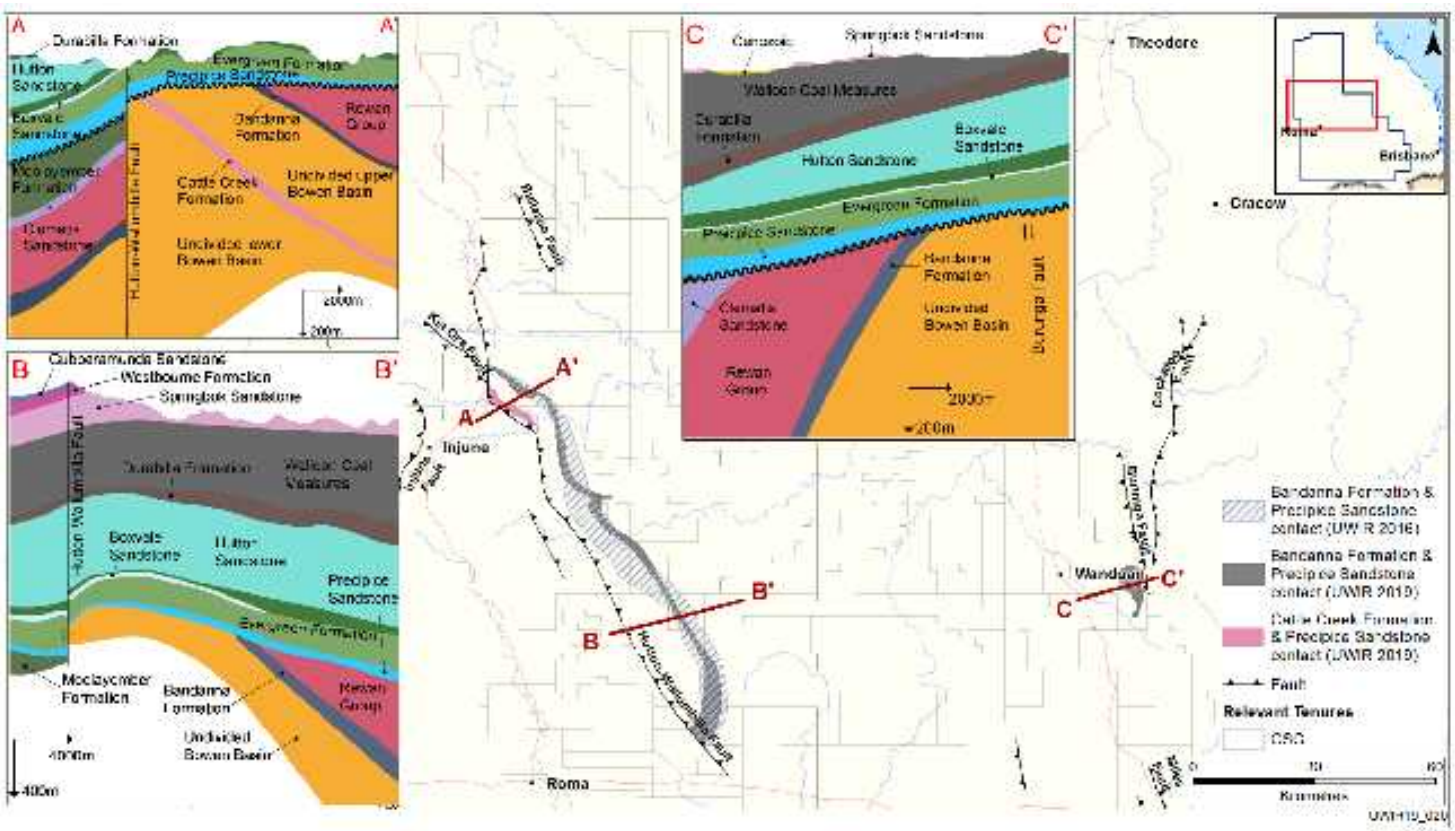


Figure 13. Contact Zones Between the Bandanna Formation and Overlying Surat Basin (after UWIR 2019)

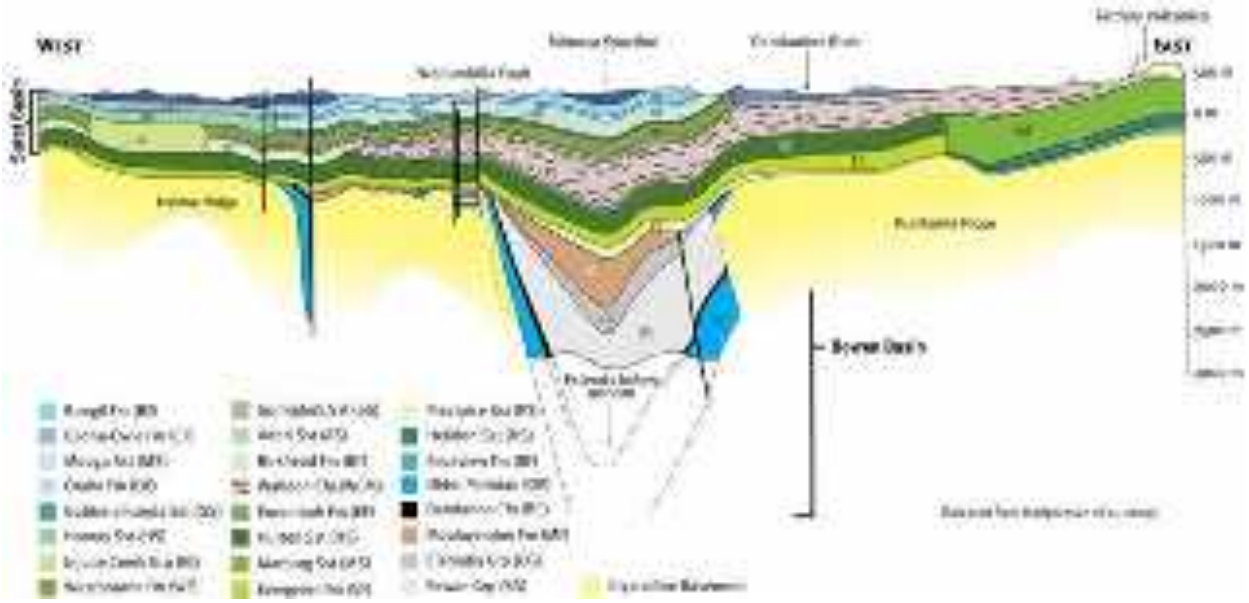


Figure 14. Cross-Section of the Surat and Bowen Basins

Source: Esterle et al., 2013

2.5.5 Seismic History of Santos Eastern Queensland Tenements

2.5.5.1 Vulnerability

Earthquakes in Australia are generally caused from the release of built-up stress in the interior of the Indo-Australian plate, which is being pushing north (NNE) and is colliding with the Eurasian, Philippine, and Pacific plates. Geoscience Australia reported that there are on average 200 earthquakes of magnitude 3.0 or more in Australia each year. Earthquakes above magnitude 5.5 occur on average every two years, and those of magnitude 6.0 or more occur approximately every five years.

The area of southern central Queensland in the immediate vicinity of the Project tenures is one of the least seismically active areas on Australian continent. The most seismic activity near the Project area is in the Hervey Bay area, approximately 500 km to the east. While more frequent and larger in magnitude earthquakes occur in the Hervey Bay area, little is felt in the area surrounding the tenures. A study performed in the 1990s found that there is a 90% chance that the unitless peak ground acceleration (a term used in civil engineering to estimate forces on structures) will not exceed 0.05 in any 50-year period for this area. This indicates that regardless of the epicentre of any possible earthquake, little ground movement will occur here.

2.5.5.2 Local Historic Faults and Potential Seismic Activity

Figure 10 shows the location of major faults related to the basin structure as mapped by the Geological Survey Queensland 2011 within the Santos EQ Project Area.

Within the Surat Basin and within the Santos EQ project area the only major fault is the north-west trending Wallumbilla Fault which crosses the Roma region and is downthrown to the west with a displacement of ±450 m in the basement but just 30 m in the overlying sediments. Small north-west trending faults elsewhere in this field are likely related to the historic movements that formed the Hutton- Wallumbilla Fault (URS, 2008) (**Figure 13** and **Figure 21**).

Further information on the Hutton-Wallumbilla Fault is discussed below.

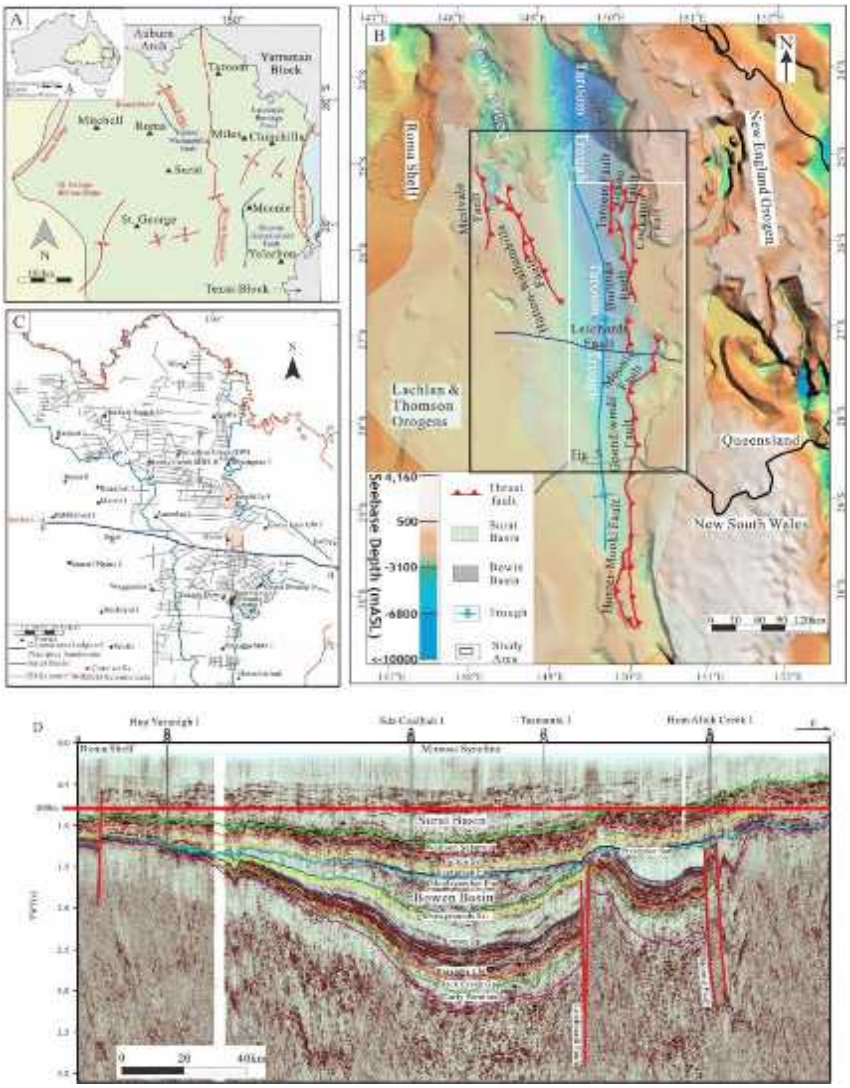
Of the other minor faults, the seismic cross-sections presented in **Figure 12**, **Figure 15** to **Figure 17**, **Figure 21,** and **Figure 27** to **Figure 29** illustrate how these fault and fold structures affect the Bowen and Surat Basin sequences. Of note is the deep-seated nature of the basement structures, particularly the faults. These largely do

not penetrate upward beyond the Bowen Basin stratigraphy. The structures are predominantly compressional and do not generally have large fault-throws within the Bowen stratigraphy and negligible throws in the Surat stratigraphy.

The Hutton-Wallumbilla Fault

The Hutton-Wallumbilla Fault (**Figure 16**) is a near-vertical thrust fault dividing the Comet Ridge Platform from the lower Roma Shelf (Green, 1997). The main thrust fault event occurred in the Early Permian during the back-arc extension phase of the Bowen-Gunnedah Basin, which produced a series of graben and half-graben structures along the eastern margin of the Australian continent (Jones & Veevers, 1983). Periods of reactivation have extended the fault through the overlying sediments and have resulted in pervasive en échelon faulting with evidence of reactivation in the near surface (Coote, 1984; Jensen et al., 1964). While the fault system exhibits more than 300 m of displacement in the Bowen Basin, faulting in the Surat Basin is more subdued.

There are several important connectivity features associated with this fault, including the regionally significant Precipice–Bandanna contact zone (OGIA, 2019c). This section, however, will focus on a multidisciplinary case study around a group of springs that are found in the vicinity of the Hutton-Wallumbilla Fault (OGIA, 2015). This site has been selected due to several lines of evidence for structural control on local groundwater dynamics. The Lucky Last and Abyss spring complexes are located approximately 20 km north of Injune (**Figure 17**). OGIA has



undertaken a detailed conceptualisation of these sites as part of a spring wetland conceptualisation project (OGIA, 2015).

Figure 15. Surat Basin

Notes: (A) Geographic location and the main structural elements of the Surat Basin. (B) Pre-existing basement faults and structures interpreted from seismic reflection, magnetic, and gravity data (after Babaahmadi et al., 2015). Base map comes from

Phanerozoic SEEBASE map (Oz SEEBASETM, 2005) (C) Position of interpreted seismic lines and key wells in the Surat Basin. (D) East-west oriented composite seismic line (BMR 84-14) showing the major structural elements and stratigraphy (modified from Martin et al., 2013).

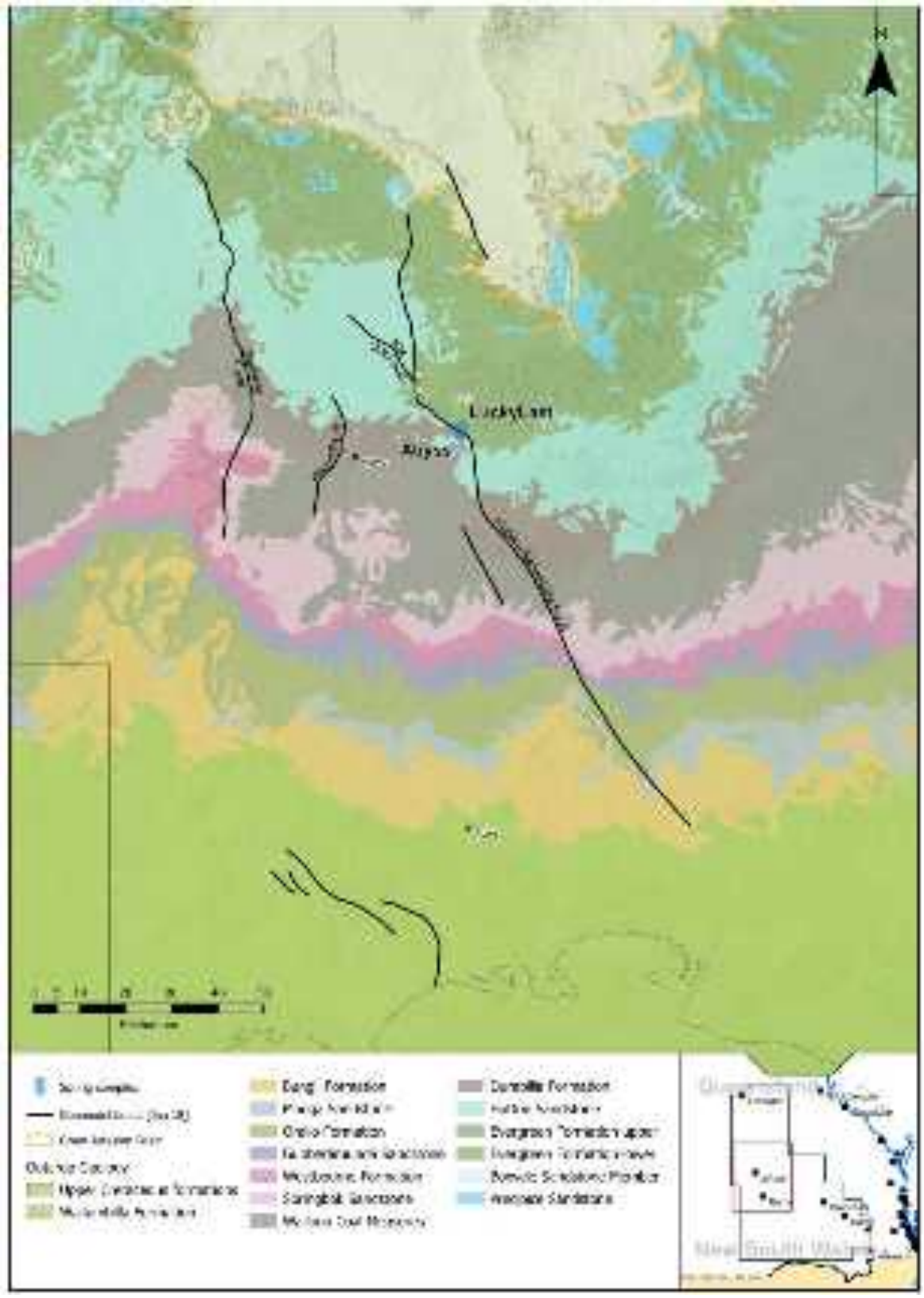


Figure 16. Hutton-Wallumbilla Fault and Location of the Springs

Source: OGIA, 2020

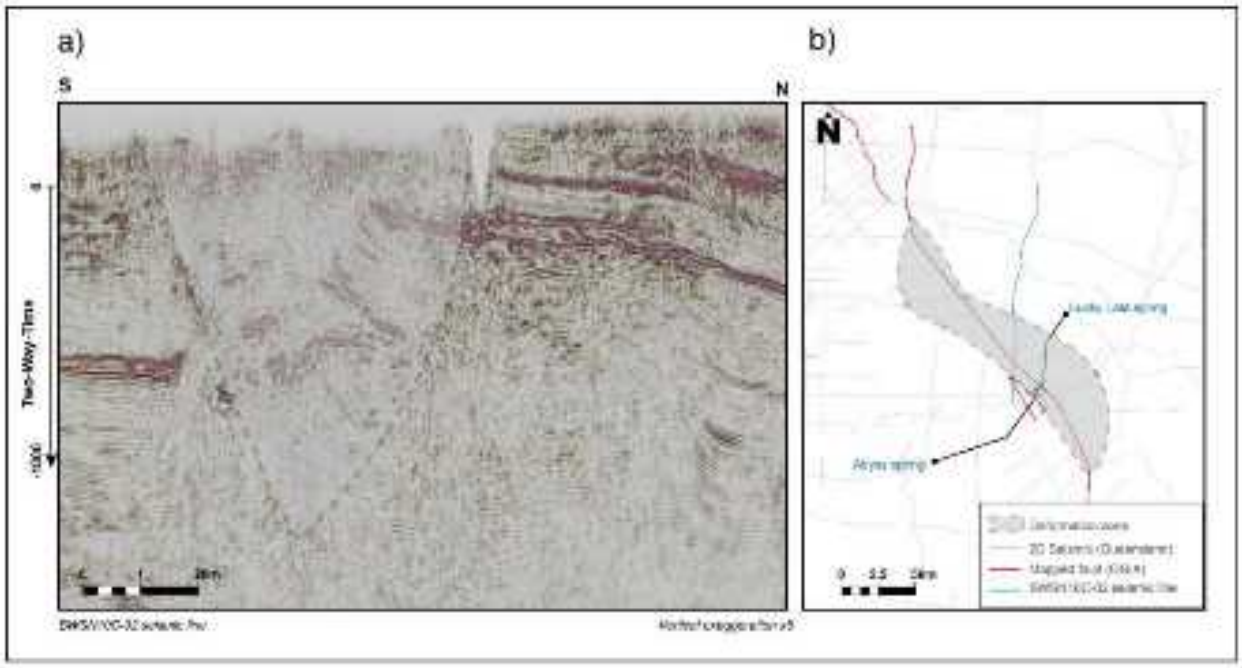


Figure 17. BWSN10C-02 Seismic Line with Hutton-Wallumbilla Fault Zone

*Notes: a) Seismic Line with the Deformation Zone; b) Map Showing the Hutton-Wallumbilla Fault Zone and Spring Locations. Refer to **Figure 16** for location of springs.*

2.6 Local Geology

Conceptual geological model cross-sections through various parts of the Santos EQ Project Area are presented in **Figure 18** to **Figure 20**, **Figure 21** to **Figure 26**, **Figure 30** to **Figure 35** and present an interpretation of the key elements of the Bowen and Surat Basin geology. The locations of these cross-sections are presented on the surface geology map (**Figure 10**).

2.6.1 Roma Region

The Roma region is part of the Surat Basin and are underlain by sedimentary formations associated with the GAB, some of which are recognised as regionally significant aquifers. Jurassic to Cretaceous age sedimentary formations sub-crop and outcrop across the tenures but are predominantly overlain by Quaternary alluvium. A basalt intrusion is present at the Grafton Range towards the north of the Roma area. The gas bearing formation of interest to Santos is the Walloon Coal Measures (WCM) of the Injune Creek Group. **Section 3.5** provides a geological description of each major geological formation underlying the Roma area.

Figure 18 to **Figure 20** shows several cross-sections through the Roma area. These sections were generated using stratigraphy data available in the DEHP groundwater database and from Santos EQ gas well geology logs.

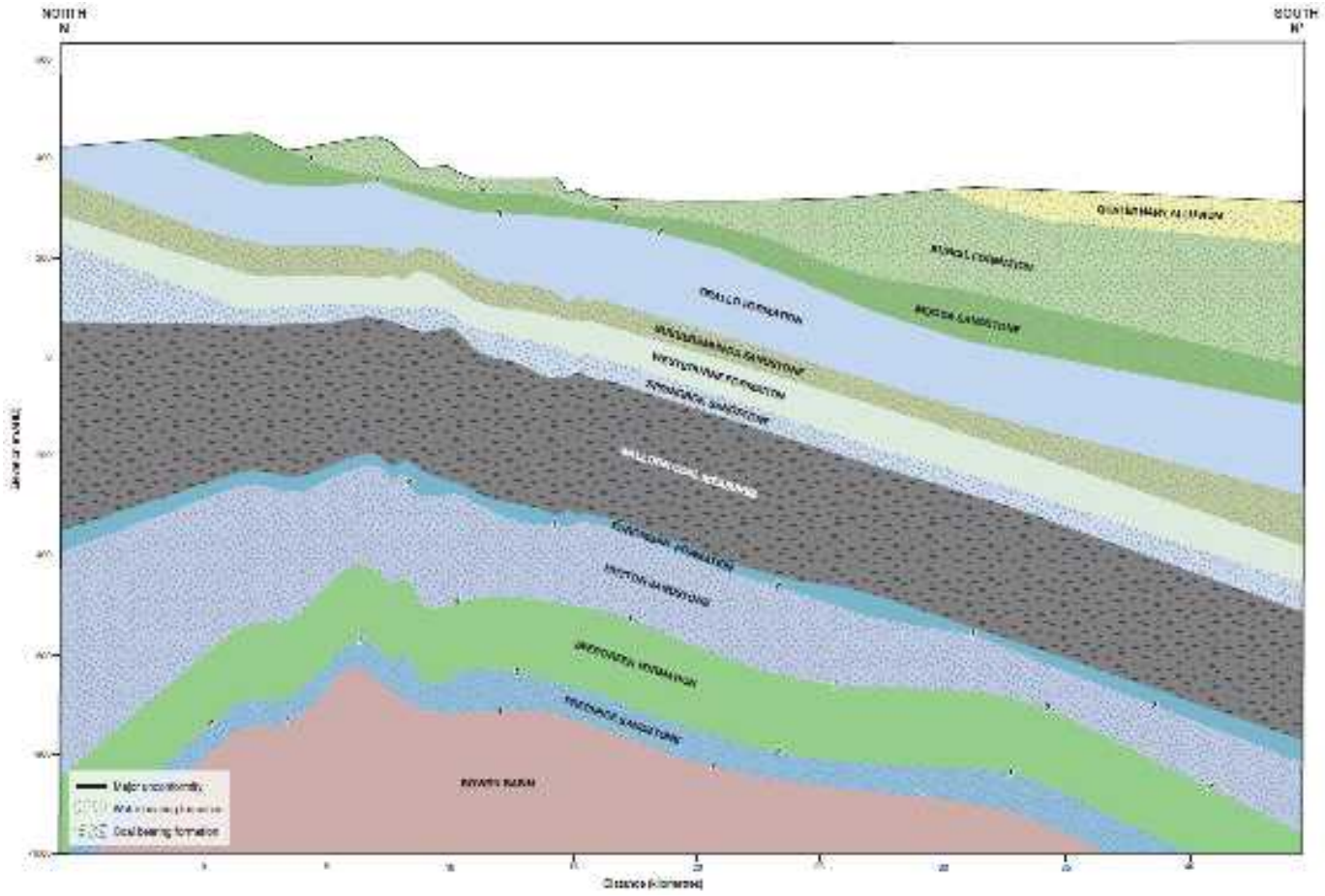


Figure 18. Conceptual Geological Cross-Section Roma North – South

*Note: Refer to **Figure 10** for Cross-Section Location*

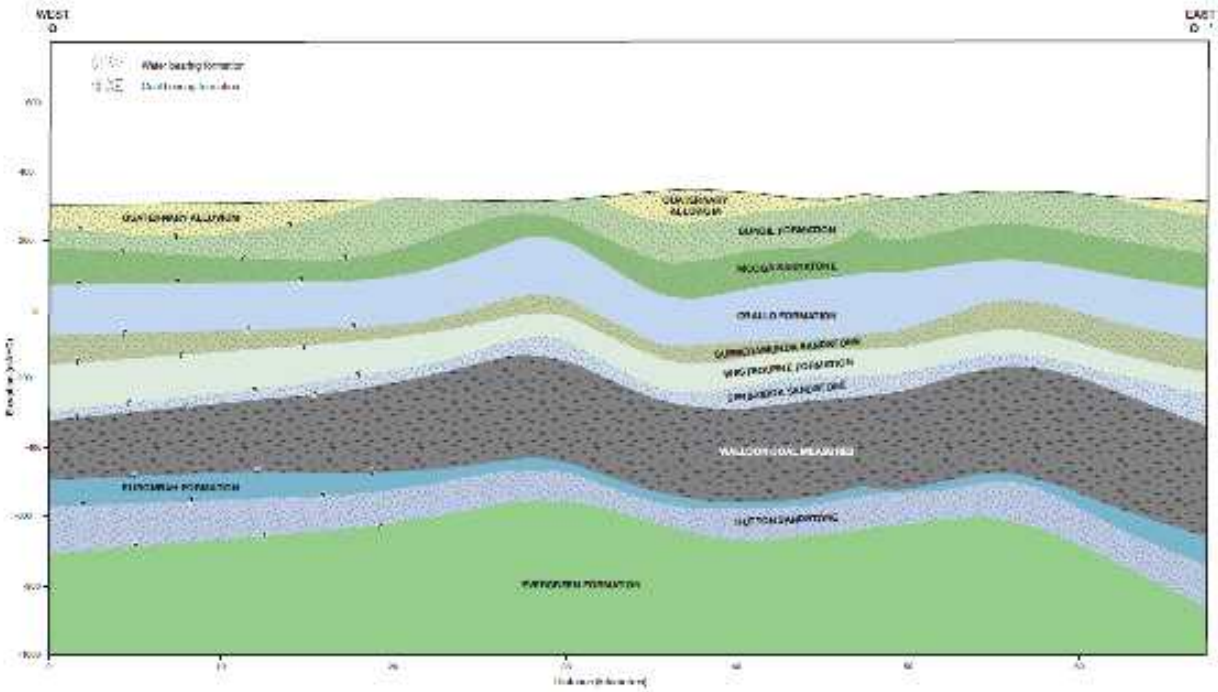


Figure 19. Conceptual Geological Cross-Section West – East

*Note: Refer to **Figure 10** for Cross-Section Location*

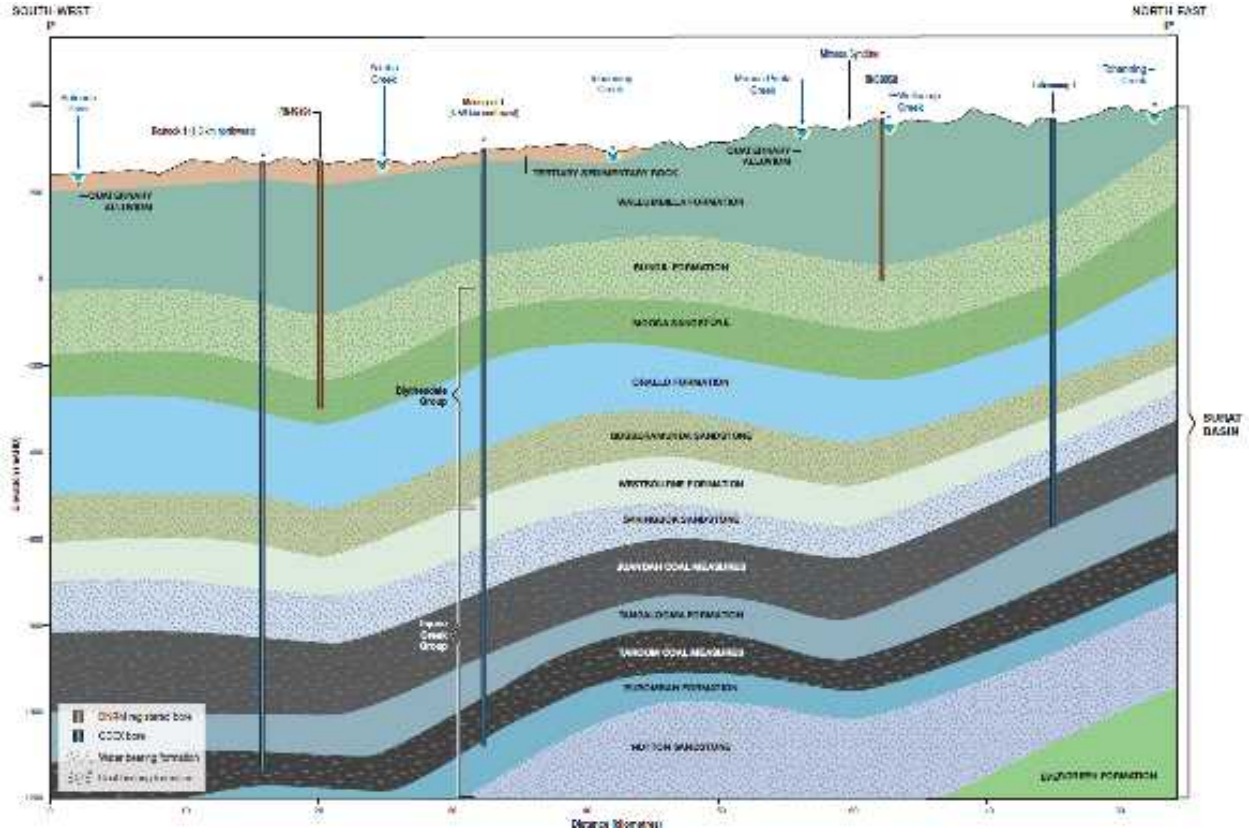


Figure 20. Conceptual Geological Cross-Section Southwest – Northeast

*Note: Refer to **Figure 10** for Cross-Section Location*

2.6.1.1 Faults and Other Geological Controls

The north-west trending Hutton-Wallumbilla Fault crosses the Roma area and is downthrown to the west with a displacement of 450 m in the basement but just 30 m in the overlying sediments (refer to **Figure 21**). Small north-west trending faults elsewhere in the Roma area are likely related to the movements that formed the Hutton-Wallumbilla Fault (URS, 2008). Further detail on the Hutton-Wallumbilla Fault is discussed in **Section 2.5.5.2**.

Other west-northwest trending faults also occur across the Roma area. These faults are likely a result of epeirogenic movements (the gradual uplift or subsidence of the Earth's surface) related to the Surat Basin through the Tertiary period (URS, 2008). These faults have limited or no vertical displacement, but they leave a clearer topographic imprint than the larger faults in the same region due to their younger age.

Importantly in this area, the main geological units, including the targeted Walloon Coal Measures (WCM) do not indicate deformation or complex faulted geology. However, the faulting and folding that is recognised in the older subsurface strata is either absent or attenuated in the outcropping Jurassic-Cretaceous sediments. Some features are, however, visible in the outcrop including the Alicker and Eurombah Anticlines, the Hutton-Wallumbilla Fault and several west north-west trending faults.

In December 2020, the OGIA concluded that the Hutton-Wallumbilla Fault generally do not cause sufficient displacement to juxtapose the Hutton Sandstone and Walloon Coal Measures and as such, the risk of cross-formational flow is low. Furthermore, the report found the other small number of faults that were identified (OGIA, 2020).

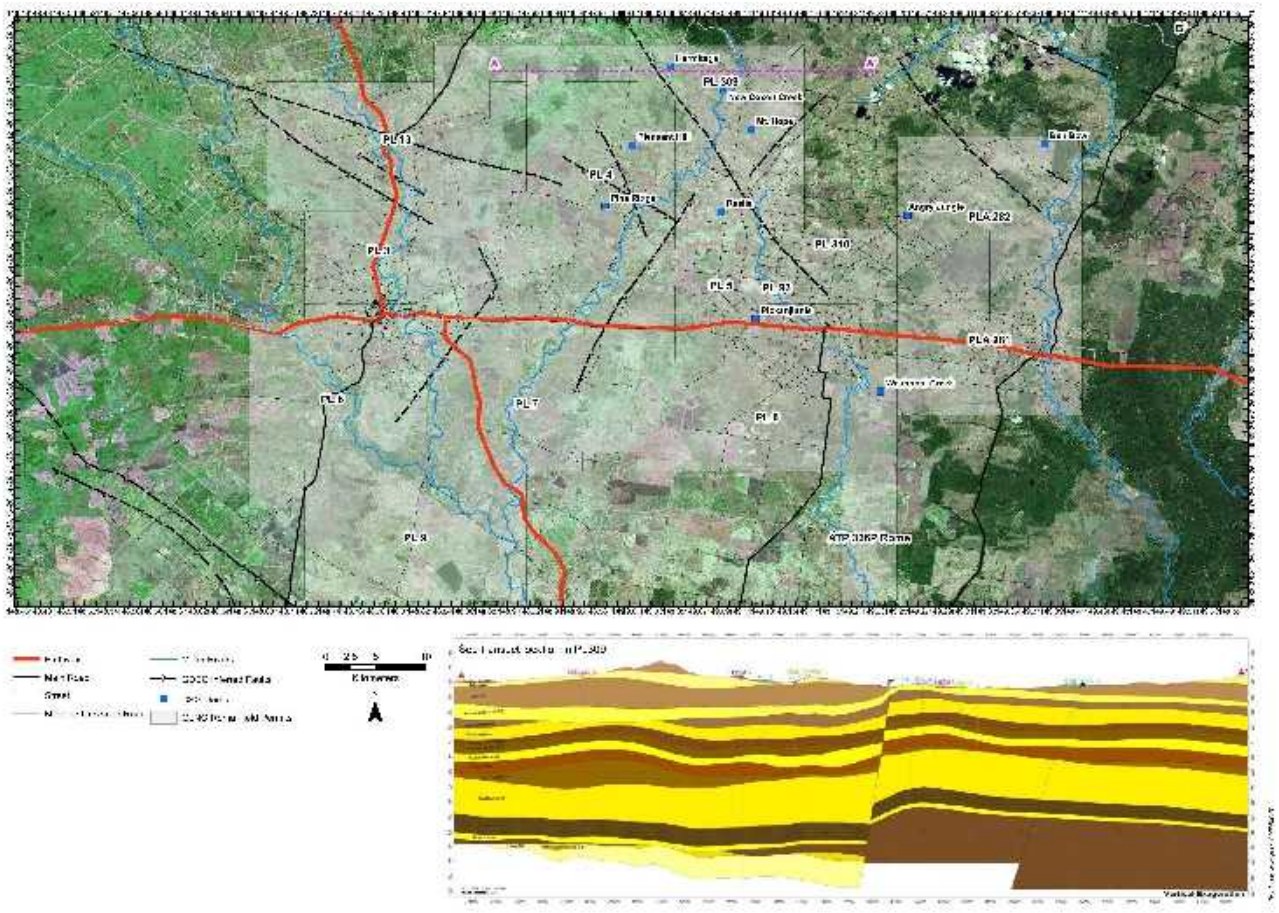


Figure 21. Wallumbilla Fault Cross-Section

2.6.2 Fairview and Arcadia Valley Regions

The Fairview region is directly underlain by the lower GAB formations of the Surat Basin (Hutton, Evergreen and Precipice Sandstone) and the formations of the upper Bowen Basin (Clematis Sandstone). The gas bearing formation of interest in the Fairview region is the Bandanna Formation from the Blackwater Group (Bowen Basin, Late Permian). In the Arcadia Valley region, the main geological units include the Precipice Sandstone, Clematis Sandstone and at depth the Aldebaran Sandstone (the Back Creek Group) in the northern portion of the field.

The Bandanna Formation is unconformably overlain by the oldest formation of the Triassic aged Mimosa Group, the Rewan Formation. This formation is the oldest formation to outcrop within the Arcadia Valley. The Clematis Sandstone is a prominent formation in the Arcadia Valley CSG field, forming the steep cliffs of the Expedition Range, and is overlain by mudstone and sandstone units of the Moolayember Formation. The Arcadia Valley has been in-filled with Cainozoic sandy sediments, which are overlain by Quaternary alluvium deposits along the drainages.

Due to compression and erosional processes, the Precipice Sandstone directly overlies, and is in hydraulic connection with, the Bandanna Formation in a limited area of the southwest Fairview region. The unconformable contact between the Moolayember Formation and the overlying Precipice Sandstone forms the boundary between the Bowen and Surat Basins.

Section 3.5 provides a geological description of each major geological formation underlying the Fairview and Arcadia Valley region **Figure 21** to **Figure 26** shows several cross-sections through the Fairview and Arcadia Valley region. These sections were generated using stratigraphy data available in the DEHP groundwater database and from Santos EQ gas well geology logs.

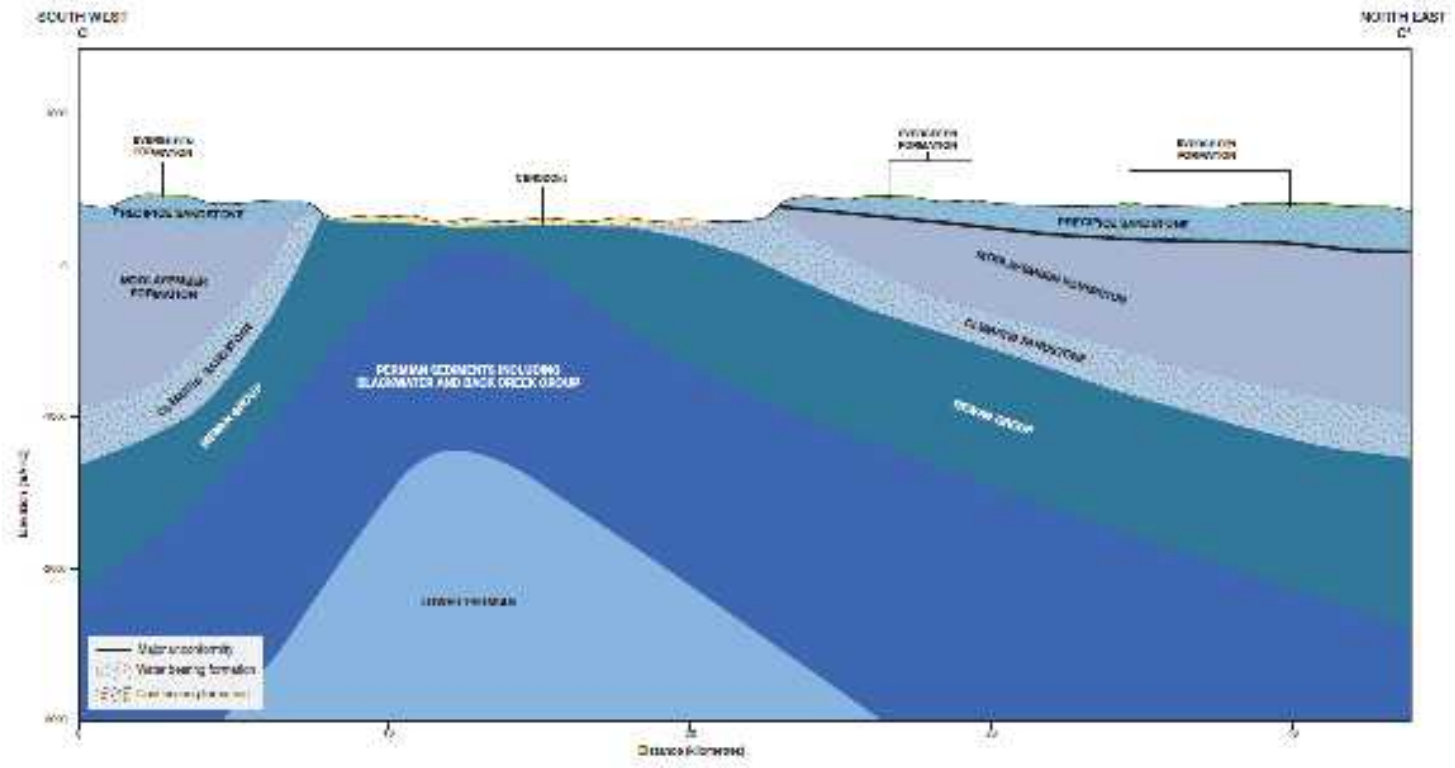


Figure 21. Conceptual Geological Cross-Section Fairview (North) South-West to North-East

*Note: Refer to **Figure 10** for Cross-Section Location*

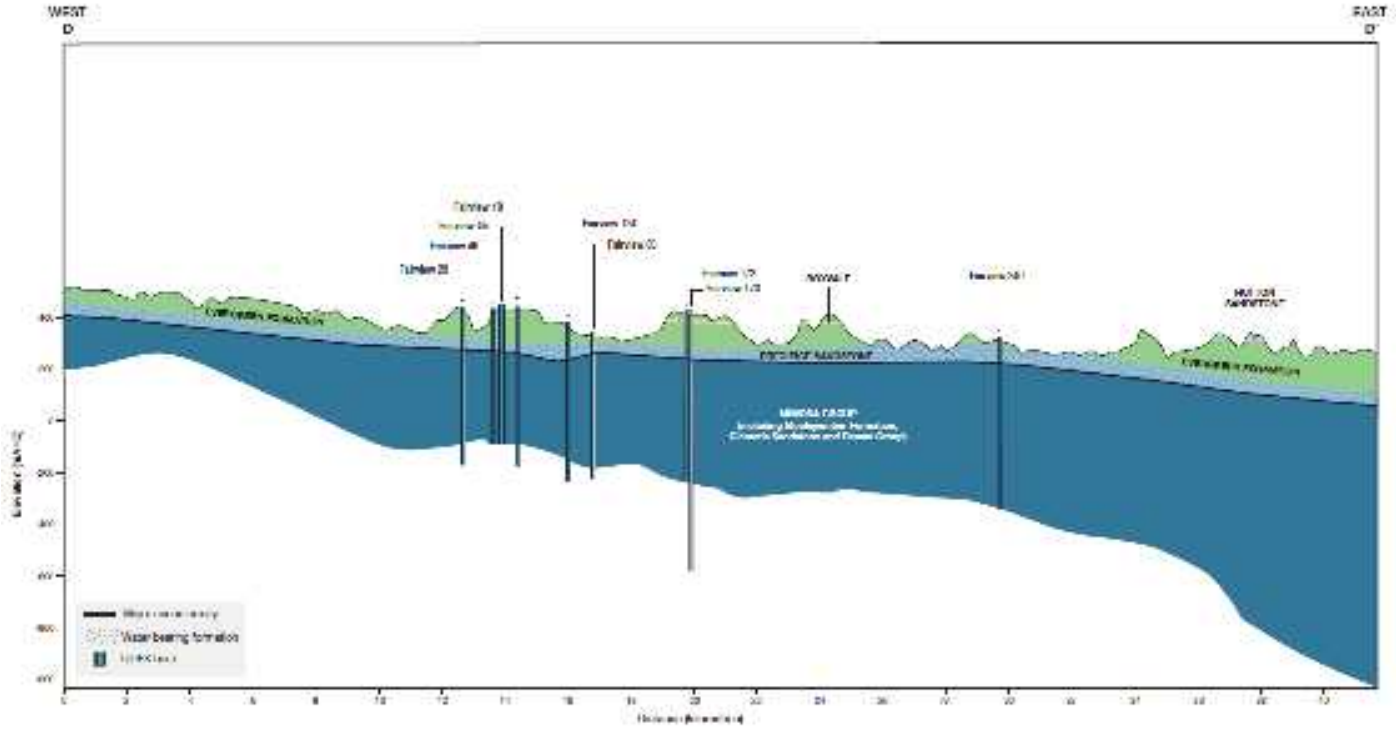


Figure 22. Conceptual Geological Cross-Section Fairview (Central) West to East

*Note: Refer to **Figure 10** for Cross-Section Location*

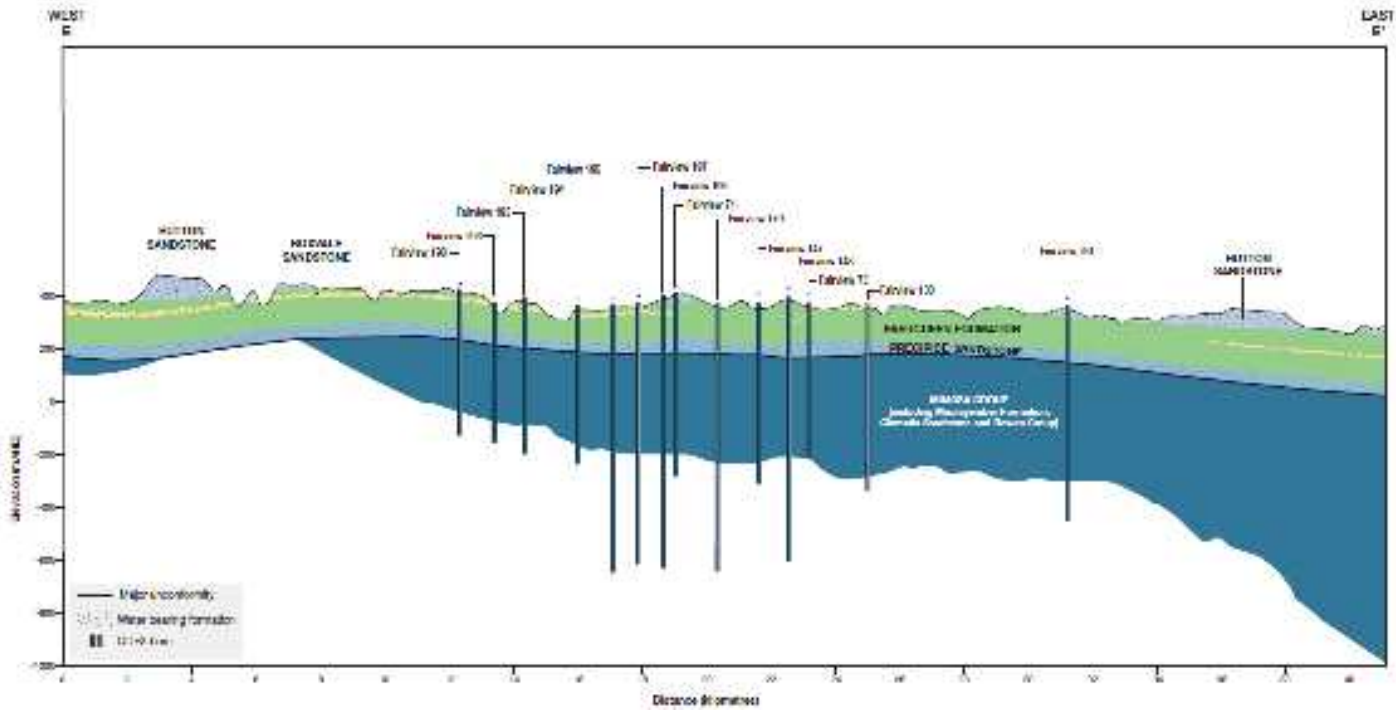


Figure 23. Conceptual Geological Cross-Section Fairview (South) West to East

*Note: Refer to **Figure 10** for Cross-Section Location*

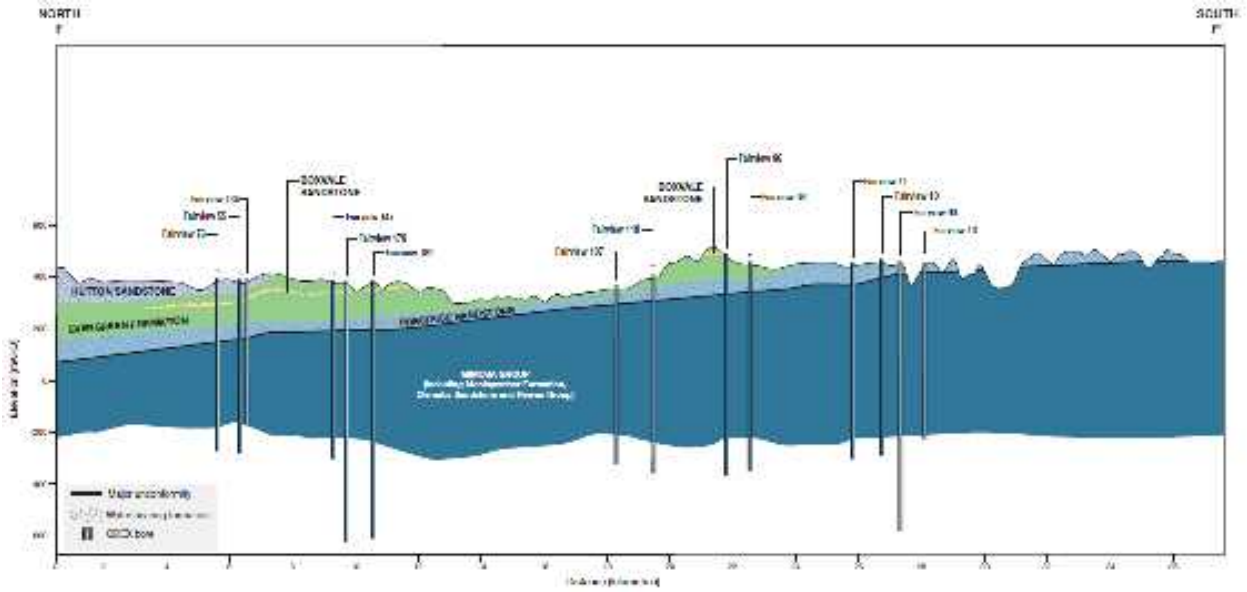


Figure 24. Conceptual Geological Cross-Section Fairview North to South

*Note: Refer to **Figure 10** for Cross-Section Location*

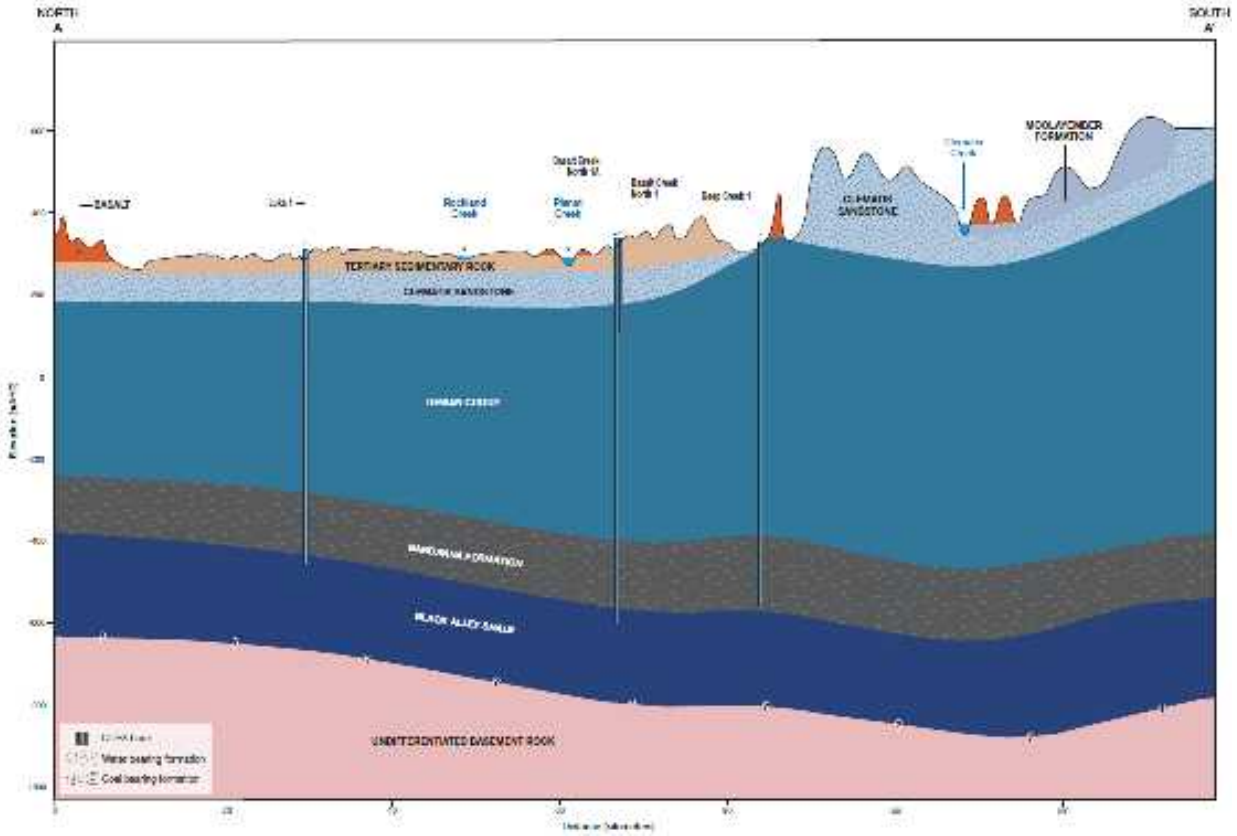


Figure 25. Conceptual Geological Cross-Section Arcadia North-South

*Note: Refer to **Figure 10** for Cross-Section Location*

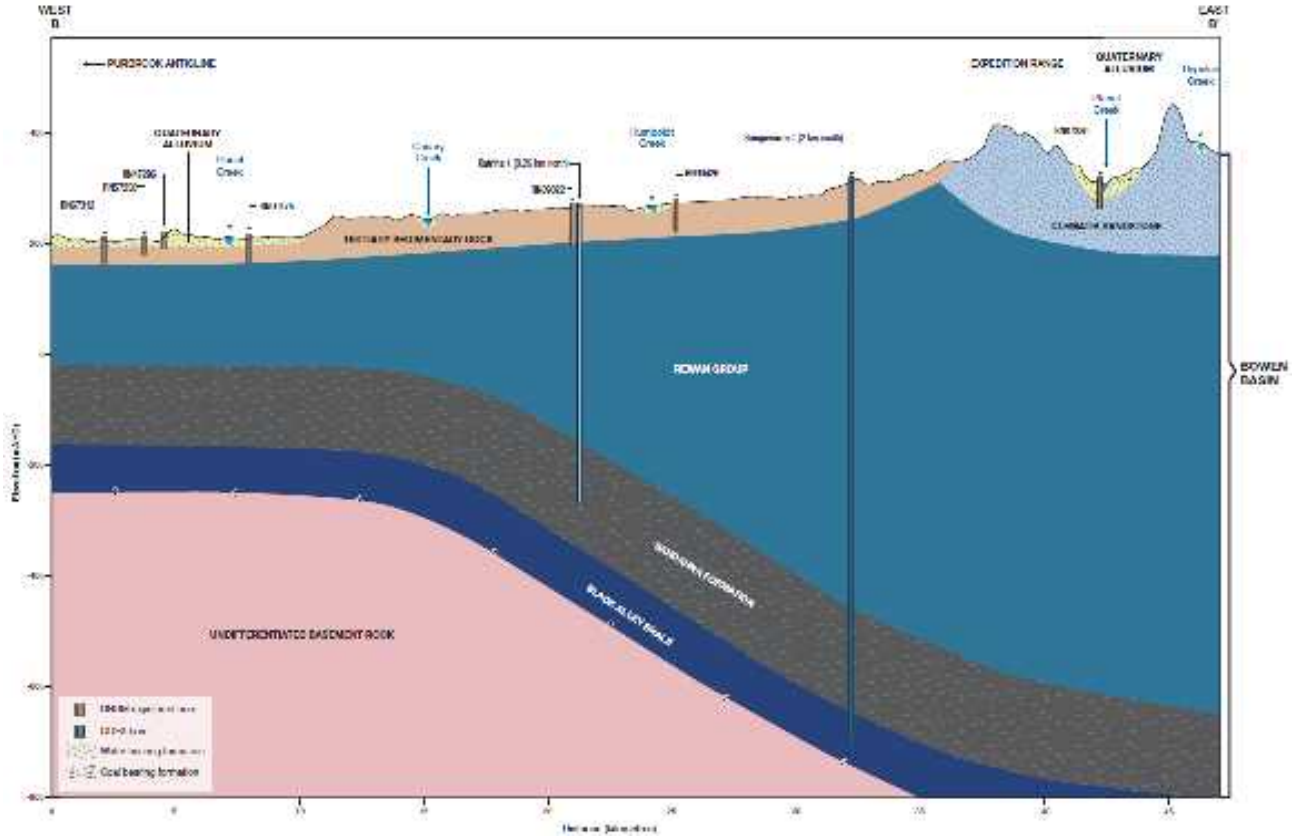


Figure 26. Conceptual Geological Cross-Section Arcadia East-West

*Note: Refer to **Figure 10** for Cross-Section Location*

2.6.2.1 Faults and Other Geological Controls

Fairview Region

The Fairview area is situated between two reverse fault systems that are oriented approximately north south (Santos, 2008) (**Figure 27** and **Figure 28**). The north-west trending Hutton-Wallumbilla Fault (refer to **Section 2.6.1.1**) runs to the west of FPA. The Fairview area is located within an anticline, which plunges to the south-southeast and corresponds to a southerly extension of the Comet Ridge in the geological basement. The anticline is complementary to the Mimosa Syncline, located to the east of the FPA.

Both the anticline and syncline were developed through the Permian and Triassic periods. In the anticlinal structure there are subsidiary minor folds, but after the period represented by the unconformity at the base of the Jurassic aged Precipice Sandstone, folding on the pre-existing axes has been slight. The warping and minor faulting of the Jurassic succession may be related to the compaction of the underlying thick sequence of Permian and Triassic sediments.

Arcadia Valley Region

The major structural feature in the Arcadia Valley is the Comet Ridge, which comprises mainly Devonian age rocks, and is covered by a relatively thin sequence of Permian and Triassic rocks. The Permian and Triassic sequence of sediments within the Arcadia Valley was folded principally during the late Triassic Period, although some of the deformation within the Permian sediments possibly occurred during the period of uplift and emergence in the Lower Permian.

Fold axes are generally parallel (**Figure 29**), trending north-west, through the area designated as Comet Ridge. The amplitude of folding on the Comet Ridge is small and the axes are short and sinuous. The Permian-Triassic folds are truncated by the erosional unconformity surface on which the Precipice Sandstone was deposited. The overlying Jurassic and Cainozoic rocks are not folded.

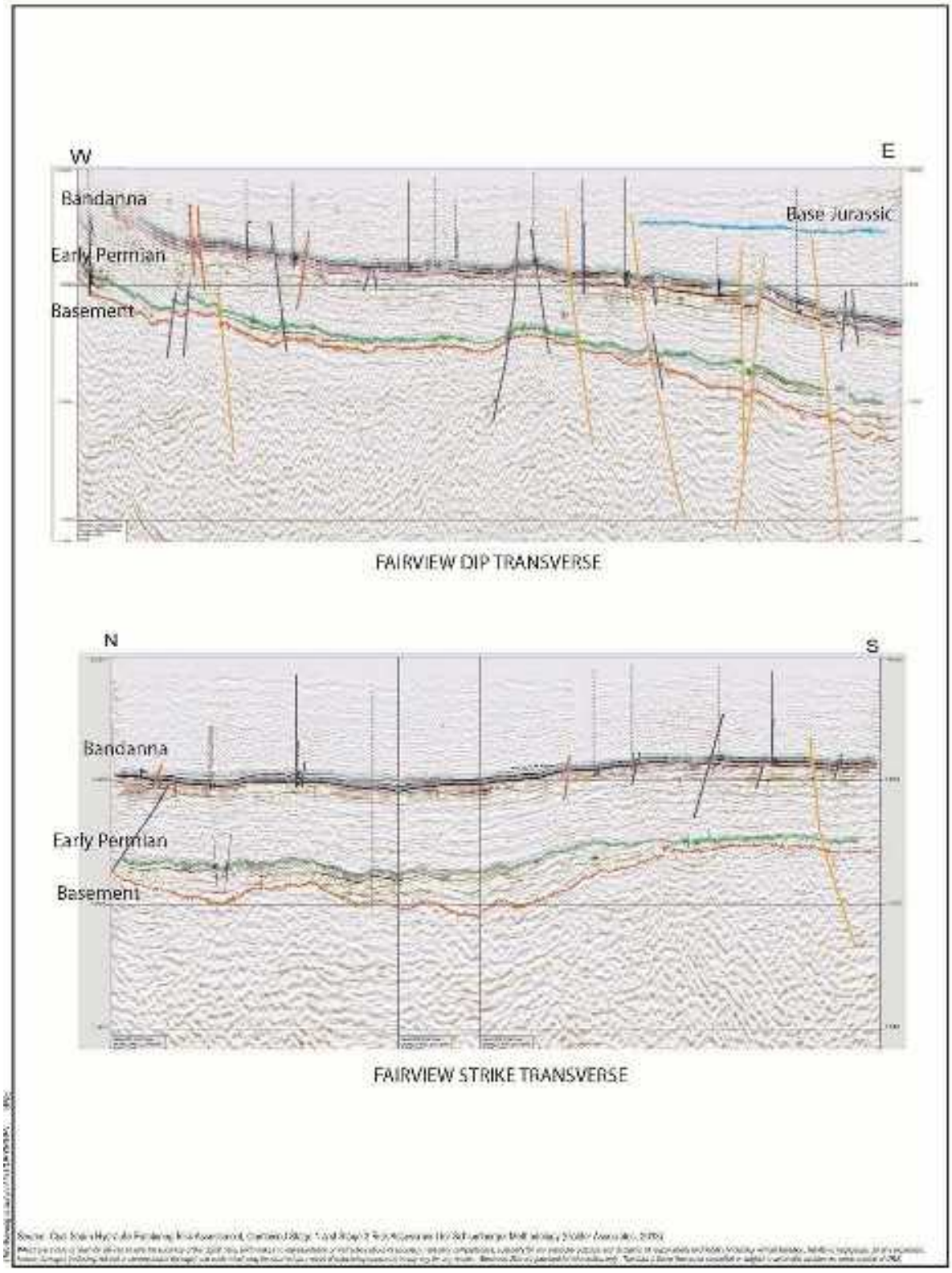


Figure 27. N – S Seismic Section for Fairview Showing Fold and Fault Structure Penetrations

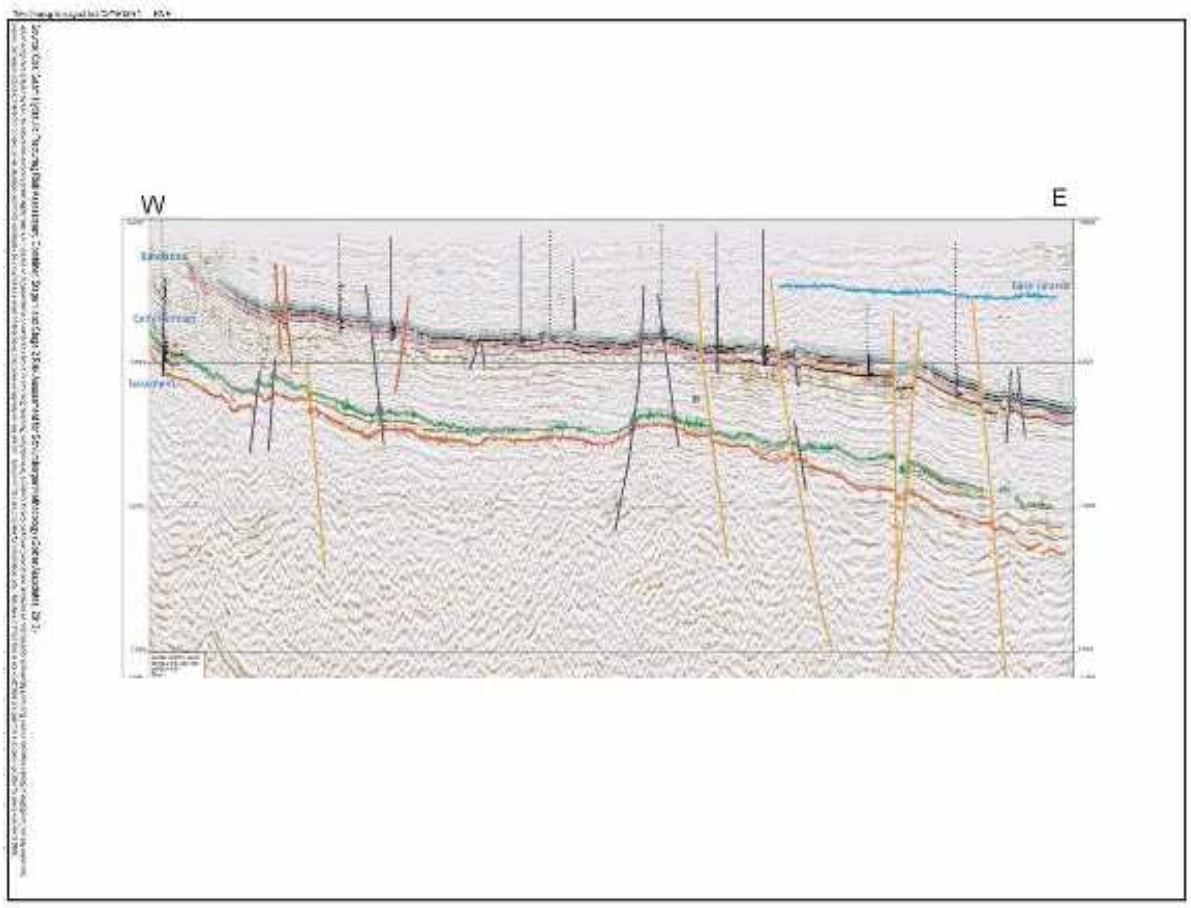


Figure 28. N – S Seismic Section for Fairview Dip Traverse Showing Fold and Fault Structure Penetrations

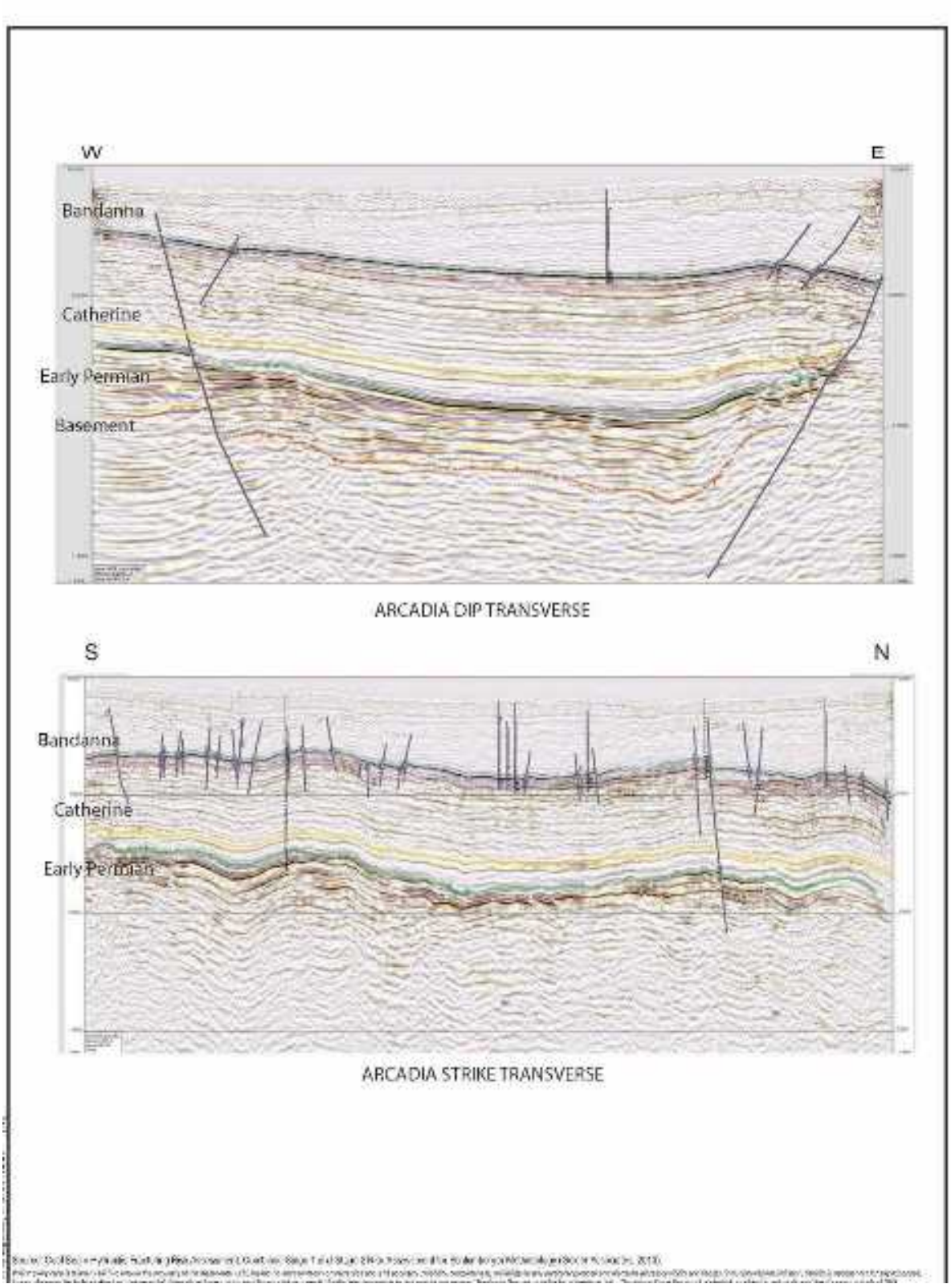


Figure 29. N – S Seismic Section for Arcadia Showing Fold and Fault Structure Penetrations

2.6.3 Denison Project Area

ATP 1191 (and associated tenures) partially capture the Denison Trough and Comet Ridge structural features of the Bowen Basin in Queensland. The Bowen Basin is a deep, elongate, sedimentary trough that extends north-south for 1,100km and covers an area of approximately 160,000km^2 from the townships of Collinsville in Central Queensland to Moree in northern New South Wales. The basin is an asymmetric retro-arc foreland basin containing Early Permian to Middle Triassic sediments. The basin is bounded to the east by a regionally extensive thrust fault system (referred to as the Burunga-Leichhardt Fault in Queensland) and is partially overlain by the Jurassic-Cretaceous Surat Basin sequence.

The Denison Trough is an elongate sedimentary sub-basin, approximately 300 km by 50 km, located along the central western margin of the Bowen Basin. The Denison Trough consists of a series of interconnected N-S to NW-SE trending inverted graben and half graben thrust ramp anticlines separated by broad structural lows. The Comet Ridge is a north-south trending regional basement high which separates the Denison Trough from the Taroom Trough, the main structural depocenter of Bowen Basin.

Figure 30 shows the stratigraphic cross-sections through the Denison region.

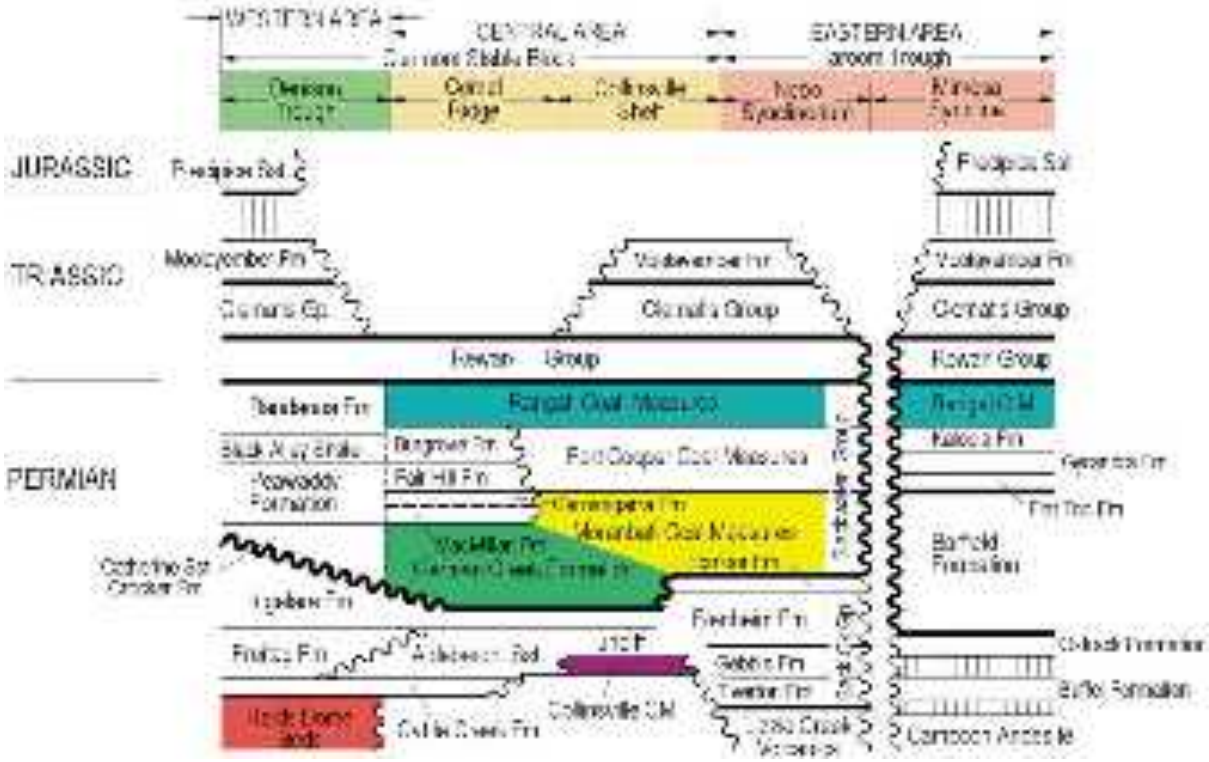


Figure 30. Stratigraphy of the Denison Trough

Source: Modified from Beeston, 1986

2.6.3.1 Faults and Other Geological Controls

The Denison Trough is not known for being seismically active. A search of Geoscience Science Australia Earthquake Mapping Tool (Geoscience Australia, 2019) for earthquakes greater than or equal to a magnitude 2.0 since 1900 showed no history of earthquakes within the Project Area. The closest earthquake identified from this search was a magnitude 3.2 earthquake near Blackwater, Queensland in June 2013.

2.6.4 Scotia Region

The Scotia region lies within the overlap area of the Early Permian to Middle Triassic aged Bowen Basin which contains shallow marine and continental clastic and volcanic rocks, and the south dipping consolidated Jurassic and Cretaceous sediments of the Surat Basin.

The Jurassic age Injune Creek Group outcrops across the majority of the Scotia region. In the Queensland Department of Environment and Resource Management (DERM) groundwater database the Birkhead formation of the Injune Creek Group is the main stratigraphic descriptor used. The Hutton Sandstone, underlying the Injune Creek Group in the Surat Basin sequence, outcrops over the north-eastern portion of the Scotia Project Area. Alluvium is present along the course of the Bungaban Creek in the far north of the Scotia area.

Within the Scotia region the Upper Baralaba Formation is the main coal-bearing unit. This is equivalent of Late Permian Bandanna Formation elsewhere in the Bowen Basin (Santos, 2011). The surface geology in the Scotia region and surrounding area is shown in **Figure 10**. Detailed stratigraphy of the formations present in the Scotia region is presented in **Figure 31** to **Figure 35**.

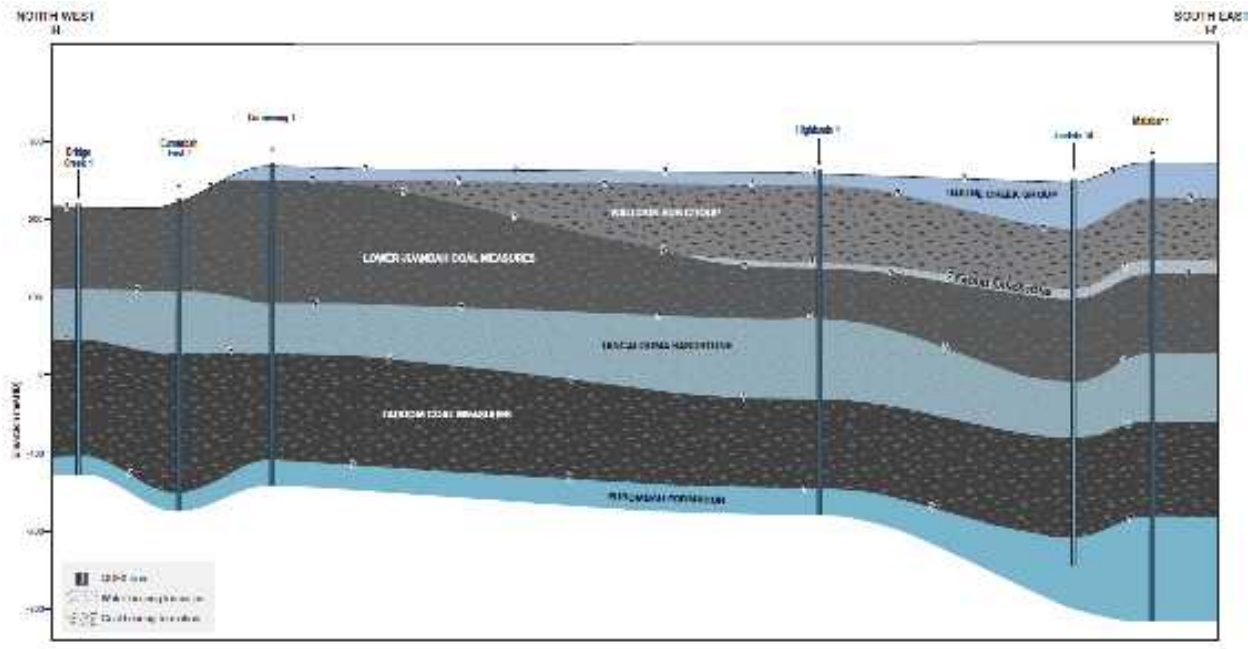


Figure 31. Conceptual Geological Cross-Section SPA North-West – South-East

*Note: Refer to **Figure 10** for Cross-Section Location*

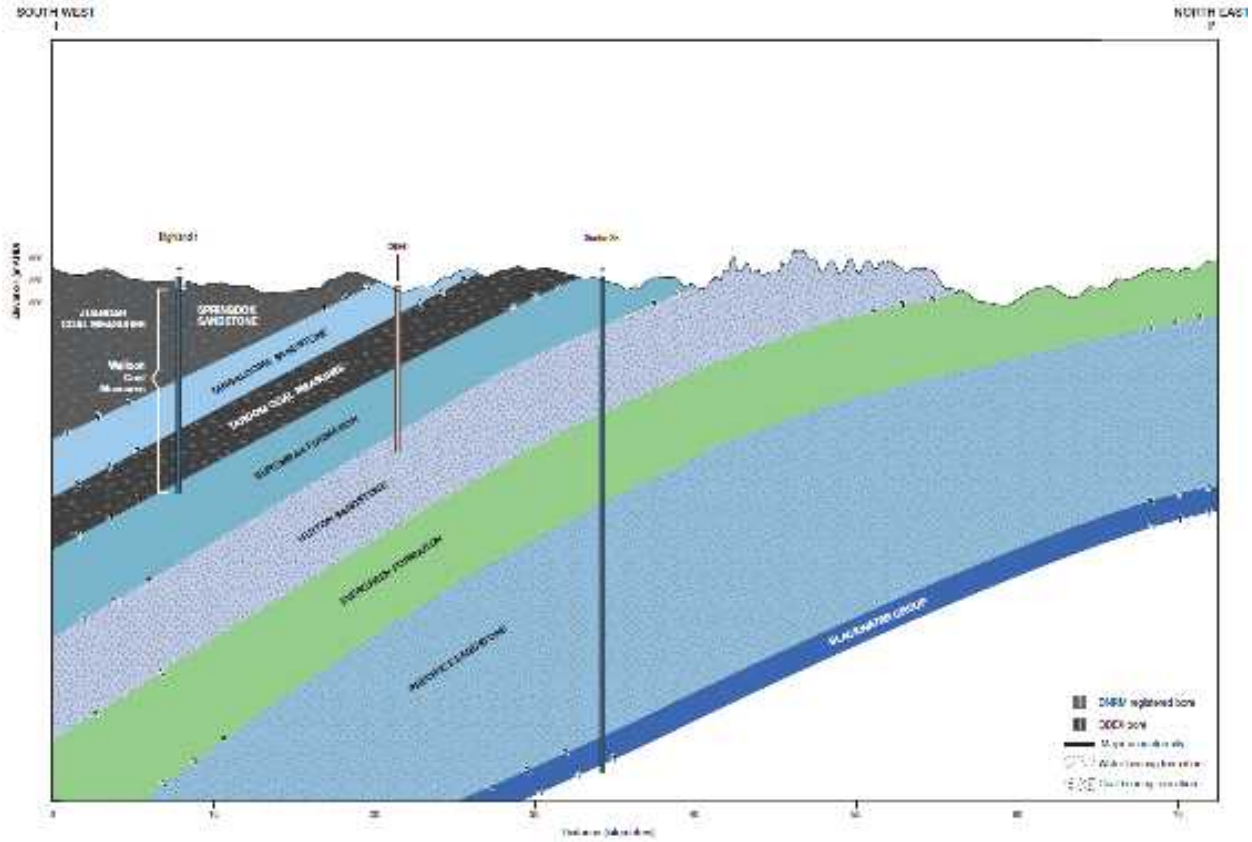


Figure 32. Conceptual Geological Cross-Section SPA South-West – North-East

*Note: Refer to **Figure 10**for Cross-Section Location*

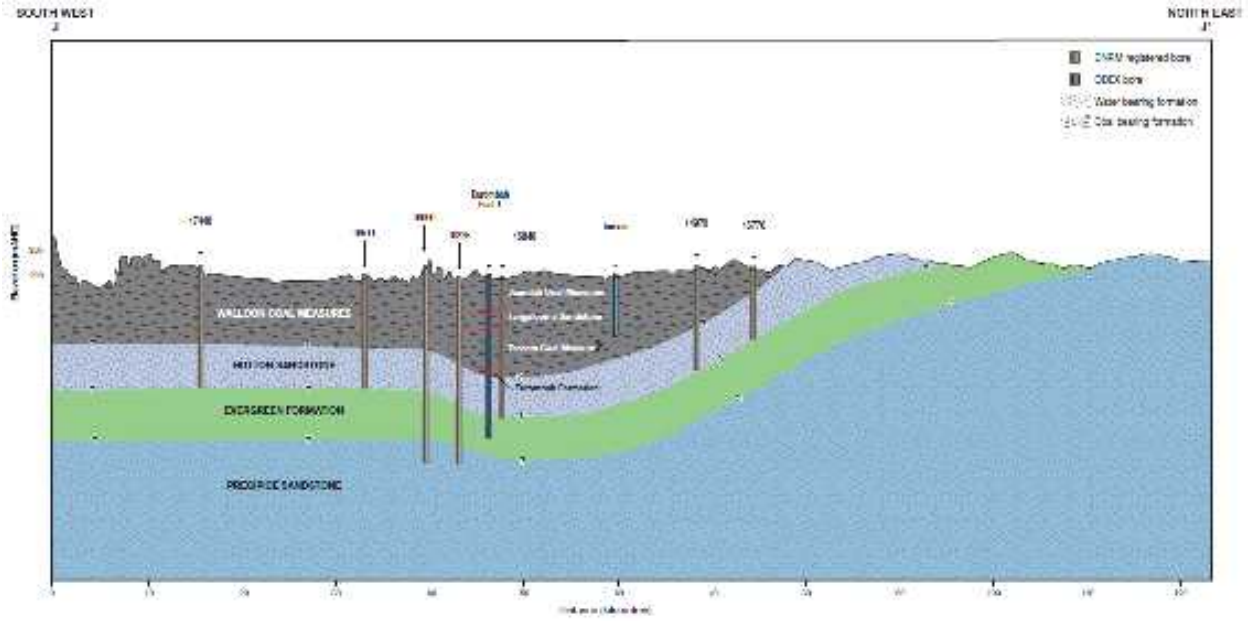


Figure 33. Conceptual Geological Cross-Section SPA South-West – North-East

*Note: Refer to **Figure 10** for Cross-Section Location*

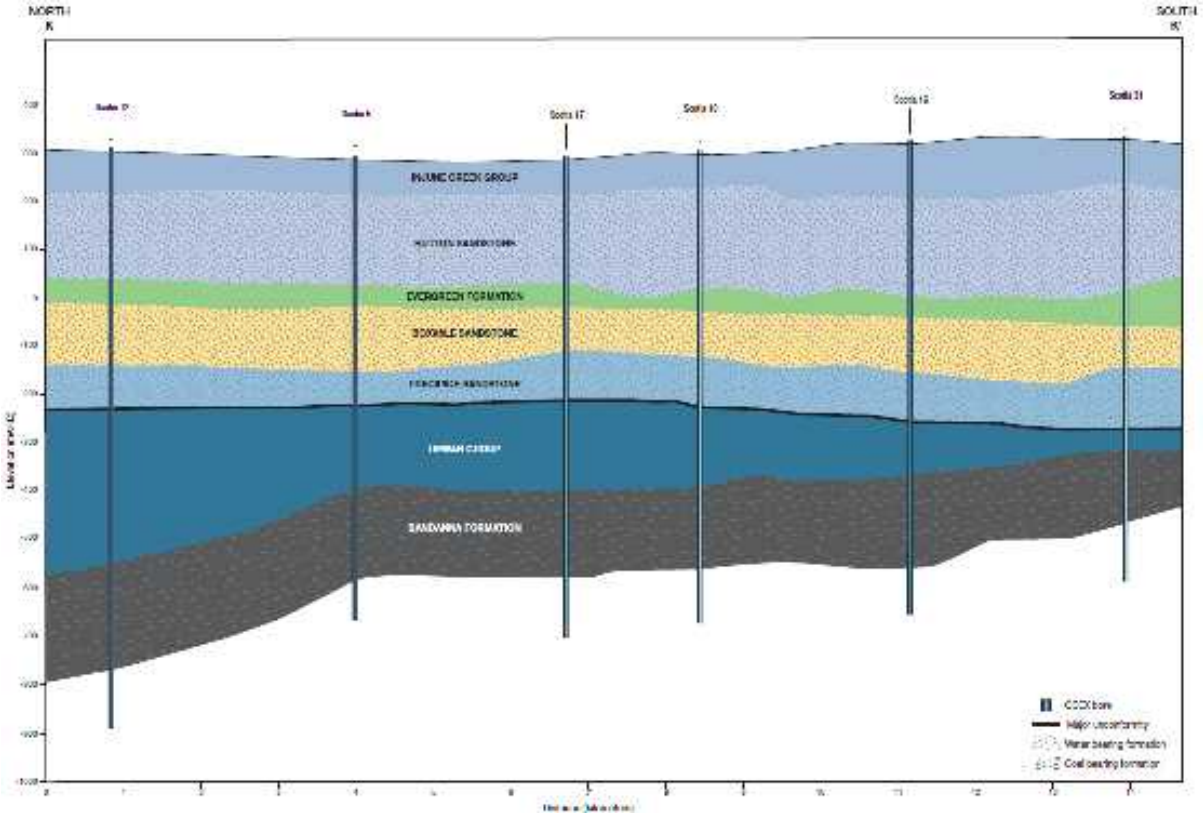


Figure 34. Conceptual Geological Cross-Section SPA North – South

*Note: Refer to **Figure 10** for Cross-Section Location*

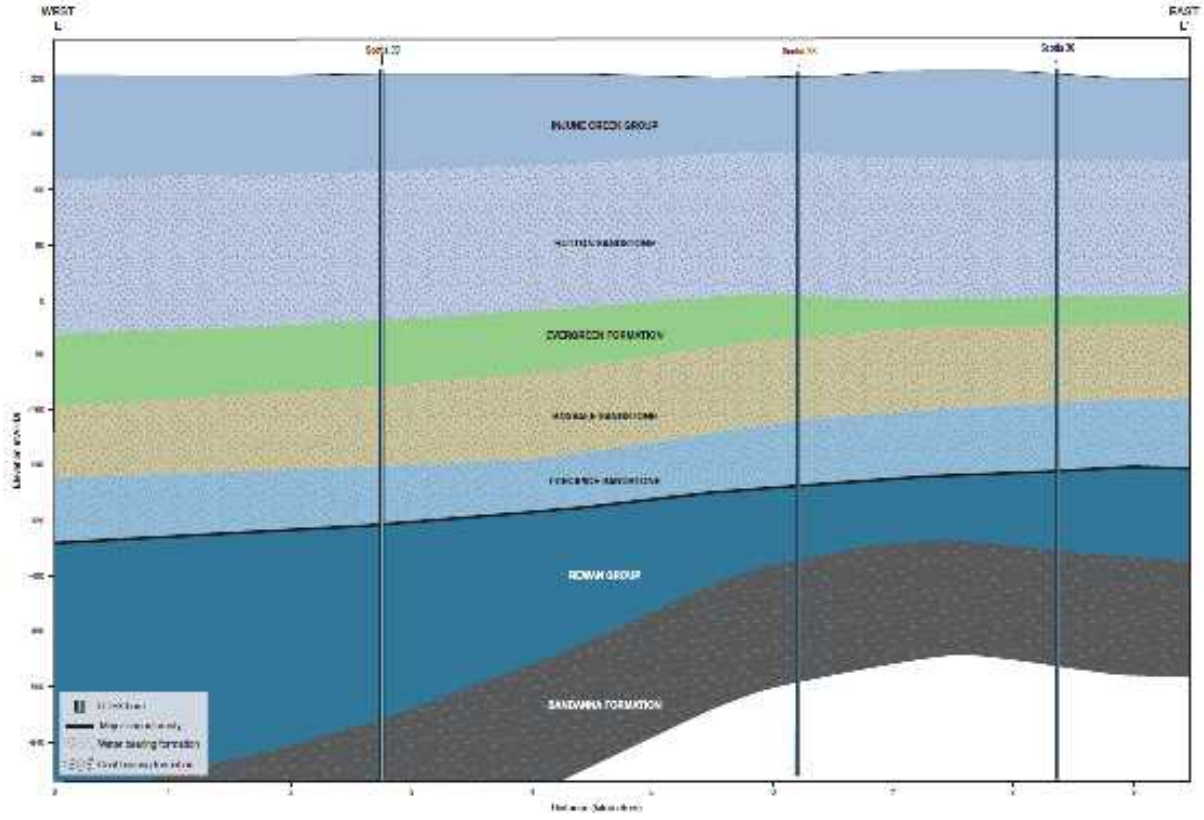


Figure 35. Conceptual Geological Cross-Section SPA West – East

*Note: Refer to **Figure 10** for Cross-Section Location*

2.6.4.1 Faults and Other Geological Controls

While no major currently or potentially active faults exist near the Scotia region, there are two (2) minor unnamed faults that could affect the broader area. Regarding part (e) of the draft EA conditions, the historic and currently active structural zones (structural faults or discontinuities) are at sufficient distance and depth (horizontal separation and vertical depth) to not pose a threat of re-activation by stimulation activities proposed for Scotia, nor are the capacities to permit water flow likely to be enhanced by such activities.

3 Hydrogeology, Groundwater Resources and Environmental Values

The information provided in this section addresses the following EA approval requirements: conditions (f), (g), (h), (i), (k), (l), (p) and (z)(1).

3.1 Regional Hydrogeology

The Santos EQ Project Area is located entirely within the large, south-dipping Permian to Cretaceous depositional basins of the Bowen Basin and Surat Basin (see **Figure 36**). The Bowen and Surat Basins are structurally separate sedimentary depositional centres; however, they are stratigraphically interconnected (DME, 1997). The Surat Basin is a sub-basin of the GAB, one of the largest artesian groundwater basins in the world.

Table 5 provides an overview of the relevant hydrogeological units of interest within each sub-Santos EQ Project Area.

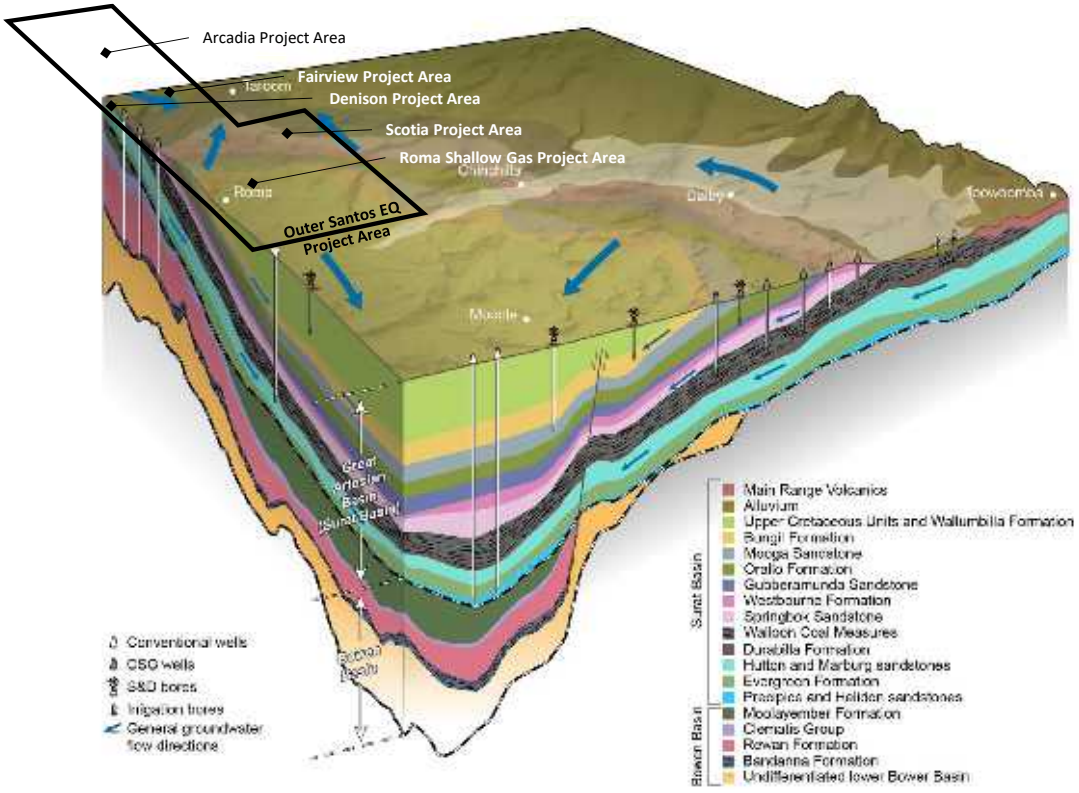


Figure 36. Hydrogeological Units within the Surat and Bowen Basin

3.1.1 Bowen Basin

The Bowen Basin (refer to **Figure 36**) is an Early Permian to Middle Triassic basin, which contains shallow marine and continental clastic and volcanic rocks. The Bowen Basin is comprised of two sedimentary depositional centres: the Denison and Taroom Troughs (refer to **Figure 12**). The main structural feature through the Project area is Comet Ridge, located along the western margin of the Taroom Trough in the southern extent of the Bowen Basin. Comet Ridge is comprised of mainly Devonian aged rocks and is covered by a relatively thin sequence of gently folded Permian and Triassic rocks, which make up the Bowen Basin.

The oldest formation included in the Bowen Basin stratigraphic sequence is the Reids Dome Beds, a unit of highly variable thickness. The Reids Dome Beds are unconformably overlain by the Early Permian aged formations of the Back Creek Group. The Aldebaran Sandstone (a member of the Black Creek group) is the deepest formation targeted for water supply within the north-western reaches of the Project area, near the town of Emerald.

Gas in the Fairview and Arcadia Valley CSG fields is extracted from the coal seams of the Bandanna Formation, at depths of 500 to 1,000 m below ground level (mbgl). The thickness of the Bandanna Formation is variable throughout the Project area, from approximately 60 to 100 m thick in the Comet Ridge area (McClure S. et al., 2008).

3.1.2 Surat Basin

The Surat Basin, (**Figure 36**) is a sub-basin of the GAB and comprises a sequence of south dipping consolidated Jurassic and Cretaceous sediments. The outcrop region of the Precipice Sandstone crosses through the northern part of the Fairview region, in the north of the Santos EQ Project Area. The younger Surat Basin formations outcrop progressively south through Roma, including the Evergreen Formation, the Hutton Sandstone and Birkhead Formation, the Springbok Sandstone, Walloon Coal Measures, Westbourne Formation, the Gubberamunda Sandstone, Orallo Formation Mooga Sandstone, and the Bungil and Wallumbilla Formations.

The Gubberamunda Sandstone and to a lesser extent the Mooga Sandstone are targeted for water supply within the region around Roma and along with the deeper Hutton and Precipice Sandstone as source aquifers for several EPBC Springs (Santos, 2012).

The Walloon Coal Measures (WCM) are the main gas bearing units (coal seams) within the Surat Basin and are the target formation for CSG operations within the Roma region. The thickness of the coal seams in Roma region ranges from 100 to 460 m, at depths ranging from 170 to 933 mbgl.

Historically conventional oil and gas wells were completed into the lower portions of the Evergreen formation and the underlying Precipice Sandstone and in some areas into the deeper Showground Sandstone unit. The upper portions of the Evergreen Formation form the capping aquitard and contains gases within these units.

Table 5. Hydrogeology within Santos EQ Project Area

Basin	Stratigraphy	Unit / Aquifer / Aquitard	Type	Relevant Regions refer to Figure 9					Description
				Arcadia Valley	Fairview	Roma	Denison	Scotia	
Bowen Basin	Rewan Group	Clematis/ Showgrounds Sandstone	Major Aquifer	✓	✓		✓		Medium to coarse grained quartzose to sub labile, micaceous sandstone, siltstone and mudstone and granule to pebble conglomerate
		Rewan Formation	Aquitard	✓	✓		✓	✓	lithic sandstone, pebbly lithic sandstone, mudstone and minor pebble conglomerate.
		Bandana Formation	Coal Seams	✓	✓		✓	✓	Sandstones, siltstone, shale, mudstone, coal, tuff and conglomerate with a thickness of up to 250 m. The total coal seam thickness within the Bandanna Formation is generally less than 10 m, up to six individual coal seams can be identified
Surat	Blythesdale Group	Bungil Formation	Minor Aquifer			✓			Glauconitic, labile to quartzose sandstone, siltstone mudstone. Carbonaceous in part.
		Mooga Sandstone	Major Aquifer			✓			Well-bedded to cross-bedded quartzose to labile sandstone, in part clayey, calcareous, pebbly: mudstone; minor conglomerate at base.
		Orallo Formation	Aquitard			✓			Very fine to medium grained, cross-bedded, lithic to lithic sub-labile sandstone, calcareous or clayey; siltstone and mudstone, carbonaceous in part; clay, some bentonite; minor coal.
		Gubberamunda Sandstone	Major Aquifer			✓			comprises fluviatile sandstone, minor conglomerate siltstone and mudstone.
	Injune Creek Group	Westbourne Formation	Aquitard			✓			alternating sequences of mudstone and lithic sandstone with minor siltstone and coal in the upper portions and thinly bedded siltstone and low permeability sandstone in the lower portions
		Springbok Sandstone	Minor Aquifer			✓		✓	Clayey lithic to very lithic sandstone with localised calcareous deposits and interbedded with carbonaceous mudstone and siltstones
		Walloon Coal Measures						✓	Thin-bedded, claystone, shale, siltstone, lithic and sublithic arenites, coal seams and partings. The Walloon Coal Measures can be mapped as having the following recognisable formations: Upper Walloon Formation (aquitard); Macalister Coal Seams (aquifer/aquitard); Juandah Sandstone (aquifer); Lower Jundah Coal Measures (aquifer/aquitard); Tangalooma Sandstone (aquifer); and Taroom Coal Measures (aquifer/aquitard).

Basin	Stratigraphy	Unit / Aquifer / Aquitard	Type	Relevant Regions refer to Figure 9					Description
				Arcadia Valley	Fairview	Roma	Denison	Scotia	
		Euromba h Formatio n	Aquit ard	✓	✓	✓		✓	Siltstone and mudstone
	Bundamb a Group	Hutton Sandston e	Major Aquif er		✓	✓		✓	Very fine to medium grained sandstone with interbedded argillaceous to arenaceous siltstones
		Evergree n Formatio n	Aquit ard		✓	✓		✓	very fine, quartzose sandstone
		Boxvale Sandston e	Aquit ard		✓	✓		✓	Very fine-grained sandstone with interbedded siltstones
		Precipice Sandston e	Major Aquif er		✓	✓	✓	✓	Sandstone and conglomerate at its base

3.2 Regional Groundwater Flow

Both the Surat and Bowen Basin aquifers are primarily recharged by rainfall infiltration and leakage from streams into outcropping sandstone. The formations are located mainly on the eastern margins of the basins and along the western slopes of the Great Dividing Range.

Regional groundwater flow is from the topographically higher recharge areas around the basin margins towards the lowest parts of the basins in the southwest (refer to

Figure 37) however within the Scotia region an easterly flow is observed towards the Dawson River. In the Arcadia Valley region, the direction of groundwater flow is generally west to east, following the dip of the Clematis Sandstone under the Moolayember Formation.

The rate at which groundwater flows depends on the permeability and thickness of the aquifer, and the lateral hydraulic gradient of each unit. The greatest groundwater velocities are estimated in the high permeability units such as the Precipice Sandstone, Hutton Sandstone and Mooga Sandstone, and the lowest flow rate estimated in the WCM.

Table 5 presents a summary of hydrogeological units underlying the Santos EQ Project Areas. A greater description of the key hydrogeological units is further provided in **Section 3.5**.

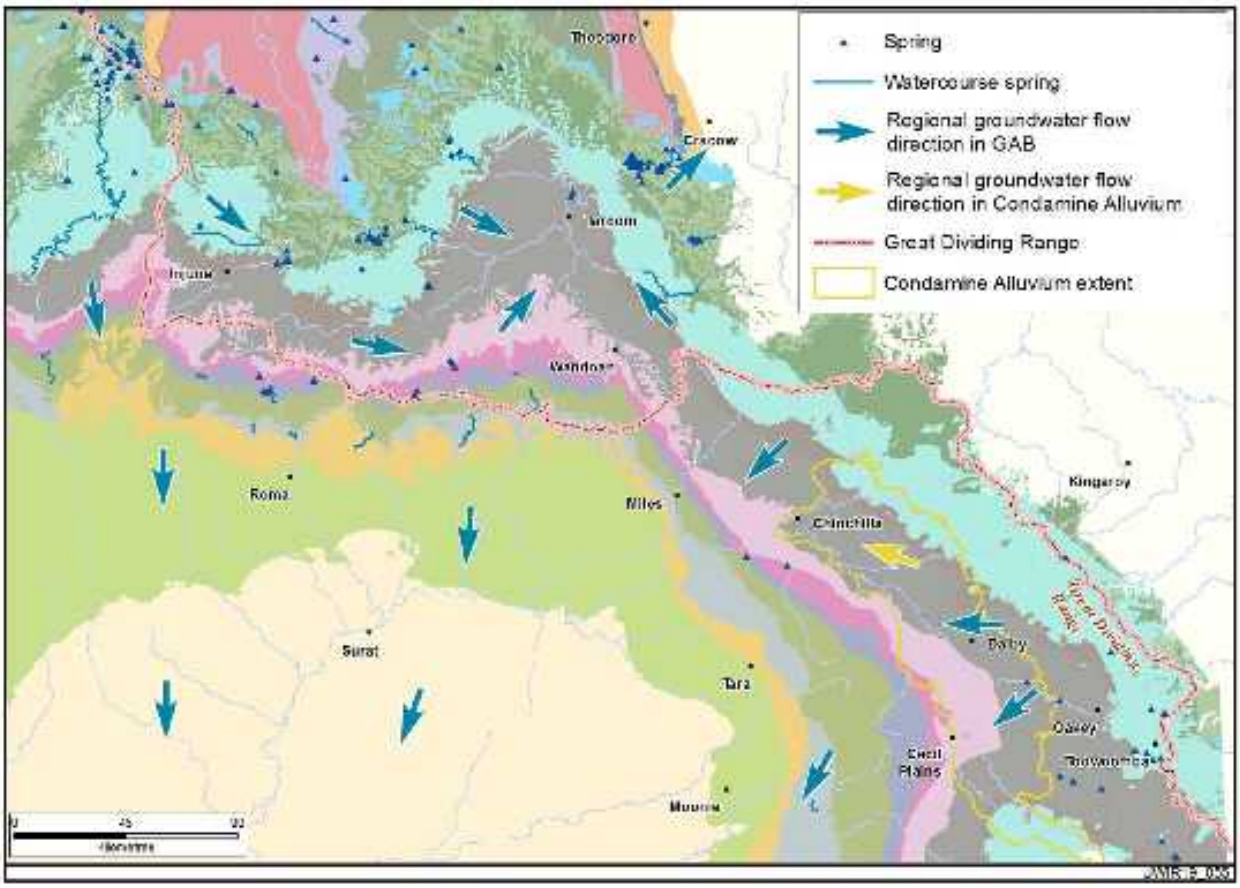


Figure 37. Representation of the Main Groundwater Systems in the Surat CMA (after UWIR 2019)

3.2.1 Recharge / Discharge

Groundwater–surface water interactions occur across the Santos EQ project area in a variety of forms including:

- Discharge of groundwater to streams (watercourse or baseflow springs).
- Recharge of groundwater systems via leakage from streams.
- Interaction between streams and associated alluvial groundwater resources.

The most significant interaction in the Santos EQ project area is discharge of groundwater to streams by watercourse springs. Discharge also occurs via bores where groundwater is extracted for stock and domestic supply, and to a lesser extent, agriculture.

The GAB aquifers are recharged by infiltration (rainfall), and leakage from streams into outcropping sandstone formations, mainly on the eastern margins of the GAB along the western slopes of the GDR. Regional groundwater flow is from the topographically higher recharge areas around the basin margins towards the lowest parts of the basin in the southwest. The Scotia, Roma and Fairview regions are located over outcrop regions of the water-bearing formations in Surat Basin, which are the part of the 'intake beds' of the GAB.

3.2.2 Aquifer and Aquitard Hydraulic Properties

Several flow and pressure test have been carried out on bores in the area of interest to determine the transmissivity for the water producing aquifers. Hydraulic parameters were defined from static recovery tests (over 240 tests) within and around the Santos EQ Project Area and exploration tests.

The hydraulic parameters characterising the formations are presented in **Table 6**. The data presented in the table are based on field measurements and an extensive literature review.

Table 6. Summary of Key Hydrogeological Properties and Uses for Major Aquifers

Unit / Aquifer / Aquitard	Median K [B,C] [max - min] (m)	Porosity	Transmissivity [A] (m2/d)	specific yield (Sy), Storativity (S)	Average Yield (L/s)
Rewan Formation	1.0E-3 (1.0E-5 – 2.0)	No data	No data	Sy = 0.11(1) S = 1.0x10^{-5} to 2.1x 10^{-6}	No data
Bandana Coal	1.0E-4 (1.0E-7 – 2.0)	No data	No data	Sy = 0.01(1) S = 5.0x10^{-5} - 5.1x 10-6	No data
Deep Bandanna	7.5x 10^{-3} – 2.25x10^{-} 2	No data	No data	Sy = 0.05 Ss = 4.0x10^{-6}	No data
Mooga Sandstone		10% - 30%	50	S = 5x10^{-3}	0.6 – 6 (Av 1.7)
Orallo Formation	5.0E-1 (1.0E-5 – 5.0)	10% - 30%	50	S = 5x10^{-3}	Up to 35 (Av 1.3)
Gubberamunda Sandstone	5.0E-1 (1.0E-7 – 10)	10% - 30%	50	S = 5x10^{-3}	4.6 for high yield bores
Westbourne Formation	No data	10% - 30%	150	S=5x10^{-3}	No data
Walloon Coal Measures	1.0E-4 (10E-11 – 20)	<1% coal; 10% - 30% others	50	Ss = 5x10^{-4} Sy = 5x10^{-6}	1.1
Eurombah Formation	0.14	No data	6.8	No data	No data
Hutton Sandstone	1.0E-1 (2.0E-8 – 200)	10% - 15%	100-150	S = 3x10^{-6} /m	No data
Evergreen Formation	0.1 – 0.0001	15%	No data	S = 5x10^{-4} S = 10^{-5} - 2x10^{-5} (1)/m	No data
Precipice Sandstone	1 (2.0E-2 – 40)	15% - 20%	150	Ss = 3x10^{-6} – 2.75x10^{-5} (1) Sy = 0.14(1)	No data

[A] *Estimated from the 2019 UWIR Surat CMA*
[B] *Interconnectivity Risk Assessment (2016)*
[C] *GLNG Gas Field Development Groundwater Technical Report (2014)*
[D] *URS Santos (2010)*

3.3 Regional Groundwater Quality

Groundwater in the Surat and Bowen Basin are used for a range of purposes, predominantly for agricultural use followed by the stock and domestic (S&D) use. For the last 10 years, a significant proportion of extraction has evolved through development of the CSG industry (KCB, 2016). This is however 'associated water' produced primarily from the target formations being exploited for gas, which are relatively lesser used for water supply.

Groundwater quality from the Department of Natural Resources and Mines (NRM) bores in the Santos EQ Project Area was assessed based on identified groundwater management units (GMUs, refer to **Figure 38**) and major aquifers (**Table 7**). Groundwater chemical data in the NRM database has been collected over a period of 30 years with most data collected between 1980 and 1999. The quality of available water quality data cannot be verified, they are presented in **Table 8**.

Figure 39 compares total dissolved solids (TDS) concentrations in groundwater from all groundwater management units/formations in the Santos EQ Project Area currently undergoing development. Water salinity varies from fresh to saline with TDS values ranging between 51 and 12,955 mg/L. The majority (71%) of the groundwater samples are classified as fresh with TDS values less than 1,000 mg/L and approximately 23% as slightly brackish with TDS values between 1,000 and 3,000 mg/L. Brackish waters with TDS concentrations between 3,000 mg/L and 10,000 mg/L are less common and contributed 6% of groundwater samples collected.

Salinity is spatially presented in **Figure 40**. Several brackish and saline groundwater types were identified in the northern portion of the Project area, to the north-west and north-east of the Arcadia Valley. Brackish groundwater was observed in Tertiary and volcanic formations surrounding the Arcadia Valley, in the Bowen Basin area, particularly in bores completed in the Bandanna Formation, and in alluvium. In addition, TDS concentrations in the Blackwater Group were close to the brackish/saline boundary (approximately 8,700 mg/L).

The distribution of brackish waters in the Surat Basin, appears to increase to the southeast in several groundwater management units. TDS values exceeding 5,000 mg/L were reported for Mooga Sandstone and Bungil Formation bores.

A Piper Diagram of all groundwater samples within the Santos EQ Project Area is presented as **Figure 41** The red line represents conservative (non-reactive) mixing of fresh water and seawater. The position of the markers away from the conservative mixing line is an indication of a geochemical reaction.

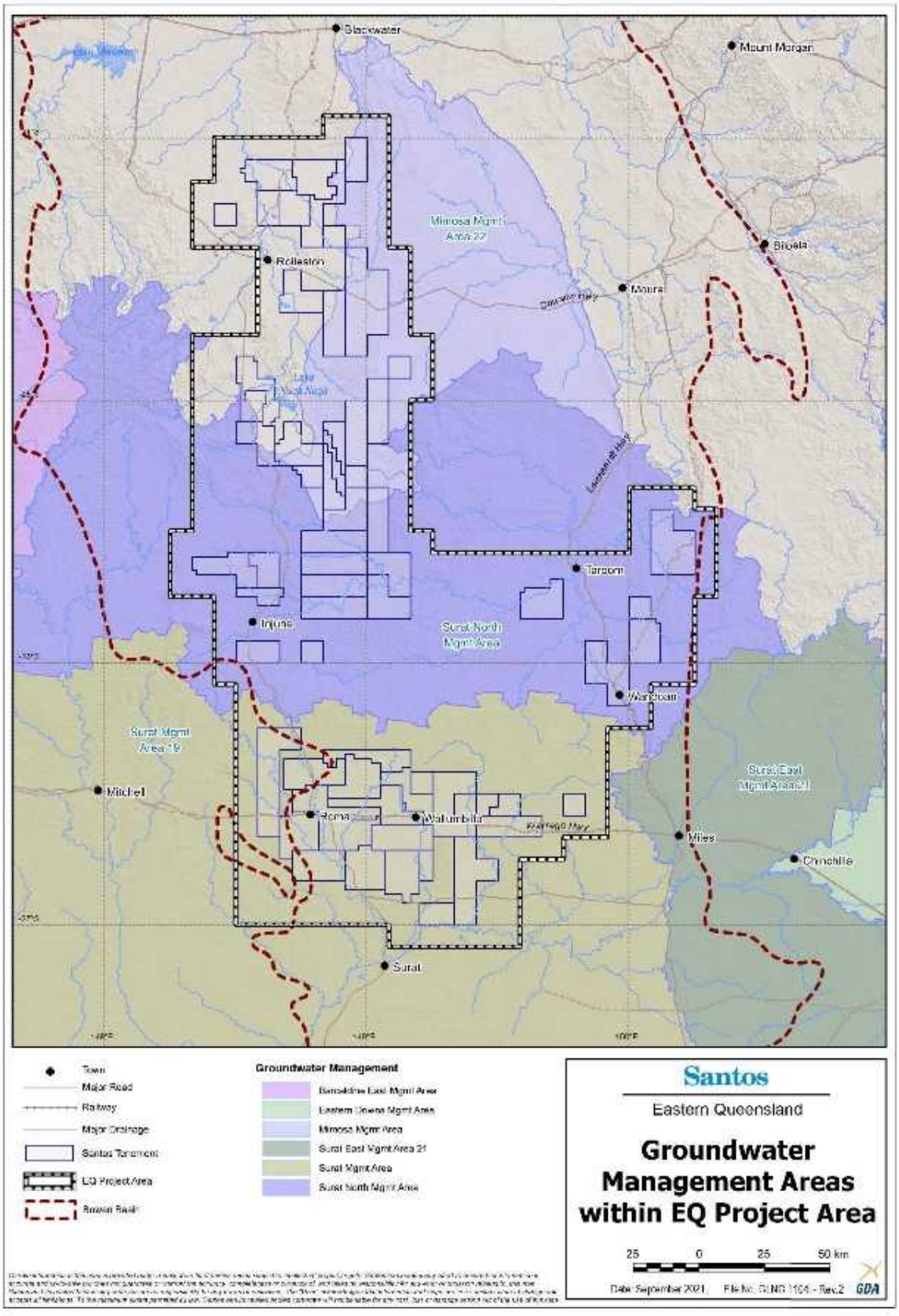


Figure 38. Eastern Queensland Groundwater Management Areas

Table 7. Summary of Groundwater Data Groups

Management Unit	Assessment Group	Stratigraphic Formation	GMA	Relevant Region	Symbol	# Samples
Shallow	Alluvium	-	Bowen	-	+	26
	Alluvium	-	Surat North	Fairview	+	2
	Tertiary	-	Bowen	-	x	11
	Tertiary	-	Surat North	Fairview	x	2
	Volcanics	-	Bowen	-	□	53
	Volcanics	-	Mimosa	Arcadia Valley	□	2
	Volcanics	-	Surat North	Fairview	□	1
Surat 1	Surat 1	Doncaster Member	Surat	Roma	●	9
Surat 2	Surat 2	Bungil Formation	Surat	Roma	●	17
	Surat 2	Minmi Member	Surat	Roma	●	1
Surat 3	Surat 3	Mooga Sandstone	Surat	Roma	●	48
Surat 4	Surat 4	Orallo Formation	Surat	Roma	●	2
	Surat 4	Gubberamunda Sandstone	Surat North	Roma	▲	1
	Surat 4	Gubberamunda Sandstone	Surat	Roma	●	13
	Surat 4	Southlands Formation	Surat	Roma	●	1
Surat 5	Surat N1	Birkhead Formation	Surat North	Between Roma and Fairview	▲	4
	Surat 5	Eurombah Formation	Surat	Roma	●	4
	Surat 5	Injune Creek Group	Surat	Roma	●	4
	Surat N1	Injune Creek Group	Surat North	Between Roma and FPA	▲	8
	Surat N1	Walloon Coal Measures	Surat North	Between Roma and Fairview	▲	1
Surat 6	Surat N2	Boxvale Sandstone	Surat North	Fairview	▲	15
	Surat 6	Hutton Sandstone	Surat	Roma	●	3
	Surat N2	Hutton Sandstone	Surat North	Fairview	▲	26
	Surat 6	Evergreen Formation	Surat North	Fairview	●	1
Surat 7	Surat 7	Precipice Sandstone	Surat	Roma	●	2
	Surat N3	Precipice Sandstone	Surat	Roma	▲	8
Surat 8	Bowen 1	Moolayember Formation	Mimosa	Fairview	<	3
	Mimosa	Clematis Sandstone	Mimosa	Arcadia Valley, Fairview	■	47
	Bowen 1	Rewan Formation	Bowen	Arcadia Valley, Fairview	<	2

Management Unit	Assessment Group	Stratigraphic Formation	GMA	Relevant Region	Symbol	# Samples
Bowen 2	Bowen 2	Black Alley Shale	Bowen	-	<	1
	Bowen 2	Black Water Group	Bowen	-	<	5
Bowen 3	Bowen 3	Aldebaran Sandstone	Bowen	-	<	10

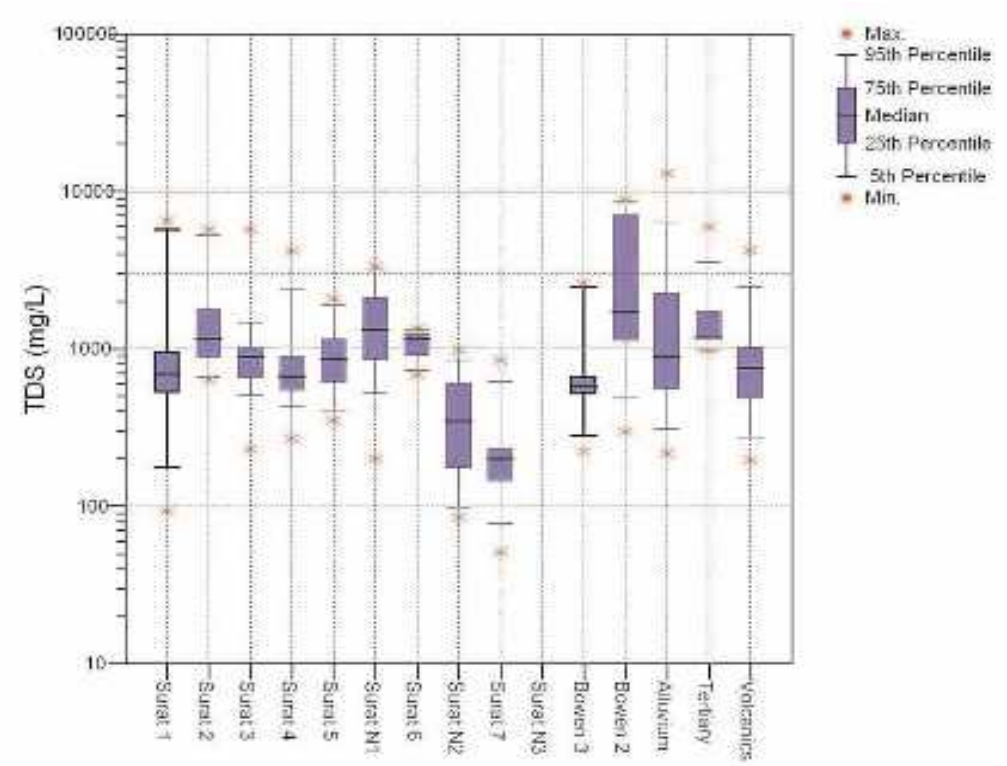


Figure 39. Comparison of Groundwater Salinity in Surat and Bowen Basins

Source: Golder, 2013a

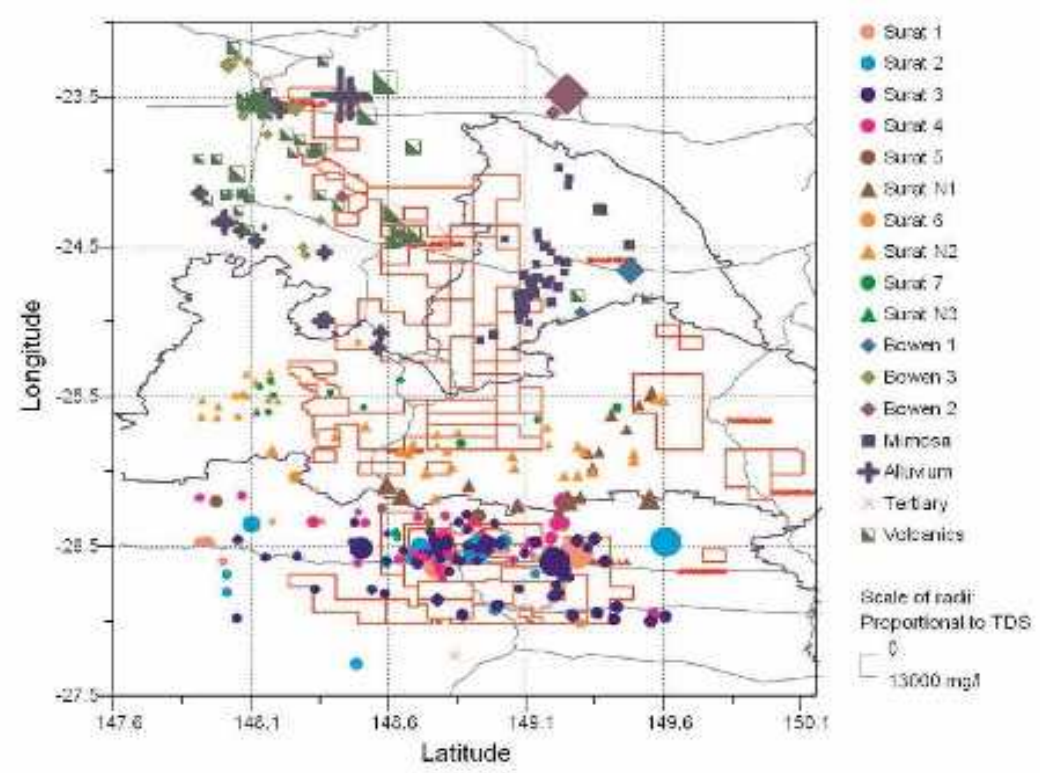


Figure 40. TDS of Groundwater in the Santos EQ Area

Source: Golder, 2013a
*Note: For description of the major management, units see **Table 7***

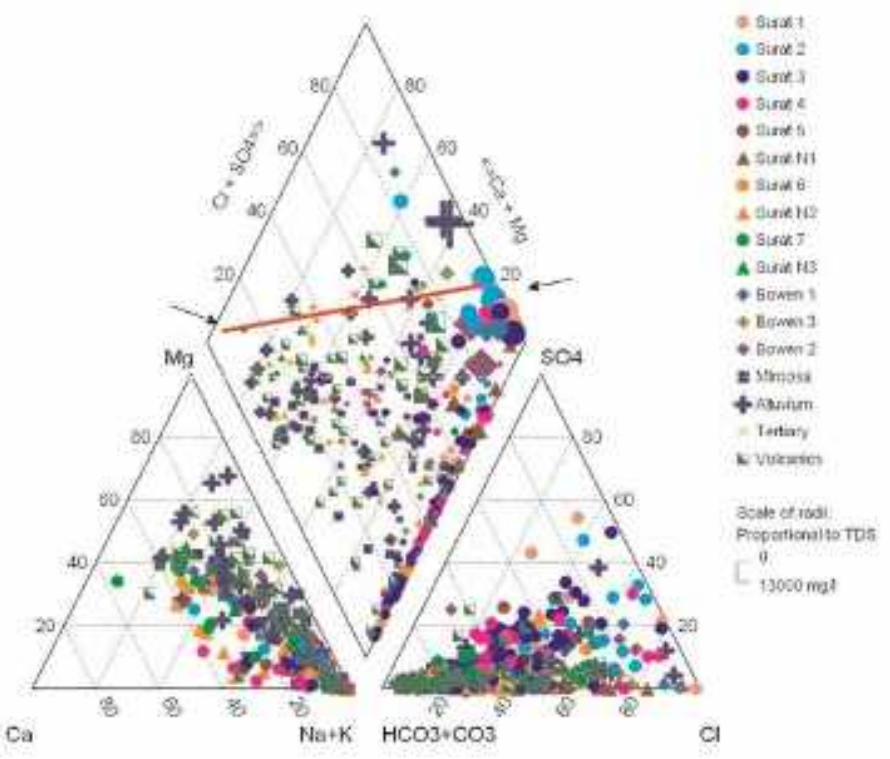


Figure 41. Piper Diagram of DEHP Groundwater Samples in the Santos EQ Project Area

*Note: For description of the major management, units see **Table 7***

Table 8. Summary of Key Hydrogeological Properties and Uses for Major Aquifers

Unit / Aquifer / Aquitard	Median TDS[A] (mg/L)	Median Calcium [A] (mg/L)	Median Sodium [A] (mg/L)	Median Chloride [A] (mg/L)	Median Fluoride [A] (mg/L)	Yield [B,C] (L/sec)	Typical Use[B]
Clematis Sandstone	522	23	76	50	0.2	Av = 3.7 Max = 25	Major aquifer, moderate yield and good water quality
Rewan Formation						Av = 2.2	Deep groundwater level and poor water quality
Bandana Formation	1,576	6	498	177	1.4		Main gas bearing unit (Bowen Basin)
Mooga Sandstone	1,558	3	462	210	0.9	Typically < 5	Important aquifer in the Surat Basin; Roma, Wallumbilla and Yuleba town water supplies
Orallo Formation						Typically < 1 Max = 5	Stock and domestic use
Gubberamunda Sandstone	1,126	3	350	150	0.3	Av = 6 Max = 40	Roma town water supply, most highly developed aquifer in the Surat Basin
Springbok Sandstone	1,970	11	654	844	0.7	Highly Variable	Stock and domestic use
Walloon Coal Measures	1,877	34	550	597	0.4		Main gas bearing unit (Surat Basin)
Hutton Sandstone	1,297	29	321	310	0.3	Av = 2.8 (0.01 – 9)	Source of Injune town water supply
Precipice Sandstone	184	3	45	16	0.2	Av = 4.9	Good yield and water quality

[A] *Estimated from the 2019 UWIR Surat CMA*
[B] *Interconnectivity Risk Assessment (2016)*
[C] *GLNG Gas Field Development Groundwater Technical Report (2014)*

3.4 Hydrogeological Context of Gas Development

During gas extraction, the target coal seams are depressurised by extracting groundwater from the coal seams to enhance the release of gas from the coal. During this process, significant inward vertical hydraulic gradients are induced between the coal seams and the overlying and underlying aquifers (i.e., towards the coal measures from which gas is extracted). This is predicted to result in some inter-aquifer transfer of groundwater from the adjacent aquifers (and aquitards) into the coal seams. The extent of inter-formational flow depends on the hydrogeological and stratigraphic relationship between the coal seams and adjacent aquifer units. In other words, the amount of this flow depends what type of layers, aquifer or aquitard layers, which encase the coal seams. Almost exclusively, aquitard layers overlie and underlie the target coal seams for gas extraction. An exception occurs where the Springbok aquifer comes into contact with the upper Walloon coal seams in the Surat Basin stratigraphy.

The establishment of inward hydraulic gradients during gas extraction has important implications with respect to the fate and transport of injected hydraulic fracturing fluids within the coal seams, as it significantly limits the potential for vertical migration of the fluids to adjacent aquifers developed for water supply. This is discussed in further detail in subsequent sections of this report.

3.5 Local Hydrogeology

3.5.1 Roma Region

3.5.1.1 Hydrogeological Units and Groundwater Flow

The Roma region is contained within the areal boundaries of the Surat GMA 19 (**Figure 38**). The main aquifer units in terms of groundwater development within RSGPA include:

- Mooga Sandstone
- Gubberamunda Sandstone
- Springbok Sandstone
- Hutton Sandstone
- Precipice Sandstone.

The main confining units within RSGPA include:

- Orallo Formation
- Westbourne Formation
- Moolayember Formation
- Evergreen Formation

Localised cross-sections of the main hydrogeological formation underlying the Roma area are shown on **Figure 18** to **Figure 20** with a localised hydrogeological description provided below. The location of each cross-section transect is show on **Figure 10**. Local hydrogeological discussion on each major unit present within the Roma region is provided below. **Table 9** provides a summary of formation hydraulic properties within the Roma region.

Table 9. Summary of Formation Hydraulic Properties within the Roma Region

Formation	Type	Horizontal K (min) m/day	Horizontal K (max) m/day	Vertical K (min) m/day	Vertical K (max) m/day	Minimum Porosity (%)	Maximum Porosity (%)
Wallumbilla Formation	Minor Aquifer	0.038[a]	0.060[b]	0.1[b]	0.1[b]	-	-
Bungil Formation	Minor Aquifer	0.040[b]	0.4[a]	0.004[b]	0.152[c]	-	-
Mooga Sandstone	Aquifer	0.009[d]	0.4[b]	0.0008[d]	0.0613[a]	22[d]	22[d]
Orallo Sandstone	Aquitard	0.07[a]	0.172[d]	8.64x10^{-7}[(d)]	0.004[c]	21.9[d]	28.1[d]
Gubberamunda Sandstone	Aquifer	0.13[b]	1.59[e]	0.00035[d]	0.432[a]	19[d]	35[d]
Westbourne Formation	Aquitard	0.0001[b]	0.005[c]	4.32x10^{-6}[(d)]	0.0015[c]	14.5[d]	25.4[d]

Parameter Sources
(a) Santos DST
(b) UIWR 2019
I APLNG, 2010, DST
(d) URS, 2011
(e) Maranoa Shire Council, 24 hour pumping test.

Mooga Sandstone

The Mooga Formation grades upward into the Bungil Formation and occurs between the Nebine and Kumbarilla Ridges within the Surat Basin (Exon, 1976). It comprises fluvial quartzose to sublabile sandstone with thinly inter-bedded dark grey mudstone and siltstone of swampy origin. The sandstone is thin but persistent throughout the Surat Basin and it partially outcrops in the north and east of the Roma CSG field.

Orallo Formation

The Orallo Formation occurs east of the Nebine Ridge, 120 km west of the Roma CSG field, and acts as a confining bed for the Gubberamunda Sandstone. It comprises lithic sandstone, siltstone and mudstone deposited dominantly in swamps and as overbank deposits (Exon, 1976). The formation thickness varies from 140 to 270 m, averaging 200 m and is not present on the Nebine Ridge where the Mooga Sandstone rests directly on the Gubberamunda Sandstone. Recharge to the minor aquifers in this formation occurs in the northern and eastern margins of the Surat Basin.

Gubberamunda Sandstone

Gubberamunda Sandstone outcrops in a thin band just north of the Roma area. These outcrops are considered to be part of the recharge area for these aquifers. Five springs are mapped in the Gubberamunda sandstone. Groundwater levels (and the direction of flow) is presented in **Figure 42**.

The general water quality within the Gubberamunda Sandstone can be described as fresh, and is NaCl dominant (URS, 2009) with the average total dissolved solids (TDS) of 760 mg/L.

Westbourne Formation

The Westbourne Formation has very low permeability and underlies the Gubberamunda Sandstone. It comprises alternating sequences of mudstone and lithic sandstone with minor siltstone and coal in the upper portions and thinly bedded siltstone and low permeability sandstone in the lower portions. This formation reaches a thickness of greater than 60 m in the Roma area and was deposited in a low energy fluvial and marginal-marine environment. These sediments outcrop in the northern part of the Surat Basin (Exon, 1976 ref. URS, 2011).

Springbok Sandstone

Over the Roma region, the Springbok Sandstone is continuous, but its hydraulic conductivity is highly variable. At some locations it is an important aquifer and in others it is highly compacted and has very low permeability. Therefore, the Springbok Sandstone hydraulic characteristics vary, and the formation can be divided into a lower and an upper Springbok. The lower Springbok is a poor aquifer of low hydraulic conductivity associated to the deposition of volcanic ash. As a result, the sandstone contains clay minerals with dominance of smectite which significantly lowers its permeability and porosity characteristics (QWC, 2012). Where there is localised unconformable contact between the lower Springbok Sandstone and the upper coal beds of the Walloon Coal Measures they are considered to be in hydraulic connection (Scott S. et al., 2004).

The Springbok Sandstone underlies the Westbourne Formation and unconformably overlies the Walloon Coal Measures. The Springbok Sandstone was deposited by streams in small channels which eroded into the uppermost siltstones of the Walloon Coal Measures and occasionally into its coal seams. This has resulted in direct contact of the Springbok Sandstone with the CSG producing coal layers within the Walloon Coal Measures in some areas. In other areas, the Springbok is separated from the producing coal layers by low permeability sediments of the upper part of the Walloon Coal Measures.

Groundwater levels (and the direction of flow) is presented in **Figure 42**.

Walloon Coal Measures

The Walloon Coal Measures are a member within the Injune Creek Group and are the main gas bearing unit of the Surat Basin. At the Basin scale, the Walloon Coal Measures are considered an aquitard, although in some places they function as an aquifer. The coal seams are generally the more permeable units.

The thickness of the formation is 100 to 460 m in the Roma area. It comprises siltstone and silty sandstone and relatively small intervals of coal (approximately 10%) which were deposited by swamps or lakes and sluggish streams (Exon, 1976). The geology is generally complex.

The Walloon Coal Measures can be mapped as having the following recognisable formations:

- Upper Walloon Formation (aquitard);

- Macalister Coal Seams (aquifer/aquitard);
- Juandah Sandstone (aquifer);
- Lower Jundah Coal Measures (aquifer/aquitard);
- Tangalooma Sandstone (aquifer); and
- Taroom Coal Measures (aquifer/aquitard).

Associated water (AW) at Roma region is expected to range in salinity (TDS) from 200 mg/L to 5,000 mg/L with groundwater levels (and the direction of flow) is presented in **Figure 43.**

Hutton Sandstone

The Hutton Sandstone consists of very fine to medium-grained sandstone with interbedded argillaceous to arenaceous siltstones. It tends to be the thickest aquifer in the Surat Basin. It is a major GAB aquifer but has many tight (low permeability) zones. The Hutton Sandstone has an upper and lower upwards fining sequence. The base of the upper is generally more sand-rich and the most productive for groundwater. The highly permeable zones tend to be thin whilst the rest of the sequence has a large storage capacity and contributes to formation transmissivity.

The groundwater flow direction in the Hutton Sandstone is south to south-east. This differs from the general south-west groundwater flow direction observed for the other hydrogeological units of the GAB and is thought to demonstrate a low level of connectivity between the Injune Creek Group and the Hutton Sandstone (Golder, 2011a).

Groundwater levels (and the direction of flow) is presented in **Figure 44**.

Precipice Sandstone

The Precipice Sandstone is a major aquifer of the GAB comprised of sandstone and conglomerate at its base. Sediments were deposited in a fluvial environment in braided river systems. Regionally, the Precipice Sandstone is approximately 80 m thick and mostly hydrologically isolated from the Hutton Sandstone by the Evergreen Formation. Regionally, groundwater flows in an easterly direction within the Precipice Sandstone in the Development area. The average total dissolved solids (TDS) is 1,216 milligram per litre (mg/L) and the average pH is 7.7 (Parsons Brinckerhoff, 2014).

The Precipice Sandstone in the Roma region is considered to be hydraulically discontinuous. There are limited groundwater bores in the Precipice in the Roma region. The Precipice Sandstone is characterised by a dome structure or pockets. Each pocket is formed by high permeability sediments, which have been found to contain natural gas; these pockets do not contain any groundwater and have been characterised as dry petroleum reservoirs. The sediments of the Precipice Sandstone surrounding these pockets are characterised by low to very low permeability and are considered to be largely an aquitard. The domes of The Precipice Sandstone have and continue to be exploited for methane gas production.

Groundwater levels (and the direction of flow) is presented in **Figure 44**.

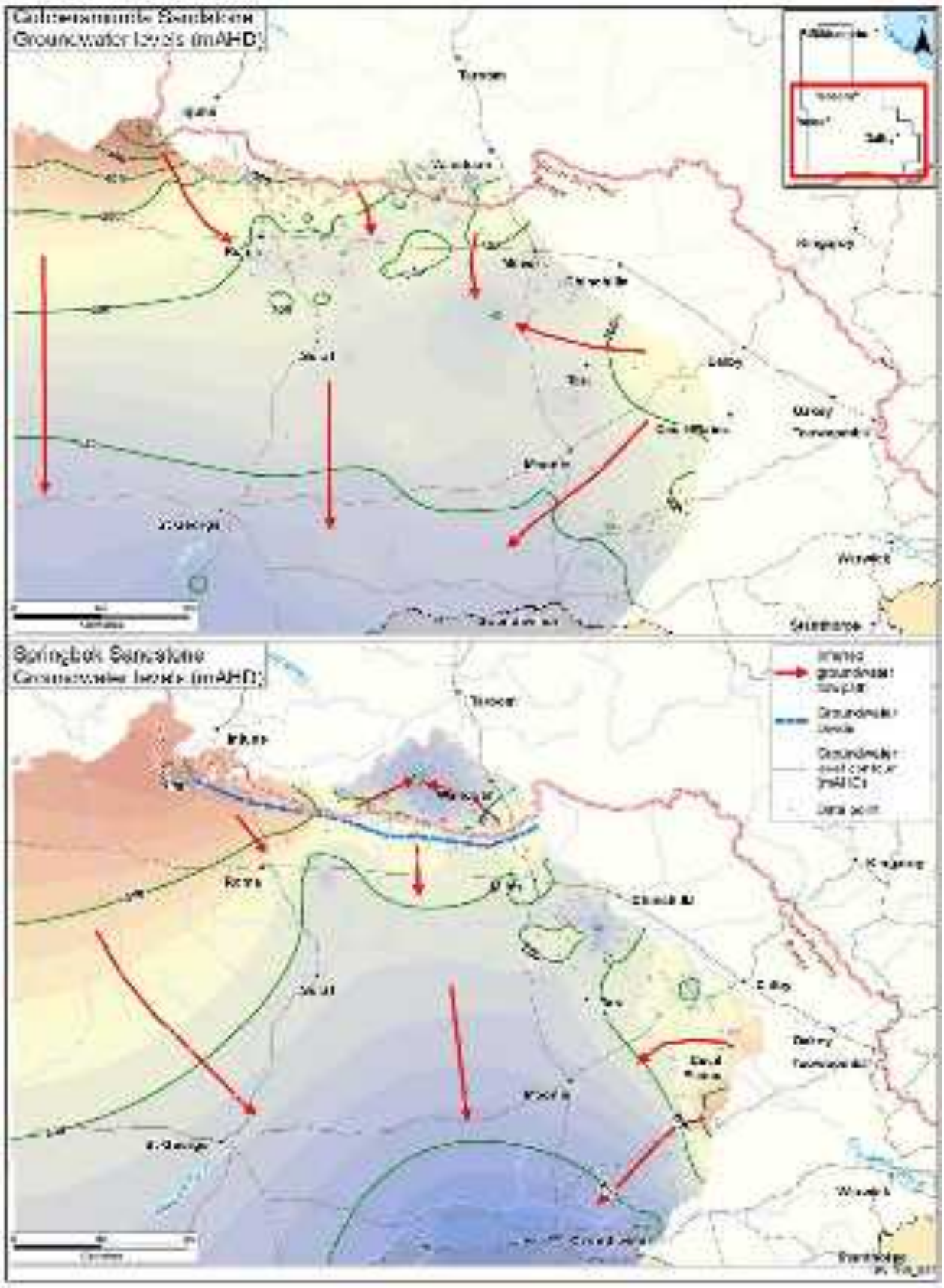


Figure 42. Interpreted Groundwater Flow Directions – Gubberamunda Sandstone and Springbok Sandstone (after UWIR 2019)

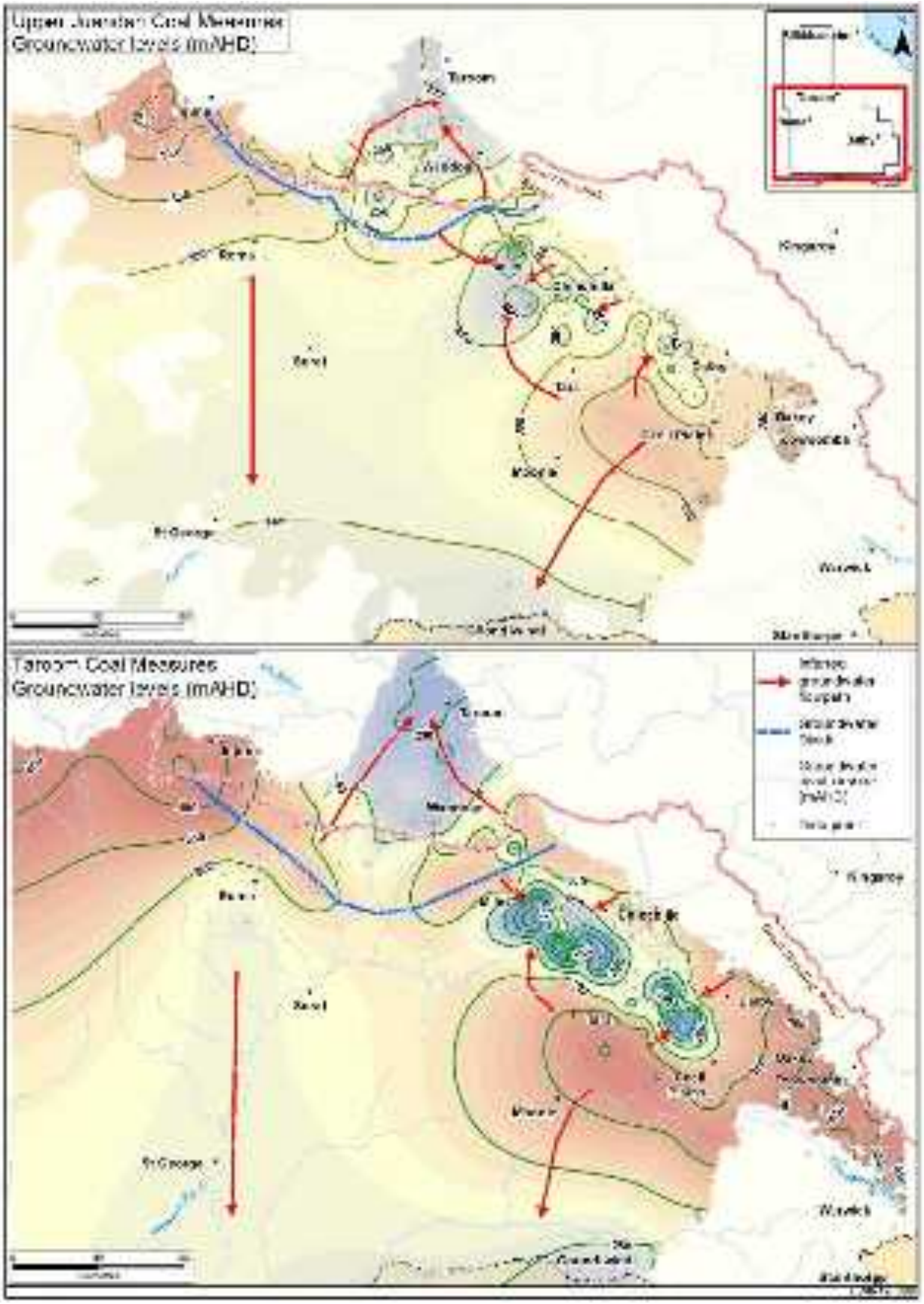


Figure 43. Interpreted Groundwater Flow Directions – Upper Juandah Coal Measures and Taroom Coal Measures (after UWIR 2019)

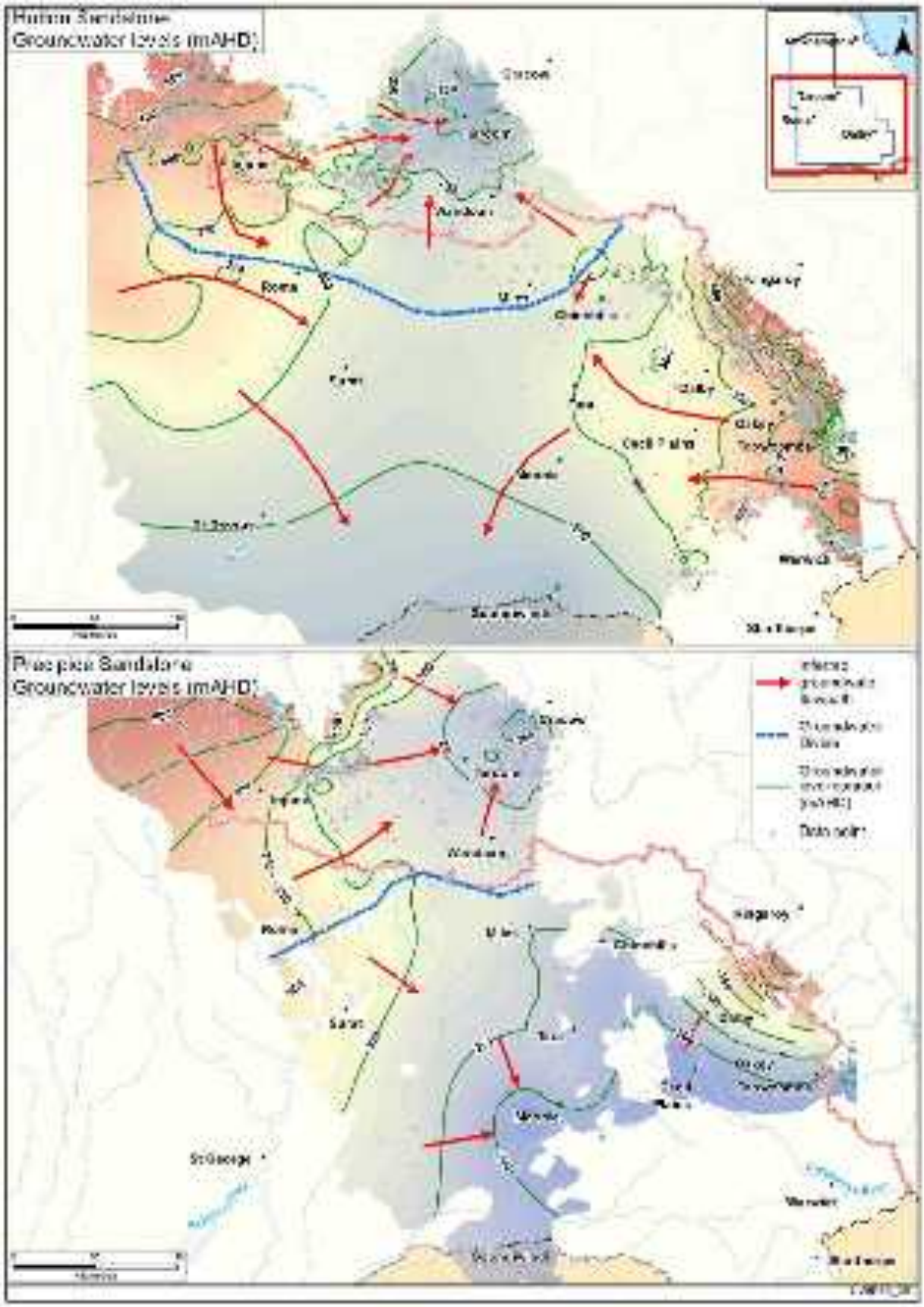


Figure 44. Interpreted groundwater Flow Directions – Hutton Sandstone and Precipice Sandstone (after UWIR 2019)

3.5.2 Fairview Region

3.5.2.1 Hydrogeological Units and Groundwater Flow

The Fairview region is directly underlain by the lower GAB formations of the Surat Basin namely:

- Hutton Sandstone
- Evergreen Formation
- Precipice Sandstone and the GAB formations of the upper Bowen Basin, namely:
  - Moolayember Formation, and
  - Clematis Sandstone

The gas bearing formation of interest to Santos EQ is the Bandanna Formation from the Blackwater Group (Bowen Basin, Late Permian) as well as the Early Permian Cattle Creek Formations.

Localised cross-sections of the main hydrogeological formation underlying the Fairview region are shown in **Figure 21** to **Figure 24** with a localised hydrogeological description provided below. The location of each cross-section transect is show in **Figure 10**. Local hydrogeological discussion on each major unit present within the Fairview region is provided below.

Hutton Sandstone

The Hutton Sandstone outcrops across most of the Fairview region and is unsaturated in many areas. Despite the Hutton Sandstone being considered a major water resource aquifer, across the Fairview region, the Hutton Sandstone is not a reliable groundwater source due to its discontinuous distribution and generally poor water quality.

Groundwater levels and the direction of flow is presented on **Figure 44**.

Precipice Sandstone

Within the Fairview region, the Precipice Sandstone provides good aquifer potential and generally produces higher yielding supplies of potable sub-artesian water when compared to other areas. A number of 'recharge springs' for the Hutton and Precipice Sandstone are present within the Fairview region. The narrow outcropping area can be considered as the northern borderline of the Surat Basin, being the oldest and deepest formation of this basin.for the Hutton and Precipice Sandstone are present within the Fairview region. The narrow outcropping area can be considered as the northern borderline of the Surat Basin, being the oldest and deepest formation of this basin.

Groundwater levels (and the direction of flow) is presented on **Figure 44.**

Clematis Sandstone

The Clematis Sandstone is not present in the Fairview region where it is considered to be undifferentiated from the Rewan Formation (an aquitard) but can be found on the flanks of the region where it can produce good supplies of potable groundwater. Also within the region, the alluvial deposits associated with larger streams can provide supplies of groundwater from shallow depths.

Low permeability formations include the Evergreen and Moolayember Formations, both of which have little potential for water use in the area.

According to information available from DEHP (Foster, 2007), alluvial deposits within the Fairview region have enhanced groundwater potential due to relatively high hydraulic conductivity. Aquifers associated with the sedimentary rocks within the hills of the 'kipper catchments' have lower yields and groundwater quality may be saline due to the depositional nature of the rocks and the reduced rainfall recharge.

Salinity of groundwater within the in the Clematis Sandstone does not vary greatly, with measurements between 131 and 1,260 microsiemens per centimetre (µS/cm) at 47 locations (Santos, 2012).

Rewan Formation

The groundwater abstracted from the Rewan Formation is generally saline, with EC measurements ranging from 4,200 and 27,500 µS/cm.

Bandana Formation

The Bandana coal seams are the only materials with appreciable permeability; groundwater flow is dependent on the permeability of the individual coal seams and their vertical and lateral interconnection (Santos, 2102). It is likely that the permeability of the coal seams of the Bandanna Formation within the deepest areas of the Bowen Basin is so low that groundwater flow does not occur. There is limited groundwater extraction from this formation and groundwater quality is variable.

3.5.3 Arcadia Valley

3.5.3.1 Hydrogeological Units and Groundwater Flow

The Arcadia Valley region are located entirely within the Bowen Basin. The target formation for gas production is the Bandana Formation.

The main aquifer units in terms of groundwater development within Arcadia valley region include the Clematis Sandstone. The main confining units include the Moolayember Formation and Rewan Formation. Many bores are also completed in shallow Tertiary sediments, basalts and alluvium deposits. The Rewan Formation acts as effective hydraulic barrier (aquitard), although a few low yielding stock and domestic bores are also completed within this formation.

Localised cross-sections of the main hydrogeological formation underlying the AVPA are shown in **Figure 25** to **Figure 26** with a localised hydrogeological description provided below. The location of each cross-section transect is show in **Figure 10**. Local hydrogeological discussion on each major unit present within the Arcadia Valley region is provided below.

Cross-section presented in **Figure 26** is characteristic of the central and southern part of region. To the north the formations are shallower and form a monocline, the Precipice Sandstone is not present anymore; the Clematis Sandstone is present to the east corresponding with the National Park and the ranges. A very thick Rewan Formation prevents any direct contact between the Bandanna Formation and the Clematis.

Clematis Sandstone

In the Arcadia Valley region the lower to middle Triassic age Clematis Sandstone is generally unconfined to semi-confined and consists of sandstone, siltstone and mudstone units deposited by fluvial processes. In some areas where it is overlain by the Moolayember Formation, water pressures in the Clematis Sandstone are artesian and there are many springs located along the Clematis-Moolayember boundary to the northeast, following the Arcadia Valley sandstone cliff walls.

The Clematis Sandstone conformably overlie the relatively impermeable Rewan Formation, as such there is limited hydraulic connection between this unit and underlying aquifers, including the Bandana Formation.

Rewan Formation

The Rewan Formation is considered to be a low permeability confining aquitard, the Formation confines the underlying Bandanna Formation. It is comprised of lithic sandstone, pebbly lithic sandstone, mudstone and minor pebble conglomerate.

Bandana Formation

The Bandana Formation contains the target coal measures within the Fairview, Denison and Arcadia Valley region. It is comprised of sandstones, siltstone, shale, mudstone, coal, tuff and conglomerate with a thickness of up to 250 m. The total coal seam thickness within the Bandanna Formation is generally less than 10 m, up to six individual coal seams can be identified (Santos, 2012). The formation outcrops to the northern boundary of the Surat Cumulative Management Area.

3.5.4 Denison Region

3.5.4.1 Hydrogeological Units and Groundwater Flow

The main aquifer units in terms of groundwater development within Denison region include:

- Precipice Sandstone.
- Clematis Group

The main confining units within DPA include:

- Rewan Formation
- Moolayember Formation

Localised cross-sections of the main hydrogeological formation underlying the Denison region is shown in **Figure 30** with a localised hydrogeological description provided below. The location of each cross-section transect is show in **Figure 10**. Hydraulic conductivity data and storage data for the hydro stratigraphic units relevant to the Denison region are summarised in **Table 10** and **Table 11** respectively. These localised values are based on the following sources of information:

- Site-specific permeability data for the Rangal Coal Measures from modular formation dynamics tester (MDT) and drill stem test (DST) testing and from calibration of reservoir models to water production data for pilot wells;
- Calibrated numerical groundwater models where their model boundary overlaps aquifers relevant to the Project Area;
- Rolleston Coal Mine Expansion Environmental Impact Statement (EIS) (Glencore, 2013);
- Arrow Bowen Basin EIS (Ausenco-Norwest, 2012);
- Surat Cumulative Management Area Underground Water Impact Report (CMA UWIR) (OGIA, 2016);
- Surat Cumulative Management Area Underground Water Impact Report, October 2019 (OGIA, 2019a); and
- Surat Cumulative Management Area Groundwater Modelling Report October 2019 (OGIA, 2019b).

Table 10. Summary of Hydraulic Conductivity Data

Formation Name	Average Kh (m/d)	Average Kv (m/d)	Average Thickness in Project Area (m)	Transmissivity (m^2/d)
Moolayember Formation	4.11E-01	8.33E-06	1.14E+02	4.68E+01
Clematis Sandstone	1.03E+00	6.90E-05	2.38E+01	2.45E+01
Rewan Group	2.44E-05	1.99E-05	1.89E+02	4.61E-03
Bandanna Formation	4.18E-01	5.93E-01	2.83E+02	1.18E+02
Black Alley Shale	4.40E-04	3.30E-07	8.95E+01	3.94E-02
Mantual Formation	-	-	7.95E+01	-
Peawaddy Formation	-	-	6.69E+01	-
Ingleara Formation	-	-	3.34E+01	-
Aldebaran Sandstone	-	-	9.94E+01	-
Cattle-Creek Formation	-	-	1.42E+02	-
Reids Dome Beds	-	-	4.43E+01	-

Notes:
Kh = hydraulic conductivity - horizontal
Kv = hydraulic conductivity - vertical
m = metres
m2/d = square metres per day
m/d = metres per day

Table 11. Summary of Specific Yield and Storage Data

Formation Name	Specific Yield (-)			Specific Storage (-)		
	Mean	Min	Max	Mean	Min	Max
Quaternary Alluvium	0.03	0.01	0.18	1.90E-04	1.00E-05	1.00E-03
Tertiary Sediments	0.15	0.12	0.2	5.00E-05	5.00E-05	5.00E-05
Tertiary Basalt	0.005	0.0001	0.13	1.40E-06	6.00E-10	2.00E-04
Clematis Sandstone	1.70E-01	1.70E-01	1.70E-01	5.50E-05	5.00E-05	6.00E-05
Rewan Formation	1.00E-02	1.00E-03	1.80E-01	7.10E-06	1.30E-07	5.00E-05
Rangal Coal Measures/Bandanna Formation (Blackwater Group [equivalent parameters])	1.0E-02	-	-	4.9E-06-	-	-
Blackwater Group (interburden)	7.00E-03	1.00E-03	5.00E-02	1.10E-05	8.00E-06	2.00E-05
Blackwater Group (coals)	2.00E-02	5.00E-03	7.50E-02	1.60E-05	6.00E-06	8.50E-05
Black Alley Shale	3.00E-03	1.00E-04	1.20E-01	1.10E-05	3.00E-06	5.00E-05

Notes:
min = minimum value
max = maximum value

Moolayember Formation

In the Denison region, the Moolayember Formation is a minor discontinuous aquifer, but regionally acts as an aquitard. The aquifer is not high yielding and water quality is often poor (QWC, 2012a). The Moolayember Formation consists of micaceous lithic sandstone and siltstone. (Parsons Brincherhoff, 2014) consider the Moolayember Formation as an aquitard based on its low permeability and considerable thickness.

Clematis Sandstone

The Clematis Sandstone is a discontinuous aquifer across the Denison region. Further detail on the Clematis Sandstone in presented in **Section 3.5.3.1**.

Rewan Formation

Further detail on the Rewan Formation in presented in **Section 3.5.3.1**.

Back-Creek Group

The Back-Creek group is underlain by various sedimentary units of Permian age, none of which are recognised aquifer units. The Black Alley Shale conformably underlies the Rangal Coal Measures (Bandana Formation equivalent) and is in turn conformably underlain by the Mantuan Beds and Peawaddy Formation. These units consist of mudstone, siltstone, tuff and sandstone. These units are regarded as relatively impermeable units confining earlier successions of the Back-Creek Group, most significantly the Upper Aldebaran Sandstone. An unconformity separates the Upper Aldebaran Sandstone from the Lower Aldebaran Sandstone, the Cattle-Creek Formation (which contains targeted coal measures) and the Reids Dome Beds, which are considered the basement of the Bowen Basin.

In the study area, the Black Alley Shale is understood to be at least 200 m in thickness below the base of the Rangal Coal Measures (Bandana Formation equivalent).

3.5.5 Scotia Region

3.5.5.1 Hydrogeological Units and Groundwater Flow

The Scotia region is located within the Surat Basin, 32 km (west) from its border with the underlying Bowen Basin, both of which comprise part of the Great Artesian Basin. The main aquifer units in terms of groundwater development within the region include:

- Hutton Sandstone.
- Precipice Sandstone.

The main confining units within DPA include:

- Eurombah Formation.
- Evergreen Formation.

Localised cross-sections of the main hydrogeological formation underlying the SPA are shown in **Figure 31** to **Figure 35** with a localised hydrogeological description provided below. The location of each cross-section transect is show in **Figure 10**. Local hydrogeological discussion on each major unit present within the SPA is provided below.

Injune Creek Group

The Injune Creek Group (likely Eurombah Formation) outcrops across the Scotia region and are considered to be recharge area for the identified aquifers within the group.

Regional groundwater flow is from the topographically higher recharge areas around the basin margins towards the lowest parts of the basins in the southwest. Regionally, the aquifers of the Surat Basin discharge to springs located to the south and west of the project area. The aquifers also discharge to artesian or sub-artesian water abstraction bores installed across the region into Surat Basin aquifers.

The primary direction of groundwater flow through most units is from north-east to south, moving from their outcrop areas and following the downward formation dip.

The rate of groundwater flow is dependent on the permeability and thickness of the aquifer and the lateral hydraulic gradient for each unit.

Hutton Sandstone

The Hutton Sandstone outcrops over the north-eastern portion of the Scotia region. Beneath the Hutton Sandstone the Evergreen Formation acts as a confining bed.

A north-westerly to northerly direction of groundwater flow is observed in data for the Hutton Formations units (refer to **Figure 44**). This is contrary to the regional picture of flow from outcrop areas in the northeast towards the south, following the formation dip. The suggested northerly trend in groundwater flows may also represent a degree of connection to overlying units or to the outcrop to the north and the upper Dawson River catchment (especially in the Hutton Sandstone).

Groundwater levels (and the direction of flow) is presented in **Figure 44**.

In the Hutton Sandstone, approximately half of the 11 bores contain a qualitative description of water quality such as potable, suitable, or salty. Occasionally conductive measurements are quoted, within the “Strata Log” field, rather than the “Field Water Quality” field. Conductivity values are present for two bores with values of 810 and 2400. Units are not quoted, but as these are field water quality values, they are assumed to be microsiemens (µS/cm).

Precipice Sandstone

The Precipice Sandstone underlies the Evergreen Formation. A major unconformity is present at the base of the Precipice Sandstone. This unconformity represents the boundary between the younger Jurassic age Surat Basin sequence and the older Permian-Triassic sequences of the Bowen Basin beneath.

The nearest surface outcrop of the Precipice formation occurs in the north-eastern part of the region. In this location several recharge springs are found and these are located along the Dawson River in ATP685 where the Precipice Sandstone outcrops (**Figure 47**).

Groundwater levels (and the direction of flow) is presented in **Figure 44**.

3.6 Environmental Values of Groundwater in the Project Areas

The EP Act defines an EV as a quality or physical characteristic of the environment that is conducive to ecological health, public amenity or safety, or another quality of the environment identified or declared to be an EV under an environmental protection policy or regulation.

In the context of the UWIR, the relevant policy is the Environmental Protection (Water) Policy 2009 (Water EPP). The Water EPP identifies specific EVs that are to be protected with

corresponding water quality objectives (WQOs). Under the Water EPP, all Queensland waters, including groundwater, have identified EVs and WQOs. In relation to groundwater, EVs in the Santos EQ Project Area include:

- Human use: consumption or use of groundwater for a range of purposes including aquaculture, recreation (e.g., waterholes), industrial, cultural and spiritual values.
- Aquatic ecosystem: groundwater aquifers, GDEs such as groundwater inflows to rivers (baseflow) and springs, and terrestrial GDEs.

3.6.1 Human Use Environmental Value

The Human use EVs considered by this study are as follows:

- Drinking water;
- Primary, secondary and visual recreational use;
- Irrigation, stock watering and other agricultural uses;
- Aquaculture use;
- Industrial use; and
- Cultural and spiritual values.

One of the main primary uses of groundwater in the area are for stock watering and domestic use with water primarily sourced from the sandstone aquifers of the GAB. The environmental values for groundwater within the Santos EQ Project Area is summarised below in Table 12.

Table 12. Groundwater Environmental Values

Environmental Values	AVPA	FPA	RSGPA	SPA	DPA
Protection of aquatic ecosystem (springs and GDEs)	✓	✓	✓	✓	✓
Primary contact recreation (e.g., swimming) – springs and pools	✓	✓	✓	✓	✓
Drinking water supplies	✓	✓	✓	✓	✓
Crop irrigation	✓	✓	✓	✓	✓
Stock watering	✓	✓	✓	✓	✓
Farm supply/use	✓	✓	✓	✓	✓
Aquaculture (e.g., red claw, barramundi)	-		✓	✓	✓
Industrial use (including manufacturing plants, power generation)	-	✓	✓	✓	✓
Protection of cultural and spiritual activities	✓	✓	✓	✓	✓

3.6.1.1 Groundwater Usage from the GAB

The location of groundwater users across the Santos EQ Project Area are shown in **Figure 45** to **Figure 47**. The majority of these bores access groundwater from 5 primary groundwater systems in the Santos EQ Project Area:

- Alluvial Unconfined Systems (usually associated with valleys and floodplains)
- Mooga Sandstone
- Gubberamunda Sandstone
- Hutton Sandstone
- Precipice Sandstone.

These are described in greater detail in **Section 3.5** . Modelled groundwater associated impacts associated with CSG activities is presented in Chapter 7 of the UWIR 2019.

In RSGPA, groundwater is used for domestic (potable) consumption and stock watering purposes and is derived predominantly from the Mooga and Gubberamunda Sandstone aquifers with contributions also from sandy intervals from the Orallo Formation. The Mooga and Gubberamunda Sandstone aquifers provide the sole source of groundwater supply for urban purposes for Roma and towns in the surrounding area (Mitchell).

The Springbok Sandstone aquifer does not constitute a viable water resource in the Roma region due to its discontinuity and general low hydraulic conductivity. The WCM may be sourced by some farmers in the Surat Basin, however in the Roma region; it is very deep, of low hydraulic conductivity and/or poor water quality.

The Hutton Sandstone underlies the WCM and is relatively undeveloped in the Roma area due to its depth. Whilst the current entitlements and use are very small for the Hutton Sandstone proximal to the Roma region, future extraction needs to be monitored as this aquifer extends beyond the Roma region and it is often used in these more distant locations.

Saturated groundwater from the Hutton, Precipice and Clematis Sandstone units in the Scotia and Fairview region are generally suitable for potable use; however, some bores exceed guideline levels for sodium, total dissolved solids and fluoride. Groundwater from these formations is also generally suitable for irrigation and stock watering use, due to having low sodium and salinity hazard.

Groundwater from the gas wells in Fairview region (Bandanna Formation) is generally unsuitable for potable use due to elevated sodium, chloride, total dissolved solid, fluoride and iron. It can be used for irrigation if treated. Groundwater from these wells is marginally suitable for stock watering, with the limiting factors being elevated concentrations of fluoride, copper, aluminium, lead and selenium above guideline values.

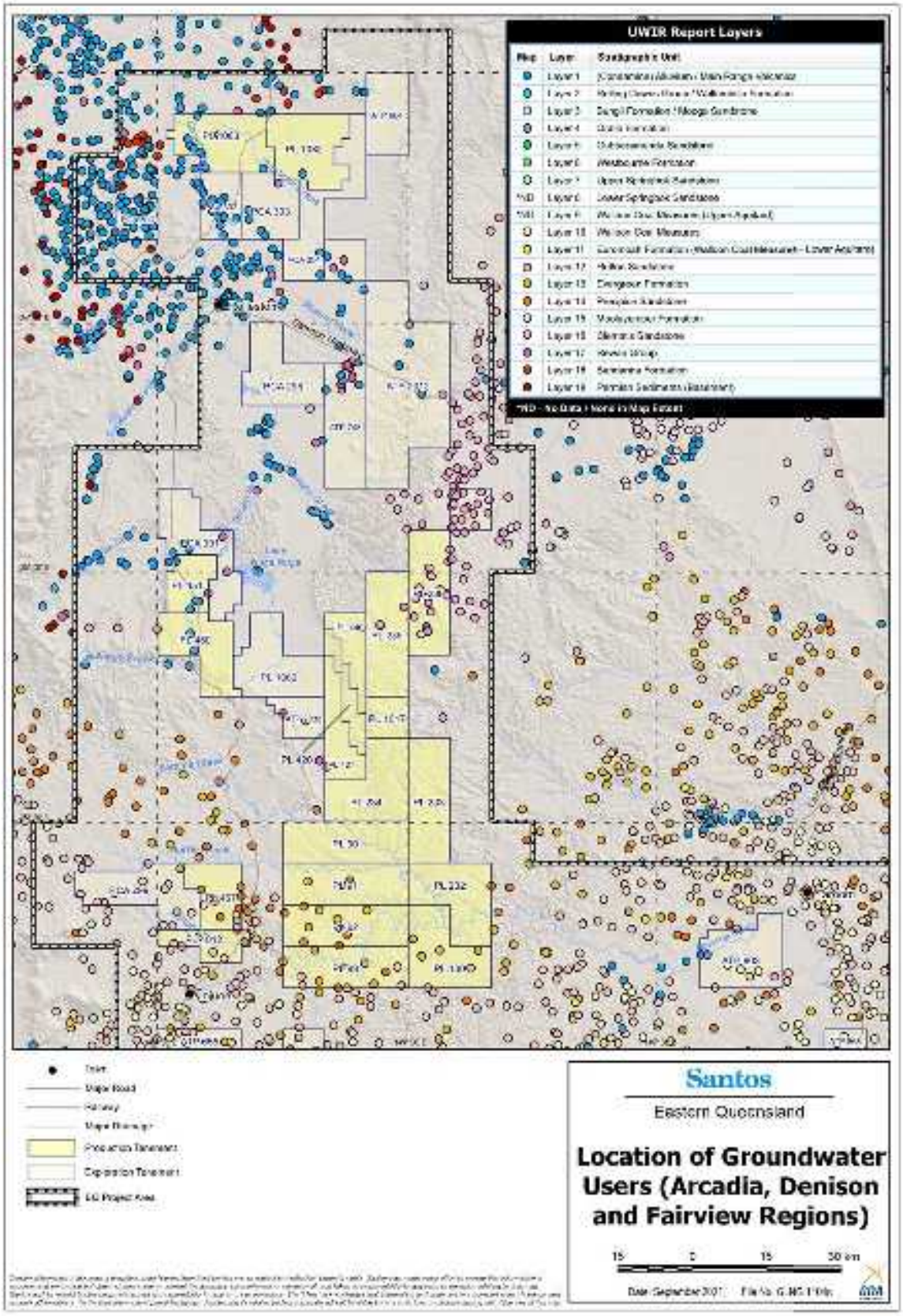


Figure 45. Location of Groundwater Users (Fairview, Arcadia Valley and Denison Region)

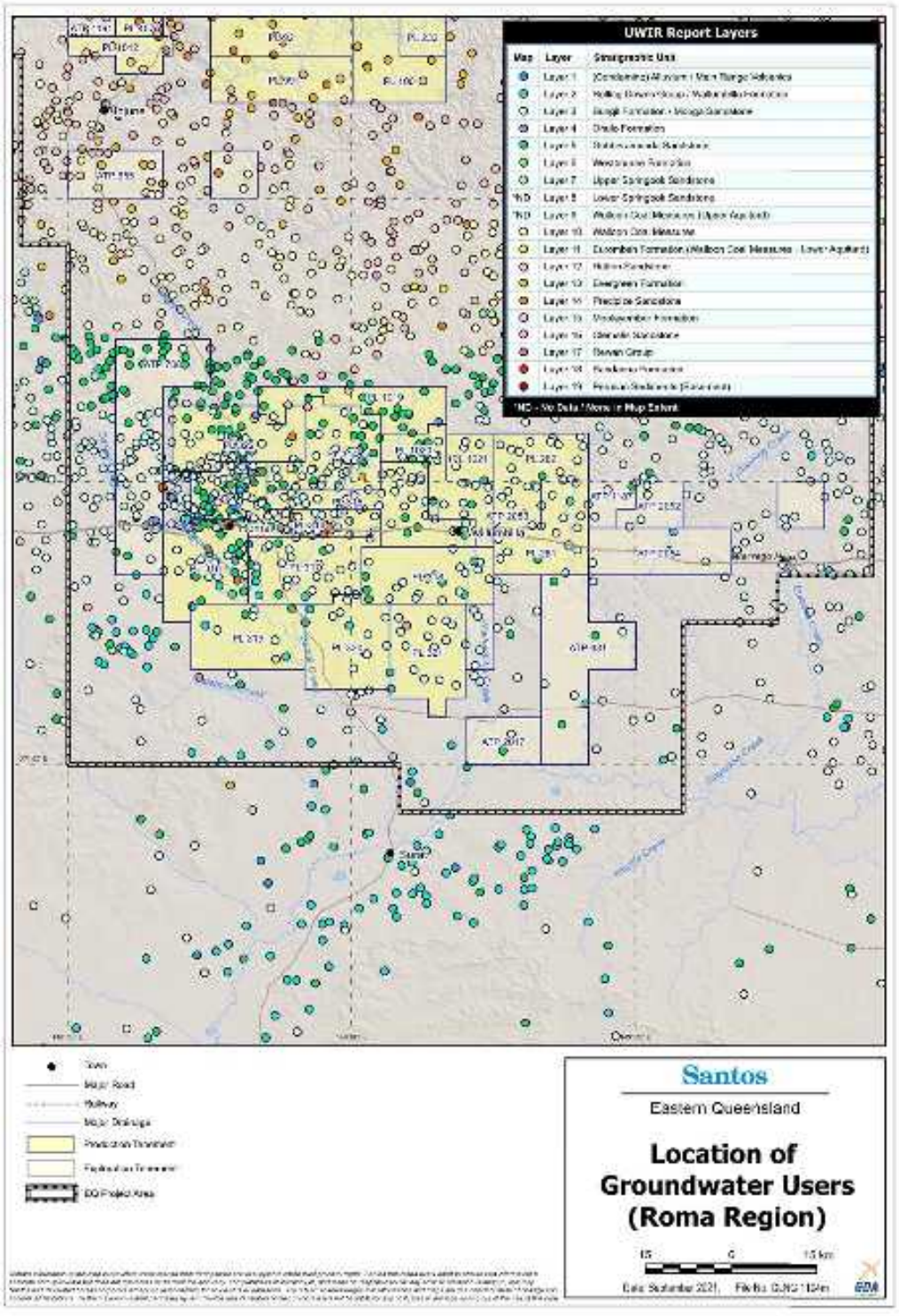


Figure 46. Location of Groundwater Users (Roma Region)

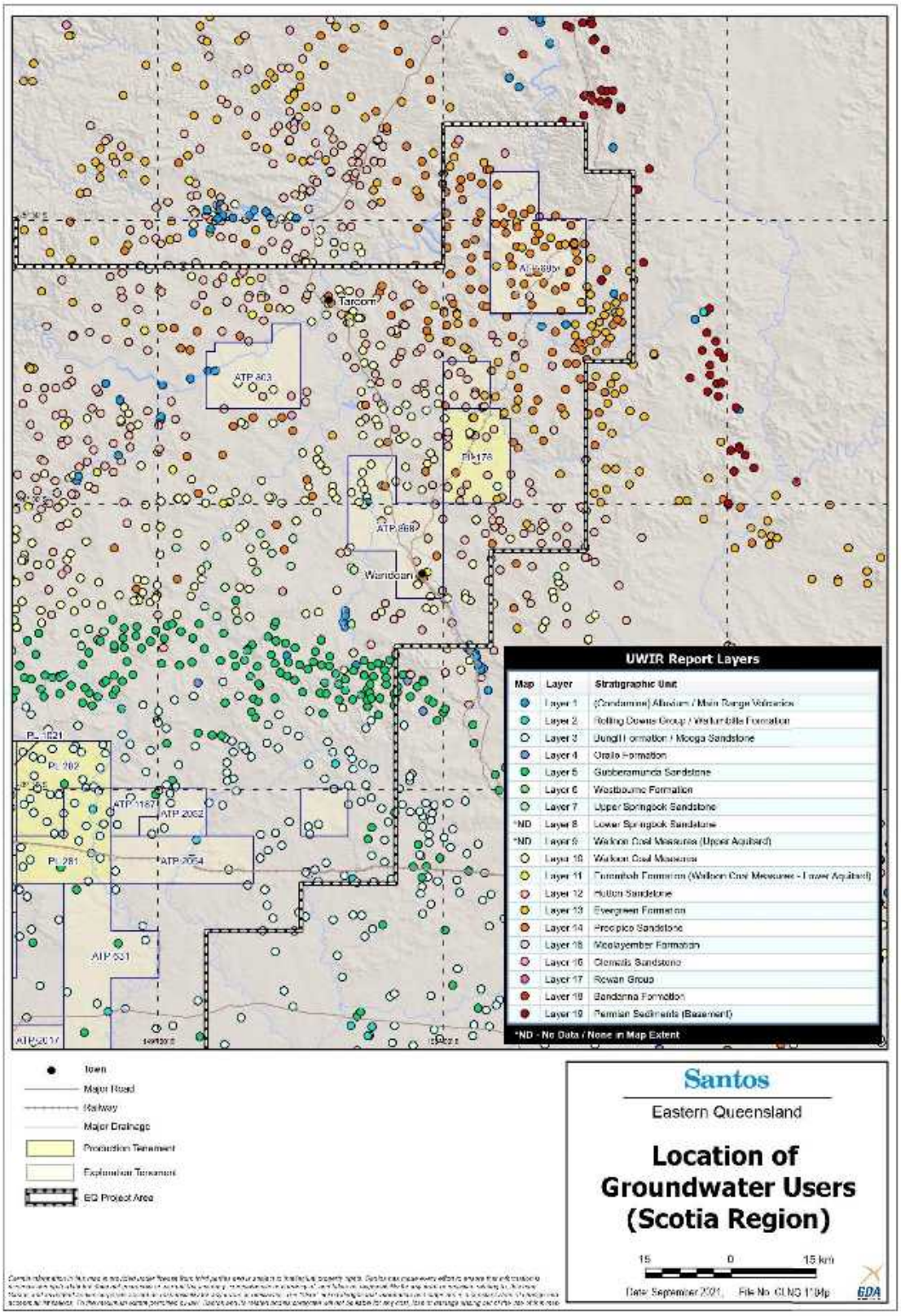


Figure 47. Location of Groundwater Users (Scotia Region)

3.6.2 Aquatic Ecosystems

The EVs associated with aquatic ecosystems comprise two inter-related aspects:

- The intrinsic value of aquatic ecosystems, habitat and wildlife in waterways and riparian areas – for example, biodiversity, ecological interactions, plants, animals, key species, (such as turtles or platypus) and their habitat, food and drinking water.
- Waterways which include perennial and intermittent surface waters, groundwaters, tidal and non-tidal waters, lakes, storages, reservoirs, dams, wetlands, swamps, marshes, lagoons, canals, natural and artificial channels and the bed and banks of waterways.

Whilst aquatic ecosystems are traditionally associated with surface water bodies rather than groundwater systems, any surface water body with a hydraulic connection to shallow groundwater would be potentially susceptible to impacts to shallow groundwater (either water quality degradation or lowering of the water table). This environmental value could be relevant to perennial creeks, rivers, and springs present within the Project area and is further defined below as GDE Sensitive Areas.

Table 13. Surface Water Environmental Value

Environmental Value	Comet River			Upper Dawson River					Lower Dawson River						Condamine-Balonne
	Main channel	Western tributaries	Eastern tributaries	Main channel (below Hutton Creek)	Western upland tributaries	Southern tributaries	Northern upland tributaries	Central tributaries	Northern upland tributaries	Main channel – unregulated reaches	Main channel – regulated reaches	Southern upland tributaries	Eastern Tributaries	Western tributaries	Dogwood Creek
Aquatic ecosystems	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Irrigation	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	
Farm	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	
Stock water	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Aquaculture											✓		✓		
Human consumer	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Primary and secondary recreation	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Visual recreation	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Drinking water	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	
Industrial use	✓	✓	✓	✓						✓	✓		✓		✓
Cultural and spiritual values	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	

3.6.2.1 Fairview Region

The waterways within the Fairview region are considered predominantly to consist of 'slightly to moderately disturbed ecosystems' and in accordance with the EPP (Water) are considered to be 'systems that have undergone some changes, with aquatic biological diversity affected to some degree but the natural communities are still largely intact and functioning' (EPA, 2005).

In the Fairview region, drainage from the Fairview and Springwater Plateaus, finds it way southward into Hutton Creek, while the northern half of the Fairview Plateau drains north into Baffle Creek and the Dawson River. In the downstream reaches of Hutton Creek, grazing, forestry and cropping are widespread. Water storages and weirs, located on the Dawson River are used for irrigation and recreational purposes supporting regional industry and urban communities.

A brief overview of the aquatic ecology, as evidenced from the field survey undertaken as part of the GLNG EIS (Santos, 2009) is provided below:

- Aquatic Flora: The diversity of aquatic macrophytes in the tributaries to the Upper Dawson is relatively low. The limited cover of macrophytes and the lack of submerged species is likely to be related to the largely ephemeral nature and/or turbid conditions of the waterways. The Upper Dawson River itself is largely perennial and is therefore likely to provide a more stable habitat for aquatic macrophytes. No rare or threatened species of aquatic flora have been recorded from the waterways in the FPA.
- Aquatic Macroinvertebrate Communities: Aquatic macroinvertebrate communities within the FPA were generally indicative of poor to moderate habitat and/or water quality. The larger waterways, such as the Upper Dawson, support more permanent water, and therefore offer a more stable habitat for a more abundant and diverse of macroinvertebrates.
- Fish Communities: Most of the fish species that were captured during the EIS survey within the FPA can tolerate a large range of water quality conditions. Spangles perch, glassfish, carp gudgeons, eastern rainbowfish and eel-tailed catfish are tolerant species that can live in water characterised by low dissolved oxygen (DO) levels, high electrical conductivity (EC) and relatively high turbidity. Although exact tolerances are not available for exotic carp, goldfish and mosquitofish, these fish are also known to have wide environmental tolerances.
- Turtle Communities: Krefft's river turtles and White-throated snapping turtles are likely to be relatively common in the larger permanent waterways of the Upper Dawson catchments. Saw shelled and Fitzroy River turtles may also be present in the faster flowing waterways of the Upper Dawson River. Eastern snake-necked turtles may be present in the ephemeral creeks of the Upper Dawson River, although their absence during the survey process (undertaken in the EIS) suggests that they are not likely to be common.

Within the Fairview region on the Upper Dawson River, there are around 30 artesian springs, which are located between Dawson's Bend and Yebna Crossing. The condition of the artesian springs varied considerably between the springs surveyed, with the state of each spring largely dependent on the presence of water, the ability of stock to gain access to the spring, and the presence and abundance of terrestrial weeds. The smaller, shallower springs provide little habitat for aquatic organisms, but usually supported some macrophytes. In contrast, the larger, more complex springs often supported abundant in-stream habitat (including larger fish and turtles) and macrophytes.

3.6.2.2 Roma Region

The Condamine-Balonne River catchments are considered predominantly to be of slightly to moderately disturbed ecosystems, as 'systems that have undergone some changes, with aquatic biological diversity affected to some degree but the natural communities are still largely intact and functioning' (EPA, 2005).

As the region is located in the upper catchment area of the MDB (predominantly the Condamine- Balonne River catchment, **Figure 6**), it is the local tributaries (extensive but largely ephemeral or intermittent meandering streams) of this drainage system that would be the receiving environment. The main streams that run through the Condamine-Balonne River catchment include Yuleba Creek, Wallumbilla Creek, Bungil Creek and the Balonne River. The four creeks discharge to the Balonne River, which in turn flows into the MDB. There are five creeks running through region, which drain south to the Balonne River, including Dargal Creek, Bungil Creek, Blyth Creek, Wallumbilla Creek and Yuleba Creek. . In the eastern part of the region, the main creeks Kangaroo, Yuleba and Cottage Creeks, with the Yuleba Creek being the main watercourse.

A brief overview of the aquatic ecology, as evidenced from the field survey undertaken as part of the EIS (Santos, 2009) is provided below:

- Aquatic Flora: The diversity of aquatic macrophytes is relatively low. The limited cover of macrophytes and the lack of submerged species is likely to be related to the largely ephemeral nature and/or turbid conditions of the waterways.
- Aquatic Macroinvertebrate Communities: Aquatic macroinvertebrate communities within the RSGPA were limited in number and diversity and generally indicative of poor to moderate habitat and/or water quality.
- Fish Communities: Most of the fish species that were captured during the EIS survey within the region can tolerate a large range of water quality conditions. Spangles perch, glassfish, carp gudgeons, eastern rainbowfish and eel-tailed catfish are tolerant species that can live in water characterised by low DO levels, high EC and relatively high turbidity. Although exact tolerances are not available for exotic carp, goldfish and mosquitofish, these fish are also known to have wide environmental tolerances.

3.6.2.3 Arcadia Valley Region

The Arcadia Valley region is part of the Fitzroy Basin (**Figure 8**). In the downstream reaches of Hutton Creek, grazing, forestry and cropping are widespread. Water storages and weirs, located on the Dawson River, are used for irrigation and recreational purposes supporting regional industry and urban communities.

There are no rare or threatened species of aquatic flora recorded from the waterways in the region. A brief overview of the aquatic ecology, as evidenced from the field survey undertaken as part of the EIS (Santos, 2009) is provided below:

- Aquatic Macroinvertebrate Communities: Aquatic macroinvertebrate communities within the Upper Dawson River were generally indicative of poor to moderate habitat and/or water quality. The larger waterways, such as the Upper Dawson, support more permanent water, and therefore offer a more stable habitat for a more abundant and diverse community of macroinvertebrates.
- Fish Communities: Most of the fish species that were captured during the EIS survey within the Dawson River can tolerate a large range of water quality conditions. Spangles perch, glassfish, carp gudgeons, eastern rainbowfish and eel-tailed catfish are tolerant species that can live in water characterised by low DO levels, high EC and relatively high turbidity. Although exact tolerances are not available for exotic carp, goldfish and mosquitofish, these fish are also known to have wide environmental tolerances.
- Turtle Communities: Krefft's river turtles and White-throated snapping turtles are likely to be relatively common in the larger permanent waterways of the Upper Dawson catchments. The Fitzroy Turtle is listed as 'Vulnerable' under the EPBC Act and is found in the drainage system of the Fitzroy River. Saw shelled and Fitzroy River turtles may also be present in the faster flowing waterways of the Upper Dawson River. Eastern snake-necked turtles may be present in the ephemeral creeks of the Upper Dawson River, although their absence during the survey process (undertaken for the EIS) suggests that they are not likely to be common.

3.6.2.4 Denison Region

The Denison tenures lie wholly within the Fitzroy River Basin. The northern and central sections form part of the catchment area of the Comet River, which is a major tributary of the Fitzroy River.

Several tributaries of the Comet River, as well as the Comet River itself, flow in a northerly direction and include the Brown River, Carnarvon Creek, Arcadia Creek, Meteor Creek and Clematis Creek. The tributaries of the Comet River are ephemeral and typically experience periods of no flow for over 50% of time.

The southern section of the Denison region lies within the upper catchment area of the Dawson River, which is also a major tributary of the Fitzroy River. Tributaries of the Dawson River that flow through the southern tenures include Baffle Creek, Hutton Creek and Injune Creek. These creeks rise in the Great Dividing Range which separates this river system from the catchment area of the Maranoa River, which is part of the Balonne-Condamine River Basin. These tributaries of the Dawson River tend to be deeply incised streams flowing through sandstone areas of the Great Dividing Range, and consequently have sustained base flows, unlike the tributaries of the Comet River catchment.

The environmental values for the watercourses within the Upper Dawson River catchment are not defined within the *Environmental Protection (Water) Policy 2009* (EPP (Water)). However, the Fitzroy River sub-basin Environmental Values and Water Quality Objectives (DEHP 2011) defines the environmental values which would apply to the Upper Dawson River.

The waterways are considered predominantly to consist of 'slightly to moderately disturbed ecosystems' and in accordance with the EPP (Water) are considered to be *'systems that have undergone some changes, with aquatic*

biological diversity affected to some degree but the natural communities are still largely intact and functioning' (URS, 2009).

3.6.2.5 Scotia Region

The Scotia region is located in the upper catchment area of the Dawson River which drains northwards and is a tributary of the Fitzroy River. The main surface water system in the region the Dawson River, Bungaban Creek and Cockatoo Creek. As above, these waterway are likely considered 'slightly to moderately disturbed ecosystems' and in accordance with the EPP (Water) are considered to be '*systems that have undergone some changes, with aquatic biological diversity affected to some degree but the natural communities are still largely intact and functioning*'.

3.6.3 Groundwater Dependent Ecosystems

Groundwater Dependent Ecosystems require access to groundwater permanently or intermittently to maintain ecological assemblages, processes and ecosystem services (Eamus et al., 2006). Three types of GDEs are broadly recognised (SKM, 2011):

- ecosystems dependent on the surface expression of groundwater: associated with wetlands, lakes, seeps, springs and river baseflow
- ecosystems dependent on the sub-surface presence of groundwater: associated with terrestrial vegetation accessing the water table below ground
- cave and aquifer ecosystems: located within the pore or void spaces of caves and aquifers.

With respect to the first two points above, the ecosystems supported by groundwater discharge vary considerably. Although it is important to understand the mechanism and source aquifer supporting a wetland/ecosystem, it is the receiving environment which will influence the way an ecosystem will respond to a change in the groundwater regime. For this reason, a wetland typology has been developed for spring ecosystems of the Surat and southern Bowen Basins which identifies five types of wetland ecosystems. The key attributes used to differentiate the types are their landscape setting, geomorphology, the nature of the groundwater flow system, the regolith and water regime.

The five wetland types are:

- Type 1: Permanent fresh-to-brackish, palustrine wetlands, dense vegetation coverage and mainly connected to artesian regional and local groundwater systems. These are typically found outside the Santos EQ Project Area but can occur where fault systems cause deeper groundwater to see to surface.
- Type 2: Semi-permanent brackish, palustrine wetlands with minor wetland soils and minor vegetation cover, mainly connected to regional groundwater systems. These are typically found in the Fairview, Scotia and Denison regions.
- Type 3: Permanent to semi-permanent riverine wetlands with minor wetland soils and moderate vegetation cover, sourced from local and regional groundwater systems and significantly influenced by surface water flows. These are typically found in the Arcadia Valley and Scotia and southern parts of the Roma regions.
- Type 4: Semi-permanent fresh riverine-to-palustrine wetlands with minor wetland soils and moderate vegetation cover, mainly connected to local groundwater systems, located within riverine environments with deep, sandy, alluvial deposits. These are typically found in the all the parts of the Santos EQ Project Area where local flow systems exist.
- Type 5: Wetlands located within riverine-to-palustrine environments with shallow-to-nil unconsolidated material. These wetlands can form in areas of where there is significant topographic variation, such as the recharge areas of the Great Artesian Basin.

An overview of each GDE type is shown on **Figure 48** with **Figure 49** to **Figure 53** detailing each type and where they are likely to occur within the Santos EQ Project Area. The location of these GDE is show on **Figure 54** to **Figure 56**.

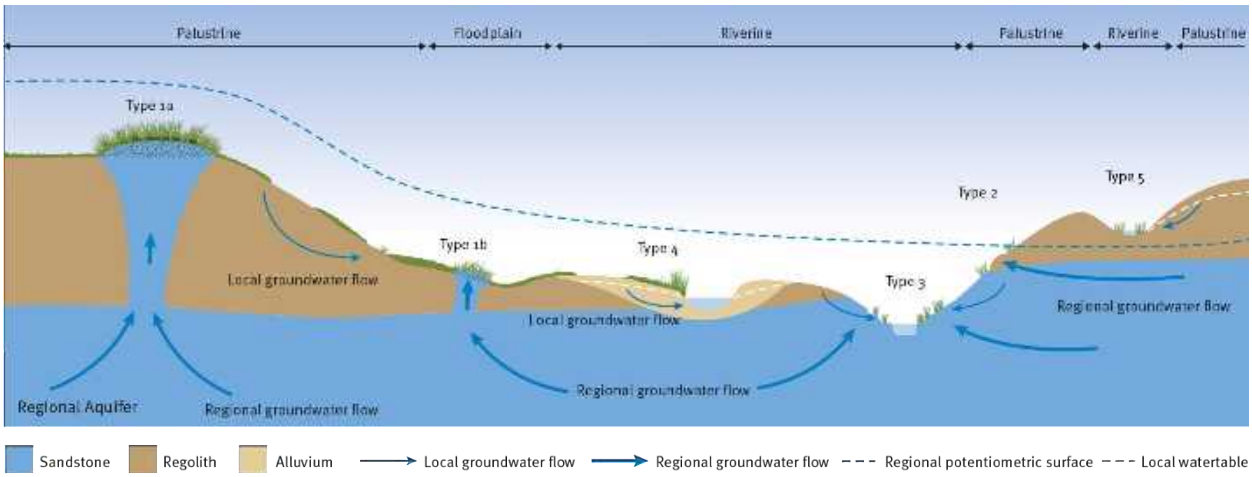


Figure 48. Spring Ecosystems of the Surat and Southern Bowen Basins — Overview

Source: https://wetlandinfo.des.qld.gov.au/wetlands/

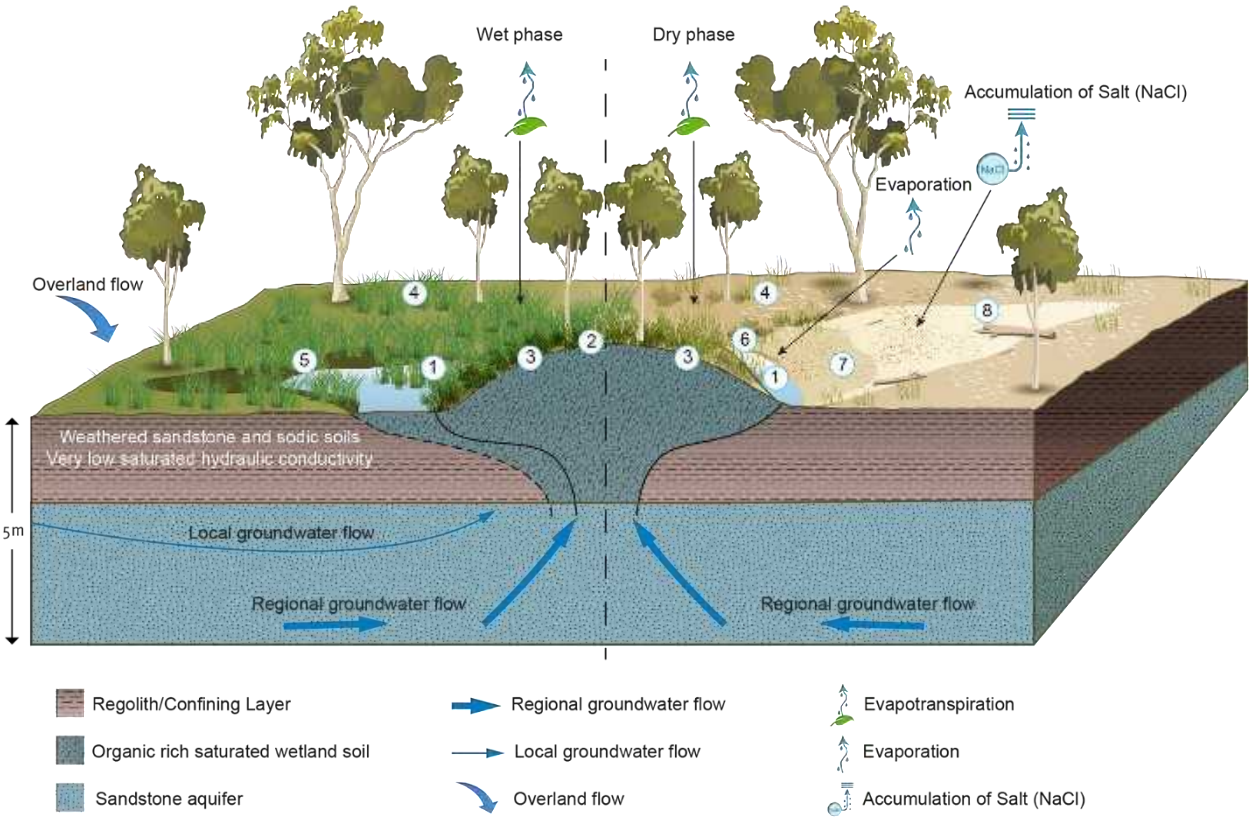


Figure 49. Spring Ecosystems of the Surat and Southern Bowen Basins — Type 1

Source: https://wetlandinfo.des.qld.gov.au/wetlands/

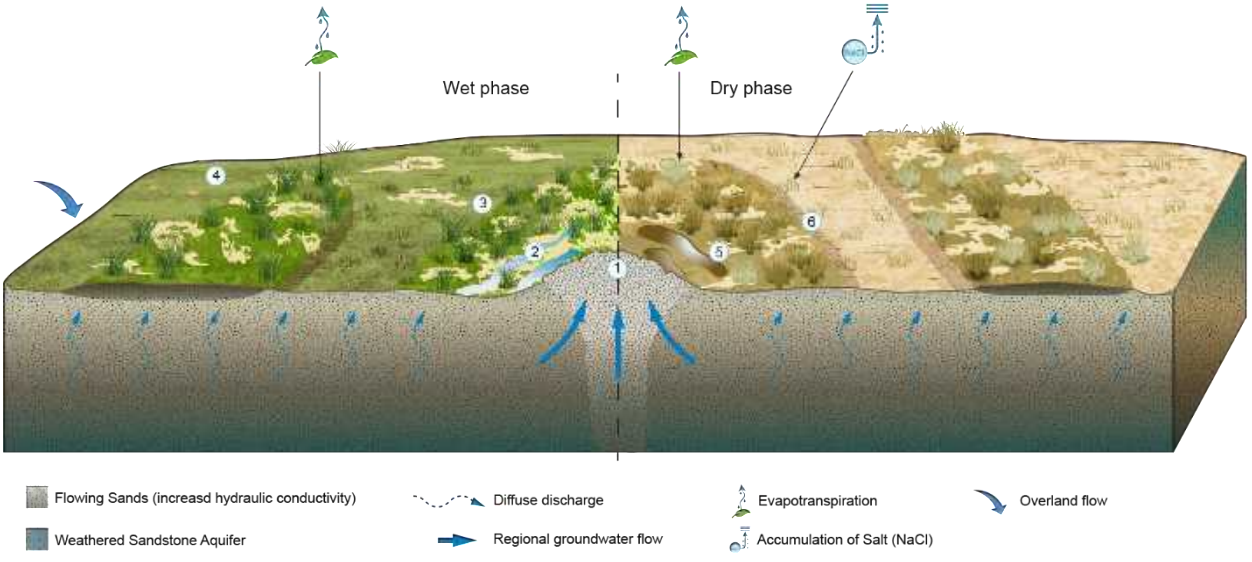


Figure 50. Spring Ecosystems of the Surat and Southern Bowen Basins — Type 2

Source: https://wetlandinfo.des.qld.gov.au/wetlands/

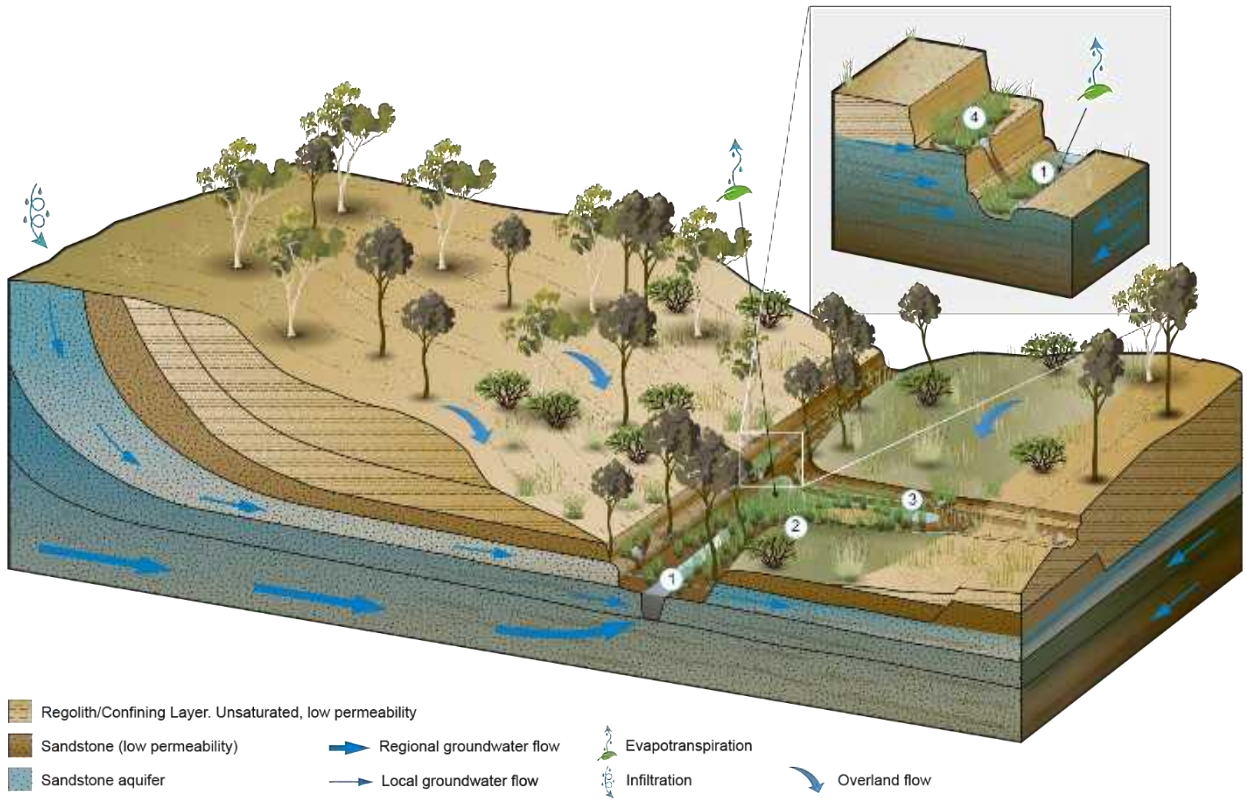


Figure 51. Spring Ecosystems of the Surat and Southern Bowen Basins — Type 3

Source: https://wetlandinfo.des.qld.gov.au/wetlands/

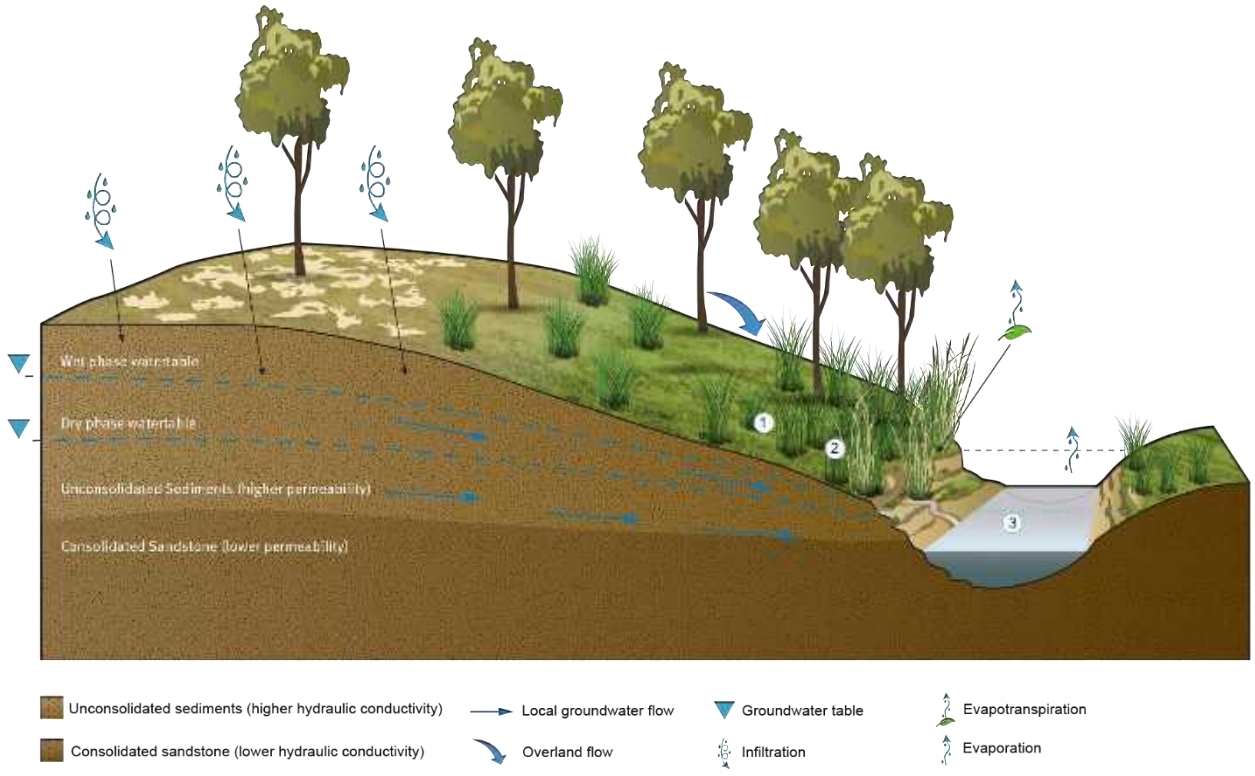


Figure 52. Spring Ecosystems of the Surat and Southern Bowen Basins — Type 4

Source: https://wetlandinfo.des.qld.gov.au/wetlands/

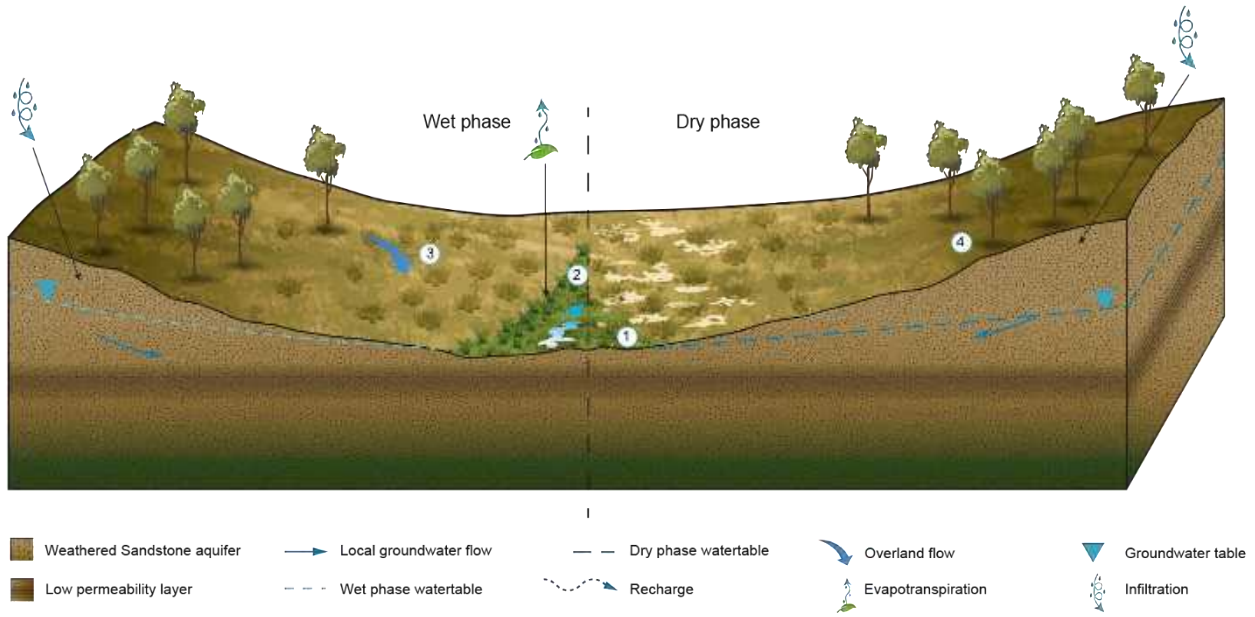


Figure 53. Spring Ecosystems of the Surat and Southern Bowen Basins — Type 5

Source: https://wetlandinfo.des.qld.gov.au/wetlands/

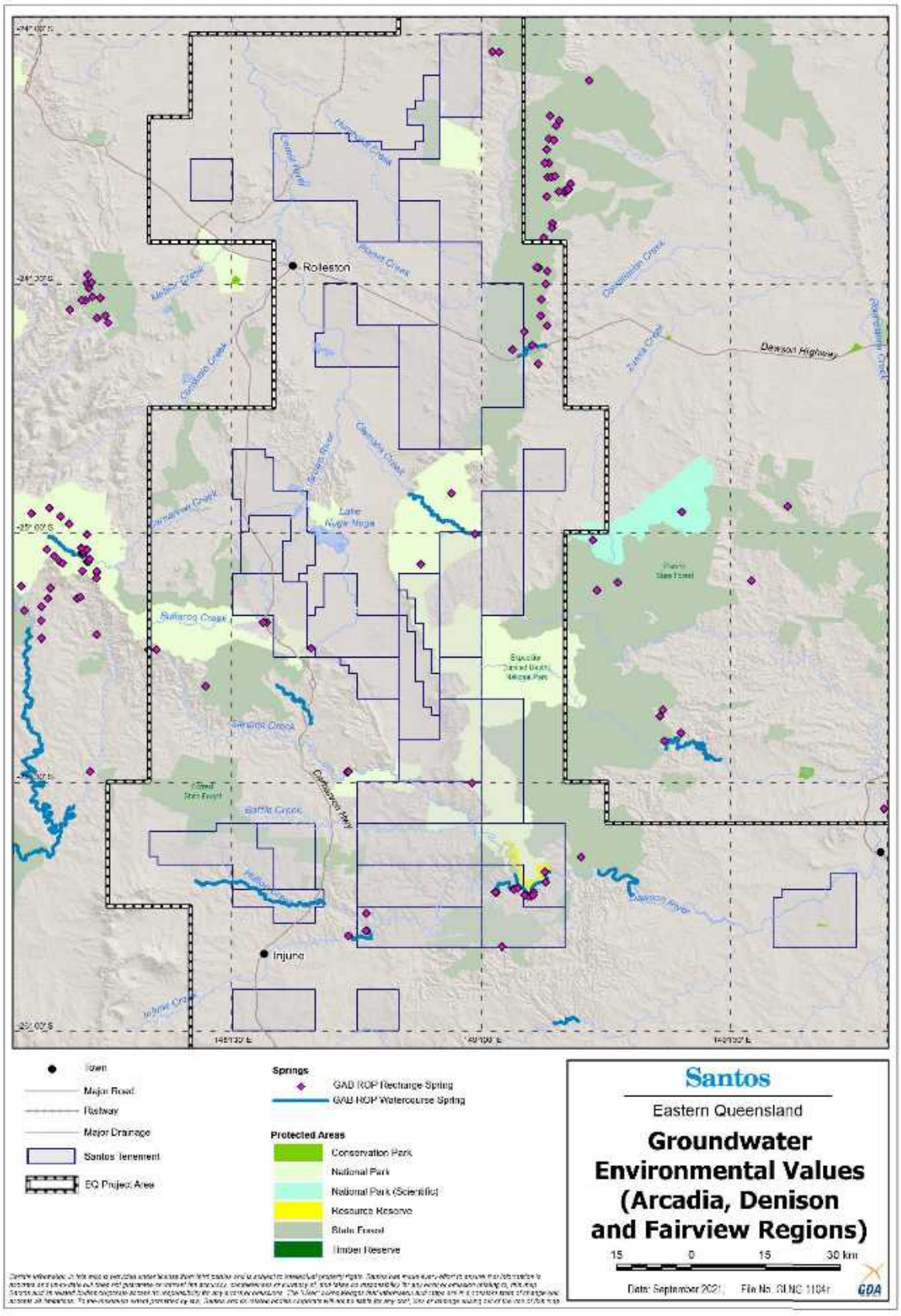


Figure 54. Environmental Values (Fairview, Arcadia Valley and Denison Region)

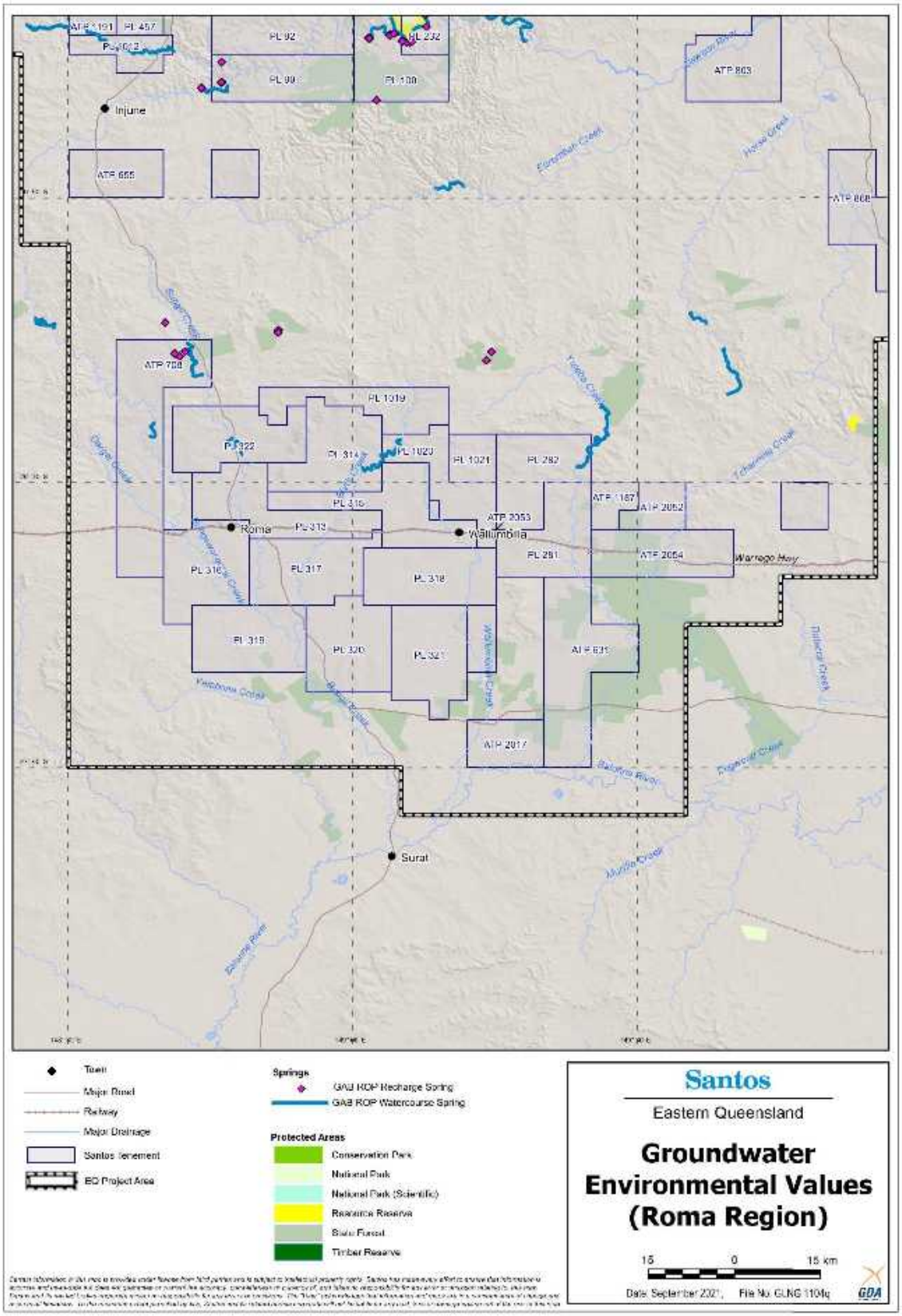


Figure 55. Environmental Values (Roma Region)

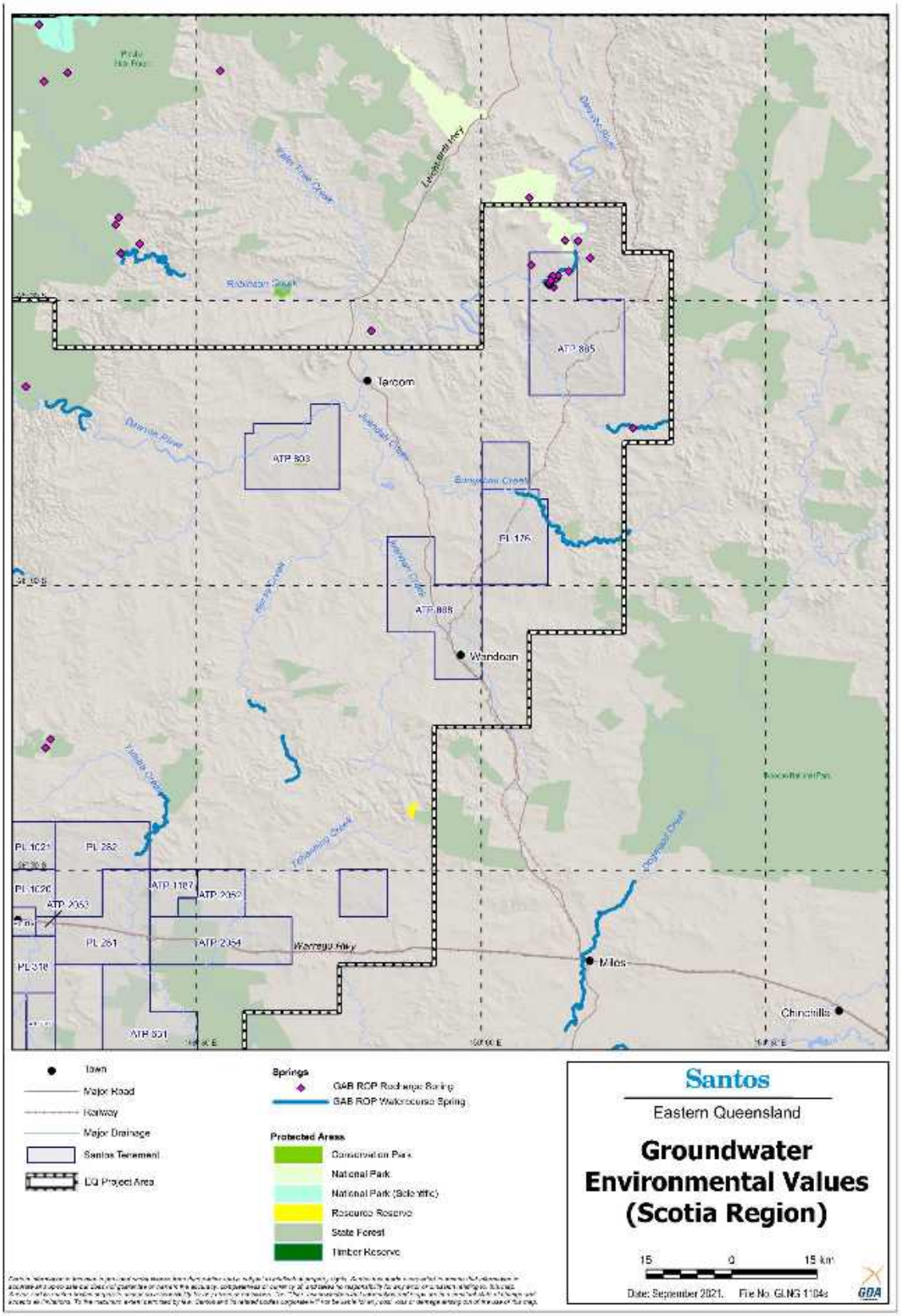


Figure 56. Environmental Values (Scotia Region)

3.7 Proximity of Overlying and Underlying Aquifers to Coal Sequences

The key aquifer units in the Santos EQ Project Area are considered to be the:

- Mooga Sandstone.
- Gubberamunda Sandstone.
- Hutton Sandstone.
- Precipice Sandstone.

The geological cross-sections provided in **Figure 18** to **Figure 20**, **Figure 21** to **Figure 26** and **Figure 30** to **Figure 35** illustrate the vertical thickness of stratigraphy, which separates the key GAB aquifers from the targeted coal measures. These thicknesses are estimated and summarised in **Table 14**.

Table 14. Stratigraphic Thickness Ranges Separating Coal Measures and Reservoirs from Aquifers

Development Area	Roma Region	Arcadia Valley Region	Fairview Region	Denison Region	Scotia Region
Mooga (GAB)	250 – 550 m	np	np	np	np
Gubberamunda (GAB)	65 – 200 m	np	np	np	np
Springbok (GAB)	0 m**	np	np	np	100 – 350 m
Hutton (GAB)	150 – 350 m	np	780 – 980 m	np, >800 m	>440
Precipice (GAB)	90 – 400 m	np	300 – 520 m	500 – 850 m	100 – 350 m
Clematis Sandstone (BB)	>550 m	200 – >750 m	220 – >760 m	350 – 450 m	np
Aldebaran Sandstone (BB)	>650 m*	>650 m*	>650 m*	>650 m*	np

np = not present
GAB = Great Artesian Basin (Surat Sub-basin, Jurassic-Cretaceous)
BB = Bowen Basin (Permian-Triassic)
** maximum (uncertain due to lack of information)*
*** generally a poor aquifer in the RSGPA but may be more viable in the eastern parts of the project area.*

3.8 Proximity of Aquifers with EVs and Potential Impacts on Surface Water

Across the Santos EQ project area, potable water supplies are primarily resourced from the following aquifers:

- Mooga Sandstone
- Gubberamunda Sandstone
- Hutton Sandstone
- Precipice Sandstone
- Clematis Sandstone
- Aldebaran Sandstone.

The proximity of these drinking water supply aquifers to the targeted coal seams are detailed in **Table 14**, described in detail in **Section 3.5** and spatially illustrated in **Figure 45** through **Figure 47.**

The Santos EQ Project Area is located in what is considered a portion of the recharge beds area for the GAB. The GAB recharge area is commonly defined as the area where the GAB sandstone aquifer formations subcrop or

outcrop on the eastern margins of the GAB. Several GAB recharge springs have been identified in the Project Area.

A reduction or loss of baseflow contribution from groundwater to rivers and creeks could potentially affect the aquatic ecology of the surface water ecosystems. For this to occur, inter-aquifer transfer associated with coal seam depressurisation would have to propagate through a thick stratigraphic sequence above the coal seams to affect the shallow 'water table' aquifers.

The Santos GLNG Project Coal Seam Water Monitoring and Management Plan – Stage 2 (S2 CWMMP) (April 2013), details groundwater modelling which indicates that the effects of inter-aquifer transfer are likely to be limited to the aquifers in close stratigraphic succession to the depressurised gas-bearing coal seams targeted by Santos EQ.

The shallow groundwater resources and surface water features are considered unlikely to be affected in Roma region.

In Fairview region, groundwater modelling has predicted impacts between 3 m (a base case scenario modelled) and 8 m (worst case scenario) within the Precipice Sandstone in the southwest corner of the FPA where the Bandanna Formation is in direct contact with the Precipice Sandstone (Rewan Formation absent). In the worst-case scenario, the predicted impact to the baseflow of the Dawson River is a decrease of 1.5% of current baseflow (UWIR, 2019).

3.9 Groundwater Extraction and Use

3.9.1 Surat CMA

There are approximately 22,500 water bores in the Surat CMA (UWIR, 2019). Of these, around 8,100 access the formations in the GAB, predominantly for stock and domestic (S&D), stock intensive, industrial and town water supply purposes. About 13,500 bores access the overlying alluvium (mainly the Condamine Alluvium) and tertiary basalts for irrigation and S&D purposes. The remaining bores access the underlying Bowen Basin.

The majority of non-CSG groundwater extraction is not metered, resulting in a high degree of uncertainty in relation to actual use. The approach initially developed for the UWIR 2016 for estimating unmetered groundwater is now further improved. Based on this refined approach and new data, current non-CSG groundwater extraction in the CMA is estimated to be around 164,000 ML/year – 20% less than previous estimates. Of this, about 25% is from the GAB formations.

CSG groundwater extraction has been relatively steady over the last three years at around 60,000 ML/year. This is likely due to a combination of declining water extraction from maturing fields and an increasing number of CSG wells in nearby areas. Extracted water is treated and primarily used for beneficial purposes or reinjected into aquifers. One reinjection scheme

3.9.2 Santos EQ Project Area

Within the Santos EQ Project Area, groundwater from the various aquifers is generally of good quality and is used for a range of activities. As previously presented, **Figure 45** to **Figure 47** show the locations of groundwater users across the Santos EQ Project Area, however some bores with non- active licenses, or bores which could not be related to GMAs (i.e., no coordinates provided), may not be presented. Of the bores above, illustrates the estimated proportional usage of groundwater in each GMA, based on information extracted from the NRM water-licensing database – Water Entitlements Registration Database (WERD).

Note that the data presented here may not account for all stock and domestic bores as those bores have not always been required to be registered in Queensland.

The primary use of water within the Surat, Surat North and Mimosa GMAs is for stock, the secondary use for domestic purposes and to a lesser extent for urban water supply, agriculture (including irrigation and intensive stock watering) and industrial purposes. suggests that the primary use of groundwater to north and north-west of the AVPA (Bowen Basin) is for irrigation, urban supply (namely town water supplies) and stock. Groundwater bores licensed for urban supply are concentrated around the town of Emerald and the irrigation bores are more spread through the region. Most of the irrigation bores are completed within the shallow alluvium deposits and a few in the Aldebaran Sandstone (Back Creek Group). The 2005 Australian Natural Resources Atlas (ANRA, 2005) confirms most bores in the Bowen Basin are being used for irrigation purposes.

Figure 58 illustrates the proportional number of licensed groundwater bores across the Project area completed within the aquifers of significant importance.

The primary aquifers targeted for groundwater extraction around Roma region are the Mooga Sandstone and Gubberamunda Sandstone. This is contrasted with the allocations around Fairview region with the largest allocations to the Hutton Sandstone and Precipice Sandstone. The primary uses of the bores in the Mooga and Gubberamunda Sandstones are domestic and stock supply whereas the primary use of the Hutton Sandstone and Precipice Sandstone bores are stock intensive and town supply, which generally require formal allocations and entitlements.

The primary aquifer targeted for groundwater extraction in Fairview region is the Hutton Sandstone, with the primary use for town water supply and domestic and stock use for the stratigraphy of the Bowen and Surat Basin). Only one percent of the licensed bores around Fairview region are completed in the alluvial and tertiary deposits within the region but significant allocations are provided from these deposits for irrigation use.

North of Fairview and within Arcadia Valley region, the primary target aquifer includes the Clematis Sandstone. Water is assigned for town water supply, domestic and stock use. Bores completed in alluvium, tertiary deposits and basalt are assigned large nominal allocations in this area and are used primarily for irrigation. As for bores in the Permian deposits of the Bowen Basin, the Aldebaran Sandstone, most bores have been licensed for town supply and irrigation.

In the Scotia region, the Precipice and Hutton Sandstone are primarily targeted however these aquifers become quite deep and uneconomical to access in the southern part of the Scotia region. In this location the lower yielding and poorer quality shallow systems are targeted for stock watering.

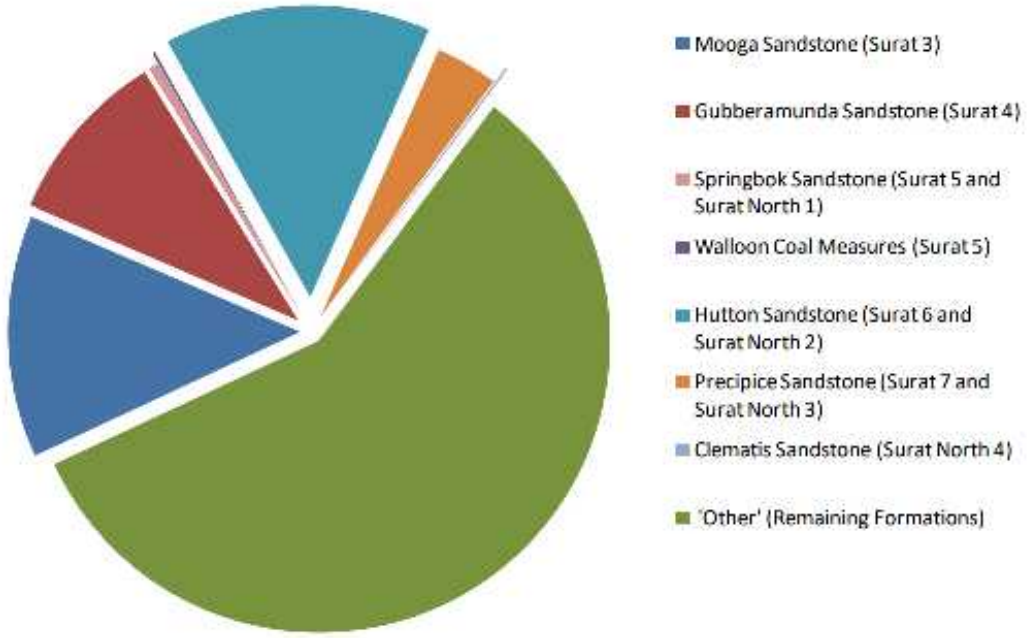


Figure 58. Distribution of Bores Completed in Aquifers of Significant Importance across the Santos EQ Project Area Currently Being Developed

4 Hydraulic Fracturing Process

The information provided in this section addresses the following EA approval requirements: conditions (a), (b), (m), (n), (o), (r), (t) and (z)(1).

4.1 Introduction

The description of the hydraulic fracturing process is covered under the following headings:

- Description of the coal seams and the gas they contain
- Purpose of the hydraulic fracturing process
- Description of the hydraulic fracturing process
- How is hydraulic fracturing carried out
- Infrastructure and equipment used
- Stages of hydraulic fracturing
- Assessment techniques for determining extent of stimulation activities
- Practices and procedures used to ensure fracture remains in target zone
- Program for wells to be fractured
- Frequency of hydraulic fracturing
- Distribution of wells fractured to date and to be fractured
- Location of landholders' active bores
- Chemical constituents in acid and hydraulic fracturing package.

Prior to considering the practice of hydraulic fracturing to enhance gas well production, two important matters require addressing in accordance with the requirements of the EA conditions, namely:

- Comparison to international best practice – are the procedures employed by Santos' contractors considered international best practice?
- Well mechanical integrity – are the gas production wells constructed by Santos EQ and their well contractors completed in a manner to ensure well integrity? What testing methods are employed by Santos to ensure that they are built in an appropriate manner such that they maintain their integrity under normal operational use?

These matters are discussed in the following sections.

4.2 Code of Practice and International Best Practice

The Queensland government has developed a *Code of Practice for the Construction and Abandonment of Petroleum Wells and Associated Bores in Queensland* (Version 2, 16 December 2019). The code covers all petroleum well types including exploration, appraisal, monitoring, injection, development and production wells. It also covers water bores, including water observation, water supply and water injection bores. The Code of Practice applies to the following well life cycle phases:

a) well planning and well design
b) well construction (up to the production wing valve of the well head/Christmas tree) including construction of new water bores by operators
c) well evaluation
d) well completion including hydraulic fracture stimulation activities
e) well production and operation
f) well integrity management
g) conversion of petroleum wells to water bores
h) well suspension
i) well abandonment

For all the stages the code of practice considers equipment and material selection, risk assessment (both safety and environment), industry practices, monitoring and reporting. This guidance has been developed using international best practices including the following key guidance and references:

- Queensland Government, Code of Practice for Constructing and Abandoning Coal Seam Gas Wells in Queensland. Version 1. November 2011.
- American Petroleum Institute (API) Recommended Practice 10B-2/International Standards Organisation (ISO) 10426-2, Recommended Practice for Testing Well Cements
- API Recommended Practice 10B-3/ISO 10426-3, Recommended Practice on Testing of Deepwater Well Cement Formulations.
- API Recommended Practice 10B-4/ISO 10426-4, Recommended Practice on Preparation and Testing of Foamed Cement Slurries at Atmospheric Pressure.
- API Recommended Practice 10B-5/ISO 10426-5, Recommended Practice on Determination of Shrinkage and Expansion of Well Cement Formulations at Atmospheric Pressure.
- API Recommended Practice 10B-6/ISO 10426-6, Recommended Practice on Determining the Static Gel Strength of Cement Formulations.
- API Specification 10D/ISO 10427-1, Specification for Bow-Spring Casing Centralizers.
- API Specification 10D-2/ISO 10427-2, Recommended Practice for Centralizer Placement and Stop Collar Testing.
- API Recommended Practice 10F/ISO 10427-3, Recommended Practice for Performance Testing of Cementing Float Equipment.
- API Technical Report 10TR1, Cement Sheath Evaluation.
- API Technical Report 10TR3, Temperatures for API Cement Operating Thickening Time Tests.
- API Technical Report 10TR4, Technical Report on Considerations Regarding Selection of Centralizers for Primary Cementing Operations.
- API Technical Report 10TR5, Technical Report on Methods for Testing of Solid and Rigid Centralizers.
- API Recommended Practice 13B-1/ISO 10414-1, Recommended Practice for Field Testing Water- Based Drilling Fluids.
- API Recommended Practice 13B-2/ISO 10414-2, Recommended Practice for Field Testing Oil- based Drilling Fluids.
- API Recommended Practice 53, Blowout Prevention Equipment Systems for Drilling Operations.
- API Recommended Practice 65, Cementing Shallow Water Flow Zones in Deep Water Wells.
- API Recommended Practice 90, Annular Casing Pressure Management for Offshore Wells.

The following guidance documents published by API specifically for hydraulic fracturing activities describe an overview of the international best practices and procedures. Information from these guidance documents is also referenced throughout this report:

- API, Guidance Document HF1 (HF1), Hydraulic Fracturing Operations – Well Construction and Integrity Guidelines, First Edition/October 2009.
- API HF1 highlights industry recommended practices for well construction and integrity for hydraulically fractured wells and provides guidance to ensure that shallow groundwater aquifers and the environment will be protected.
- API, Guidance Document HF3 (HF3), Practices for Mitigating Surface Impacts Associated with Hydraulic Fracturing, First Edition/January 2011.
- API HF3 identifies and describes the current practices used in the oil and gas industry to minimize surface environmental impacts—potential impacts on surface water, soils, wildlife and other surface ecosystems and nearby communities—associated with hydraulic fracturing operations.

Both Santos and the hydraulic fracturing contractors operating in Australia have adopted the requirements of the Code of Practice and international best practices (as described above) which are also discussed within the Code of Practice.

In addition, the State (through disclosures to the Department of Natural Resources Mines and Energy) and the Commonwealth require full disclosure of the chemicals used in hydraulic fracturing fluid systems. Including, the chemical products used, their chemical makeup and the mass ratios of all chemicals used in the hydraulic fracturing fluid system.

Additional advancements in technology and practices – for example, using company-researched licensed technologies for placement of specifically designed treatments into each perforated zone are evolving. These innovations have included synthetic proppants, perforation agents and sealing and bridging compounds.

4.2.1 Risk Assessment and Site Location

As documented in the Code of Practice, “operators must carry out a risk assessment to identify the risks that may occur during well or bore construction, operation and abandonment. Risks to be managed must include, as a minimum, site access and preparation, well integrity, groundwater protection and safety of personnel and the community.” The core strategies of avoidance, management and mitigation (in this order) are implemented to address potential risks with the core strategies for hydraulic fracturing being focused on avoidance and management.

A core component of risk management is associated with appropriate siting of the wells. As documented in the Code of Practice this process identifies through desk top evaluations potential or suitable sites within known constraints such as tenement boundaries, topographic constraints, geologic constraints to development and environmental restrictions. Supplemental work is conducted to inform the process including seismic surveys and ground truthing with a focus on ensuring the location is ideally suited to development and that key risk and/or environmental factors (faults that have the potential to propagate from the target sequence into overlying aquifers, poorly constructed historic bores etc.) are not present.

As part of this assessment (and consistent with the requires of the Code of Practice), Santos consults with relevant stakeholders, including landholders, to choose the final, most appropriate site. This process considers all other potential constraints (e.g., access routes, environmental constraints, cultural heritage and landowner constraints). Through the combination of desk top studies, supplemental assessments, ground truthing and stakeholder engagement Santos completes all assessments required by law including:

1. environmental checks (e.g., distance from specific flora and fauna communities)
2. cultural heritage inspections (particularly regarding indigenous cultural heritage)
3. topography restrictions and issues (avoiding water courses, ravines, steep cliff faces)
4. land use restrictions (including consultation with landholders)
5. safety offsets from landholder bores to ensure no impacts on water usage or water quality
6. Avoidance of areas where inter-aquifer connectivity may exist and or structures that may facilitate movement of hydraulic fracturing fluids into overlying aquifers
7. Stakeholder and landowner liaison requirements.

Once the site location has been determined (as described above), the primary concern is the management of safety and the environment impacts during the execution of work. For safety of both site personnel and landholders, the Code of Conduct recommends that well sites be sized and prepared appropriately and may also be fenced for safety and to provide a barrier to exclude livestock and large wildlife.

4.3 Well Mechanical Integrity

A critical component of maintaining a high degree of protection of the various aquifers within the Surat and Bowen Basin sequences is through the robustness and longevity of the well construction itself. The well is required to isolate the production fluids from the aquifer units during its working life and beyond, even after it has been formally abandoned by the mandated well abandonment processes (including pressure cementing). It is this robustness of construction that permits the well to maintain its integrity.

Throughout the entire process, stringent quality control and testing is undertaken to ensure the integrity of the casing and seals. These quality control procedures are implemented through the material selection and sourcing process and installation.

NOTE: The discussion of well integrity has been drawn from discussions and information provided by Santos EQ and supplemented by information directly sourced from American Petroleum Institute publication ‘Hydraulic Fracturing Operations – Well Construction and Integrity Guidelines’ (API Guidance Document HF1 First Edition, October 2009) and the Code of Practice. The reader is urged to consult this document for a detailed description of the well completion process.

Maintaining a gas production well's integrity is essential for the two following reasons:

- To isolate the internal conduit of the well, namely the well casing pipe, from the surface and subsurface environment. This is critical in protecting the environment, including the groundwater, and in enabling well drilling and production.
- To isolate and contain the well's produced fluid (i.e., the gas) to a production well casing pipe within the well.

Groundwater is protected from the contents of the gas well during drilling, hydraulic fracturing, and production operations by a combination of drilling muds used in the process, steel casing and cement sheaths, and other mechanical isolation devices installed as a part of the well construction process. Well design and construction seek to achieve this level of robustness in a much more thorough manner than is achieved by the impermeable rock formations that lie between the gas-bearing target formations and the groundwater which have effectively isolated the groundwater over millions of years. The construction of the well is done to prevent communication (the migration and/or transport of fluids between these subsurface layers).

The primary method used for protecting groundwater consists of drilling the well borehole and then cementing steel pipe into place using specialised cement types. The casing and cement are specifically selected to accommodate several factors including formation types, groundwater quality, gas characteristics and operational conditions.

As documented in the Code of Practice (pp 10), 'all wells must be designed and constructed to ensure the safe and environmentally sound production of fluids by:

a) well objectives being met
b) preventing any cross-flow contamination between hydrocarbon bearing formations and aquifers
c) ensuring that fluids are contained within the well and associated pipework and equipment without leakage. Failure of one barrier must not lead to an uncontrolled release of formation fluids (blowout). It is noted that CSG wells typically have a single barrier between surface and a hydrocarbon bearing zone for portions of its life due to its producing arrangement. Operators must have appropriate processes in place to address this.
d) ensuring zonal isolation between differently pressured permeable formations (e.g., aquifers and hydrocarbon bearing zones) is achieved
e) prevent/avoid the introduction of substances that may cause environmental harm
f) testing and acceptance requirements are satisfied
g) wells can be monitored and maintained to contain and control wellbore fluids, provide structural support and otherwise retain well integrity throughout all reasonably anticipated construction, testing, production, injection, intervention, workover, suspension and abandonment load conditions – as may occur during the specified design life of the well.
h) The completion needs to be designed to operate within the maximum expected pressures and load conditions until final abandonment.

In accordance with the requirements of the code the casing and cement of the wells is critical for protection of aquifers.

The coal seams and reservoirs containing gas produce into the well through perforations in the steel pipe and cement sheaths opposite the respective coal seams, with the produced gas being contained within the well pipe and the production all the way to the surface. The concrete annular seal between the casing and the formation. This containment is what is meant by the term 'well integrity'.

Regular monitoring takes place during drilling and production operations to ensure that these operations proceed within established parameters and in accordance with the well design, well plan, and permit requirements. This includes testing of the well integrity during well construction and over the life of the well as described in subsequent text.

4.3.1 Drilling and Well Completions

Drilling a typical oil or gas well consists of several cycles of drilling, running casing (steel pipe for well construction), and cementing the casing in place to ensure isolation. In each cycle, steel casing is installed in sequentially smaller sizes inside the previous installed casing string. The last cycle of the well construction is well completion, which can include perforating (creating holes in the steel pipe opposite the coal seam) and hydraulic fracturing or other stimulation techniques depending on the well type.

Drilling and completing an oil and/or gas well consists of several sequential activities. A list of these activities appears below. In sequential order, these activities are as follows:

- Preparing the well location (drill pad) and installing fluid handling equipment

- Setting up the drilling rig and associated equipment
- Drilling the borehole
- Logging the borehole (running geophysical survey instruments down the borehole) (if required)
- Running casing (steel pipe)
- Cementing the casing using grouting equipment to inject specialised cement mixes
- Removing the drilling rig and ancillary equipment
- Logging the casing to test for integrity (if required)
- Perforating the casing (depending on well completion type)
- Hydraulic fracturing or stimulating the well
- Installing artificial lift equipment (if necessary)
- Install surface production equipment
- Putting the well on production
- Monitoring well performance and integrity
- Rehabilitating those areas of the drilling pad that are no longer needed and removing equipment no longer used in the gas production operations.

It is the activities highlighted in italicised text that largely ensure the integrity of the well, and which are discussed in further explanatory text below.

4.3.2 Selection and Sourcing of Casing Material

To ensure long term casing integrity, Santos EQ has developed detailed specifications for all well casings and well completion materials. These specifications meet or exceed the specifications/recommendations contained within the Code of Practice. These materials have been specifically designed and selected for the proposed application and lifecycle of the well. Material specifications differ based on the depth of the well, formation pressures, anticipated gas pressures, geochemical considerations and the nature of proposed down-well infrastructure.

All materials are inspected by Santos EQ and the contractors prior to installation to ensure compliance with the Santos EQ specifications. A similar process of inspections and testing are utilised throughout the drilling and casing installation program. This testing and inspection is discussed in the sections below.

4.3.3 Logging the Borehole

Borehole and well logging can be carried out at various stages of the wells drilling and completion, including:

- Open borehole logging is used to obtain specific information of the properties for the rock formations drilled, gas-bearing coal seam properties and the nature of the borehole created. This is primarily used to assess the gas resource, the media properties, and to provide geological and hydrogeological information used to design the well and cementing requirements.
- Cased well logging can be used to obtain specific information of the properties of the rock, cement and/or casing integrity, depending on the logging tool used. These specific issues are discussed in further detail below.

Upon completion of the drilling of a borehole section, and before casing is installed and cementing operations begin, sensor instruments can be run into the open (uncased) drilled borehole on a data cable. Alternatively, logging tools or sensors may be included in the drilling bottom hole assembly so the well may be logged as it is being drilled. The information collected and the process used is typically referred to as ‘well logging’ or ‘geophysical borehole logging’, while the sensor is typically referred to as a ‘logging tool’. Typical geophysical logging methods that are run in a well are designed for the specific location, geology, resource and well design information types and include:

- Gamma Ray: a sensor that detects naturally occurring gamma radiation (it identifies clay mineral rich rock, due to the presence of radioactive potassium commonly found in the rock mass).

- Resistivity: a sensor, which measures the electrical resistance between probes on the logging tool in the wellbore. Resistivity logging is commonly for formation evaluation in oil- and gas-well drilling. Most rock materials are essentially insulators, while their enclosed fluids are conductors. Coal and hydrocarbon fluids are an exception, because they are almost infinitely resistive. In addition, when a formation is porous and contains salty water, the overall resistivity will be low (more conductive). High resistivity values may indicate a hydrocarbon bearing formation, and this includes coal.
- Spontaneous Potential (or Self Potential, Shale Potential log) (SP): The SP log is a voltmeter measurement of the voltage or electrical potential difference between the drilling mud in the borehole at a particular depth and a copper ground stake driven into the surface of the earth a short distance from the borehole. A salinity difference between the drilling mud and the formation water is detected, and the nature of the formation can be assessed based on the differences in conductivity measured. The resulting log curve reflects the permeability of the rocks and, indirectly, their lithology (e.g., shale versus sandstones).
- Density and the Neutron log: A device used to measure the bulk density of, and, by inference, the porosity of the formation. See also sonic log.
- Calliper: A physical measurement of the diameter of the wellbore. A calliper log run through a well borehole is used to calculate the borehole size, shape and volume of the hole.

Sonic Log: Sonic logs use a pinger and microphone arrangement to measure the velocity of sound in the formation from one end of the sonde to the other. For a given type of rock, acoustic velocity varies indirectly with porosity. If the velocity of sound through solid rock is taken as a measurement of zero per cent porosity, a slower velocity is an indication of a higher porosity that is usually filled with formation water with a slower sonic velocity. Both

- sonic and density-neutron logs give porosity as their primary information. Sonic logs read farther away from the borehole so they are more useful where sections of the borehole are caved. Because they read deeper, they also tend to average more formation than the density-neutron logs do. As such, they are complimentary in that they output and provide more definitive information as to the rock types at various depth locations in the borehole being logged.

Logging produces detailed information on all rock formations logged and the groundwater quality they might contain. Logging also determines the actual depth and thickness of the subsurface formations in the drilled hole.

Many other types of logging tools are available and may be run on a case specific basis.

After cementing the casing pipe in place, ‘cased-hole’ logs can be run inside the casing to validate the quality and integrity of the cement job. These logs can include the following:

- Gamma ray (described previously)
- Collar locator (a magnetic device that detects the casing collars)
- Cement bond log (CBL) and variable density log (VDL) that measures the presence of cement and the quality of the cement bond or seal between the casing and the formation.

The CBL-VDL is an acoustic device that can detect cemented or non-cemented casing. The CBL works by transmitting a sound or vibration signal, and then recording the amplitude of the arrival signal. Casing that has no cement surrounding it (i.e., free pipe) will have large amplitude acoustic signal because the energy remains in the pipe. While casing pipe that has a good cement sheath that fills the annular space between the casing and the formation will have a much smaller amplitude signal since the casing is ‘acoustically coupled’ with the cement and the formation which causes the acoustic energy to be absorbed.

Santos EQ contract experienced contractors to run the CBL – VDL and the results are evaluated to determine the integrity of the cement seal.

Santos EQ contractors most commonly use CBL-VDL cement evaluation tools, however other types of cement evaluation tools are available and, depending on the situation, are considered as a part of the cement evaluation program.

Cement logging and evaluation is completed in accordance with the Code of Practice. Logging is completed in each new field/geological area or for each significant change in design to demonstrate repetitive successful zonal isolation.

4.3.4 Well Completion Design

On the basis of the drill-chips and borehole core retrieved from the drilling of the well hole (when applicable), together with the information gained and analysed from the geophysical logging of the borehole, a well completion

design for the well is determined by the well engineering team; a typical design is illustrated in **Figure 59**. The basis of the site-specific design for the well construction emphasises barrier performance and zone isolation (including aquifer, low quality groundwater and unstable formation isolation), as well as gas production efficiency.

The well design and specifications include wellbore preparation, mud removal, casing pipe running and cement placement to provide barriers that prevent fluid migration and well leakage. The selection of the materials for cementing and casing, and the process of cement placement are important considerations in designing the well such that it ensures optimum performance of the barrier system to protect groundwater and isolate the hydrocarbon bearing zones. The well design process also includes contingency planning to mitigate and eliminate the risk failure due to unforeseen events.

The well design process also accommodates the analysis of those factors which determine the hydraulic fracturing outcomes. These include defining the optimal location and orientation of perforations such that the zone of hydraulic fracturing is contained entirely within the target formation. The latter involves the assessment of borehole core, porosity analysis, cleat orientation and density testing, bedding plane analysis, coal interbed content, and stress field analysis.

4.3.5 Casing Design and Completion

Drilling typically consists of several cycles of drilling, running casing and cementing the casing in place to ensure isolation. In each cycle, casing is installed in sequentially smaller sizes inside the previous installed casing string. These casing strings are typically installed in the order as follows: conductor casing (if required due to local ground conditions), surface casing and production casing. Specific considerations for each of these casing strings are presented below. It is important to note that the shallow portions of the well have multiple concentric strings of steel casing installed.

- If required due to local ground conditions, the conductor casing stabilises the soil zone from the drilling action of subsequent drilling phases (prevents the lose soils from caving into the borehole) and is cemented into place to ensure an appropriately robust seal (back up to ground level).
- The surface casing is typically installed to protect the shallow formations (weathered or unconsolidated rock layers) and to stabilise the well from the later drilling phases of deeper sections of the borehole.
- The surface casing is designed to achieve all regulatory requirements for isolating groundwater encountered in this hole section and also to contain pressures that might occur in the subsequent drilling process. This casing pipe is cemented into place to ensure an appropriately robust seal.
- After the production hole is drilled and logged, production casing pipe is lowered to the total depth of the borehole and cemented in place. The purpose of the production casing is to provide the final isolation between the gas-bearing coal seams and all other formations for containing and pumping the various fluids used to hydraulically fracture the coal seams from the surface into the producing formation without affecting the shallower layers penetrated by the well. It also houses the downhole production pumping equipment when the well becomes operational. During the operational phase, its most important function is internally containing the gas produced from the coal seams within the well.
- The production casing pipe is pressure cemented to achieve robust and effective isolation of the well from the various subsurface layers (aquifers and aquitards alike).

In accordance with the requirements of the Code of Practice, casing pressure tests are carried out at each stage to ensure integrity of the casing pipe for further drilling or operational conditions. These tests are conducted at pressures that will determine whether the casing integrity is adequate to meet the well design and construction objectives. The test pressure applied is greater than the maximum anticipated formation pressure that could occur at surface but does not exceed the burst pressure rating of the casing with the design safety factor applied.

4.3.6 Cementing

Cement types, additives and mixes are engineered products and are selected and designed to address site-specific conditions relevant to a particular well. Cement mixtures and installation techniques are employed to provide a robust seal that isolates the well from the

surrounding formations and protects the well materials from potentially aggressive groundwater or formation conditions. The selected cement types, additives and mixing fluid are specifically designed and laboratory tested in advance to ensure they meet the requirements of the well design and subsurface conditions at the well location. The cements are not typical building/construction cements, but are tailored cements designed for use in well construction. The type of equipment used for to place cement in the annulus in and around the casing are shown in

Figure **59**.

Placement of the cement is carried out in such a manner (and using appropriate centralising equipment) as to completely surround the casing pipe to achieve successful seal isolation and pipe integrity (

Figure **59**). That is, effective isolation of the well pipe from the various subsurface formations requires complete and even annular filling and tight cement interfaces with the formation and casing. Complete displacement of drilling fluid by cement (to eliminate ‘bubbles’ or voids) and good bonding of the cement interfaces between the

drilled hole and the casing immediately above the gas-bearing coal are important factors taken into account when designing and completing the well to ensure effective and long-lasting well and seal integrity.

The following well design, materials selection and cement procedures are typically implemented at Santos EQ well completion sites:

- The Santos EQ well design team prepares an appropriate well completion design based on a detailed assessment of borehole core, the regional geological model, reservoir analysis, and the history of nearby wells. Historical problems encountered in the area (lost returns, irregular hole erosion, poor hole cleaning, poor cement displacement, etc.) are considered during the design process.
- Computer simulation and completion planning is carried out to optimise cement placement procedures.
- Santos EQ drilling contractors are selected based on their repute, adherence to industry best practice methods and regulatory requirements. Importantly, as it effects cementing, they are required use established, effective drilling practices to achieve a uniform, stable well borehole with desired hole geometry. Additionally, they are required to satisfy Santos EQ health-safety-environmental (HSE) requirements regarding their personnel and equipment. They are required to ensure that their cementing equipment provides adequate mixing, blending and pumping of the cement in the field.
- Santos EQ drilling contractors are required to ensure that the drilling fluid selection is appropriate for the designed well and the geologic conditions likely to be encountered and present a low risk to the environment.
- Site drilling and cementing equipment are selected to adequately achieve the well design that will meet the well design objective and ensure effective isolation.
- Prior to cementing a section of well casing pipe in place, Santos EQ drilling contractors ensure that appropriate well borehole preparation, hole cleaning, and conditioning measured implemented to ensure the cementing works are effective.
- Santos EQ drilling contractors are required to employ casing pipe centralisers to help centre the casing pipe within the borehole and provide for good mud removal and cement placement, especially in critical areas, such as coal seam zones, and groundwater aquifers.
- Santos EQ drilling contractors are required to use appropriate cement testing procedures to ensure cement slurry quality and designs are adequate. These include implementation of appropriate cement slurry quality controls - with testing to measure the following parameters depending on site- specific geological and groundwater quality conditions:
  - Slurry density
  - Thickening time
  - Fluid loss control
  - Free fluid
  - Compressive strength development
  - Fluid compatibility (cement, mix fluid, mud)
  - Sedimentation control
  - Expansion or shrinkage characteristics of the set cement
  - Static gel strength development
  - Mechanical properties (Young’s Modulus, Poisson’s Ratio, elastic/compressibility characteristics, etc.)
- Cement design may include pumping two different slurry designs, using a ‘lead’ cement of lower density and a ‘tail’ cement of higher density and compressive strength. Typically, the tail cement is used to isolate critical intervals in the well.
- Adherence to appropriate setting times ensures that the cement seals are optimal prior to commencing further drilling, hydraulic fracturing and/or operational testing.

In accordance with the Code of Practice (Section 3.6.2) achievement of primary cementing objectives can be demonstrated by achieving a minimum of three of the verification methods below:

- Slurry mixed and placed in accordance with contractor approved cementation procedures and the cement job pressure charts show pressure rise during cement displacement in line with expectations.

- Shoe track volume not over displaced when displacing cement slurry.
- Downhole losses not greater than the excess pumped within the cement procedure, and calculated TOC using final circulating pressure (FCP) and measured fluid returns achieves the objective(s) identified within the cementation program.
- No significant losses or slumping post placement of cement.
- Casing successfully pressure tested.
- Completion of an appropriate cement integrity test such as a formation integrity test.
- Completion of an appropriate cement evaluation log.

4.3.7 Summary

These logging, well design, well completion and well cementing methods ensure that the risk of impact to the containing formations is negligible by ensuring the well completion quality and integrity is maintained. This is carried out to make certain that the aquifer layers intersected by the well do not become impacted by subsequent hydraulic fracturing activities or gas production activities through the operating life of the well concerned.

4.4 Description of the Hydraulic Fracturing Process

As discussed in Section 2, the coal layers or coal 'seams' which host the gas (methane) occur as a series of interbedded layers of coal (in the coals seams of the Walloon Coal Measure and

Blackwater Group/Bandanna Formation) and interburden layers comprising mudstones-siltstones- sandstone assemblages, themselves situated at depth within a much thicker sequence of highly variable sedimentary rock types, also comprising sandstones, siltstones, mudstones and shales (**Table 3**).

The gas is predominantly adsorbed to the surface matrix of the coal or stored as free gas in the natural fracture systems commonly found in coal. Under the natural confining pressure of a typical coal seam, the gas exists in a near liquid state.

The pore spaces within the coal rock mass are made up of fracture, joint plane and micro-fracture voids (the latter are referred to as 'cleats[1]'), as is illustrated in

[1] The vertical cleavage or fracture plane in coal seams. There are usually two cleat systems developed perpendicular to each other. The main set of joints along which coal breaks when mined. They provide the predominant pore space within the coal mass and can provide void space and a conduit plane for groundwater movement and storage.

Figure 60. They impart a generally low permeability characteristic to the coal material, which means that groundwater does not readily flow through the coal under natural conditions. Even under water well pumping conditions coal seams and petroleum reservoirs are seldom considered to be good aquifers.

The procedure for recovering the gas involves drilling a series of production wells into the targeted coal seams and then pumping out the groundwater contained within the coal layers. This process lowers the hydraulic pressure within coal seams, which in turn causes the release of the methane gas from the coal. Specifically, the reduction of pressure in the coal layers causes the methane to desorb from the coal matrix and form gaseous methane, which can be drawn off to the surface via the well.

Gas production is therefore closely linked to reservoir pressure reduction, achieved by groundwater extraction. The groundwater and gas extraction process is accomplished by operating a pump in the production well, typically set in the well casing at a location below the perforations at the coal seam and initiating groundwater extraction to lower the water level in the production well, and consequentially the piezometric head pressure in the coal seam layer.

Groundwater pumping continues until the gas flows freely. Often, no pumping is required once the gas begins to flow strongly as the velocity of the gas acts as a lifting mechanism for the groundwater and the pump may be removed. When the gas flow rate falls, and the groundwater can no longer be extracted by the gas lifting effect, a pump is again set back into the well to continue the groundwater extraction until the gas has been exhausted to an economic level.

Hydraulic fracturing is employed in the gas industry to improve the production efficiency of gas wells. This is achieved by increasing the overall permeability of the coal immediately adjacent to the wells and creating a more efficient pathway for the flow of groundwater and gas from the reservoir into the well bore.

Where necessary it is carried out as one of the last activities involved in the construction of a gas production well and prior to bringing the well into service. It is typically performed on newly installed production wells, that is, after the final (there are normally many) well casing pipe has been inserted and the bore annulus cemented, the casing pipe perforated opposite the target coal seams and the well opened to access the coal seam. Production wells may be subject to multiple fracturing events over their operational life.

A process referred to as ‘cavitation’ is also used to stimulate gas production wells. This method of well stimulation involves injecting air or nitrogen gas at high pressures into the coal seam causing it to fracture and break up. This method is not considered further here since no chemical additives are added to the compressed air used in the procedure.

4.4.1 Hydraulic Fracturing Design Process

As discussed in detail in **Section 4.2**, the borehole core retrieved from the drilling of the well hole, information gained and analysed from the geophysical logging of the borehole, geomechanical stress analyses and the analysed properties of the coal media are considered by Santos EQ's well engineering team to arrive at an appropriate well completion and hydraulic fracture design for the proposed well location.

The basis of the site-specific design for the well to be hydraulically fractured is to exploit the key coal characteristics and properties to optimise the fracture density, spread, orientation and containment. The restrictions considered include but are not limited to, the following key controlling features:

- The coal porosity
- Coal cleat orientation and density (from core and geophysical logs)
- Coal quality (brightness)
- Interbed (net coal) content, density, bedding and quantity
- Bedding plane configuration
- Bulk density, elastic properties and compressibility
- Coal seam thickness
- Thickness of 'seal' rock (aquitard layer) above the top of the uppermost coal seam and below the base of the lowermost coals seam
- Interburden thickness and rock strength
- Stress field analysis to determine the maximum principal stress direction and the minimum principal stress direction.

The well design process therefore accommodates detailed analysis of those parameters, which determine the hydraulic fracturing outcomes and containment within the coal seam concerned. These include defining the optimal location and orientation of perforations such that the zone of hydraulic fracturing is contained entirely within the target formation.

The importance of maximising the in-coal fracturing density and connectedness, whilst controlling the overall containment of the fracturing entirely within the coal seam itself is paramount in achieving a useful outcome. Any fracture, which moves outside of the coal seam, has the potential to connect to groundwater from a non-coal layer (say, an aquifer unit, e.g., The Springbok Sandstone). Such an outcome would result in an inefficient gas well since excessive groundwater would have to be extracted to achieve gas liberation. As such, the well would be costly to operate, inefficient and produce excessive water requiring costly treatment and handling. Hydraulic fracturing design is thus tightly controlled to avoid such occurrences.

Section 2.4.2 provides a discussion of the methodology employed by Santos EQ for the analysis of stress and rock strength in the development areas. It is generally undertaken in-house (geomechanics team). Borehole studies utilise image log data, wireline log data, rock strength testing and drilling experience to model the stress variation between geological rock units from surface to the target coal seams, namely, the Walloons and Bandanna Coals of the Surat and Bowens Basins sequences, respectively.

The tectonic contribution to the regional compressive stress field within continental Australia is reflected in the N-NNE orientated major horizontal stress field prevalent in the Surat and Bowen Basins. The minor horizontal stress will be approximately normal to this, viz. E-ESE. The horizontal in-situ stress can be relatively high and anisotropic and exceed the vertical stress due to gravity. These factors typically define the orientation and pressures employed in hydraulic fracturing in the Santos EQ Project Area.

Again as discussed in **Section 2.4.2**, at the local scale, this regional stress field (magnitude and orientation) will be affected by discontinuities in the rock mass such as faults, and close to the surface, by topography. The magnitude of horizontal stress will also be influenced by the geotechnical properties of the layered sedimentary rocks. The stiffer rock layers, such as sandstone with few discontinuities, will attract a higher stress magnitude compared to more jointed or fractured rock layers, such as coal, which will have a lower horizontal stress. Coal seams are fractured in nature with generally near vertical and horizontal cleats or joints, which can contain water and have a higher permeability compared with a less fractured sandstone layer.

Hydraulic fracturing is very carefully designed to create hydraulically induced fractures by applying highly controlled fluid pressures to the coal seam rock concerned. This induces new fractures in the rock for the fluid to migrate along as well as along existing fractures (cleats and joints). Typical hydraulic fracturing pressures are

designed to consider the overburden pressures amongst other factors. Fracturing may be of the order of 7 to 100 megapascals (1,000 to 15,000 pounds per square inch (psi)) depending on location and depth of the coal seam being fractured and its geotechnical properties. Thus, the induced fractures are likely to be near vertical in a vertical borehole and orientated parallel to the major horizontal in-situ stress direction and likely to truncate along a low shear strength plane such as the top of a coal seam.

Casing isolations are used to isolate the fracture pressures to the target coal seams and to limit the potential for fracturing of sequences above and below the target interval. In addition, extensive monitoring is conducted to assess the fracture propagation and ensure it is contained within the targeted interval. Further discussion of the fracture-monitoring program is provided in **Section 4.4.3**.

4.4.2 The Physical Process of Hydraulic Fracturing

Hydraulic fracturing uses specially designed fluids, primarily consisting of water and sand, mixed on the surface and then injected down into the well and then through the perforations into the coal seam. Typical wellhead and possible fracture stimulation downhole equipment are shown in

Figure 61.

As discussed above, the hydraulic fracturing process occurs under varying positive high hydraulic pressures in order to physically fracture the coal matrix. The hydraulic fracturing fluids are injected through perforations in the steel well casing pipe. The perforations are 10 to 20 mm diameter holes created in the steel casing pipe and surrounding cement seal using a projectile or a high-pressure water jet.

The hydraulic fracturing fluids are injected from the surface via the wellhead works on the surface with either a coil-tubing or bridge plugs, balls and baffles used to isolate the coal seam to be fractured. The coil tubing wellhead works and setup are shown in

Figure 61 and the bridge plug or ball and baffle isolation tools are shown in **Figure 62**.

Alternative methodologies, such as multi-zone hydraulic fracturing process [e.g., Just In Time Perforating (JITP© process)] are also used in select circumstances. This process simply uses a top packer and perforation balls to provide isolation below the targeted perforation. Identical to the coil-tubing and bridge plug and packer approaches, the JITP© hydraulic fracturing process is conducted from the bottom upwards. However, unlike the previous methodology, the process is more streamlined with perforation balls used to provide the required zone isolation in the previous perforated and hydraulically fractured intervals. The perforation balls are injected at each subsequent hydraulic fracturing injection cycle to clog the perforations of the previous intervals prior to perforation of the new interval and the commencement of fracturing in this interval.

The fracture or fractures (a network of fracture openings are typically generated along inherent planes of weakness, the cleat and bedding planes) created in this manner radiate outward into the coal matrix in the immediate vicinity of the well, with fracture radii potentially up to 200 m (**Figure 63**, **Figure 64**, and **Figure 65**). These fractures provide open and connected pathways for the groundwater and gas to more efficiently flow to the gas well than would otherwise be the case.

During the hydraulic fracturing process, the hydraulic fracturing contractor closely monitors down hole pressure and hydraulic fracturing fluid viscosity (if gel-based systems are being used). This allows the hydraulic fracturing contractor to optimise the performance of the hydraulic fracturing process, and rapidly identify unexpected pressure changes that could indicate a loss of well or confining layer integrity, and hence trigger a hold point for the hydraulic fracturing operation. Further discussion of the monitoring process is provided in the sections below.

Technically speaking, the zone of fractured coal material created in the coal seam around the gas well (as illustrated on **Figure 65**) provides highly conductive channels that more effectively drain the coal seam of its adsorbed gas (i.e., it increases the ‘effective radius’ of the well from the typical casing pipe radius of up to 200 mm diameter to potentially up to 200 m). In the absence of fracturing, as groundwater and gas flows towards a coal seam well, flow rates are reduced as the flow converges radially inwards towards the well screen due to the tortuousness of the pathways to the well. This flow throttling effect is minimised considerably by the fractured rock mass when compared to the un-fractured rock mass due to its improved permeability. These new fractures also allow the gas to travel much more freely from the natural fracture cleat system and in the surface matrix of the coal, where it is trapped, to the gas production well.

In the case of Santos EQ, most of the gas wells are vertically orientated and intersect the coal at a near right angle. Increasingly, Santos EQ is employing inclined wells (referred to as ‘deviated’ wells) and horizontal wells, which intersect the coal seam at an angle.

As discussed above, because of the existing stress field properties prevalent within the Santos EQ Project Area, together with the generally horizontal nature of the bedding layers of the coal seams and its brittle nature, the fractures created by the hydraulic fracturing process, are largely contained within the coal seam. The likelihood that the fracture extends into the overlying and underlying sedimentary rock layers is considered remote, with very limited probability of fractures intercepting heavily used aquifer systems. Overlying rock types include shales, siltstone, mudstones to sandstones, which are strongly horizontally bedded rock types.

It is noted that the aquitard formations that predominantly separate the coal from the developed aquifer formations typically behave elastically and would therefore respond to applied stresses through ductile deformation rather than brittle fracturing. They would therefore be expected to resist fracture propagation beyond the target coal seam and truncate along a low shear strength plane such as the top or bottom of a coal seam.

4.4.3 Operational Monitoring and Reporting of Hydraulic Fracturing

As described above, continuous monitoring of the casing pressure and fluid viscosity during the hydraulic fracturing process provides feedback to optimize performance. Any significant changes in pressure are closely monitored to immediately identify conditions that would indicate loss of well integrity or overburden layer integrity.

Pressures are closely monitored or calculated during the activities in two critical areas:

- Inside the casing delivering the fluids.
- Calculated bottom hole pressures based on wellhead pressure, fluid densities and casing diameter and depth to the target formation.

Where a coiled-tubing tool is used, the pressures can be monitored in three areas:

- Inside the open space above the tool within the casing.
- Inside the tubing delivering the fluids.
- Inside the gas wellhead at the surface, which is outside production casing and inside surface casing.

Casing (or tubing if coiled-tubing tools are used) pressure indicates the delivered pressure to the rock underground and is used to gauge job performance in breaking down the formation and delivering fluid and proppant into it. Where bridge plugs or ball and baffles are used for isolation, temperature surveys and negative pressure testing of the bridge plugs can be conducted to assess fluid communication across the plug or packer.

Where coiled-tubing tools are used, the casing pressure monitors any fluid communication from the treatment zone to the area above the top packer. The wellhead pressure indicates if any fluid or pressure has migrated behind casing to the surface.

The casing pressure helps assess the height of fracture propagation, as perforated zones will show an increase in pressure. The safe margin for interval spacing is the upper height limit of fracture growth, based on performance, volumetric assessment and fracture modelling. Typically, the fractures propagate horizontally with very little height propagation.

In addition to process pressures, the flow rate and total volumes of hydraulic fracturing fluids are monitored. Changes in the flow rate in conjunction with pressure changes are utilised along with modelled simulations to determine the performance and propagation of fractures.

Good process monitoring and quality control during the hydraulic fracture treatment are essential for carrying out a successful treatment and for protection of the groundwater. There are certain monitoring parameters that should be observed in virtually all hydraulic fracture treatments, and others that are employed from time to time based on site-specific needs.

Sophisticated software can be used to design hydraulic fracture treatments prior to their execution and during the treatment to monitor and control treatment progression and fracture geometry in real time. During the hydraulic fracture treatment, key parameters are continuously monitored, including surface injection pressure, slurry rate, proppant concentration, fluid rate, and proppant rate.

The data that are collected are used to refine computer models that are used to plan future hydraulic fracture treatments. In areas with significant experience in performing hydraulic fracture treatments, the data that are collected in a particular area on previous fracture treatments are a good indicator of what should happen during the treatment.

Following the hydraulic fracturing activities for the gas well location, a close-out report is prepared providing the details the real-time monitoring, assessments, injection volumes and quality control reporting.

4.4.4 Hydraulic Fracturing Process Description and Methodologies

The process of hydraulic fracturing involves a stepwise implementation of a series of tasks, including pre-hydraulic fracturing well improvement tasks, and fluid injection and extraction events using a combination of specialised equipment. These events are referred to in the following terminology:

- Well casing perforation acid injection – only occasionally employed to open the coal seam cleats where they are filled with natural calcite
- Pad volume injection – hydraulic fracturing fluid, which sometimes preceded by a water injection
- Slurry volume injection – hydraulic fracturing fluid mix plus sand

- Flush volume injection – hydraulic fracturing fluid
- Flow-back – extraction of injected fluids.

The hydraulic fracturing process tasks are undertaken as a series of sequential tasks carried out with pauses in-between event types.

The following sections describe the stimulation-site equipment, the sequence of injection/flow-back events and hydraulic fracturing fluid constituents required to carry out a hydraulic fracturing event.

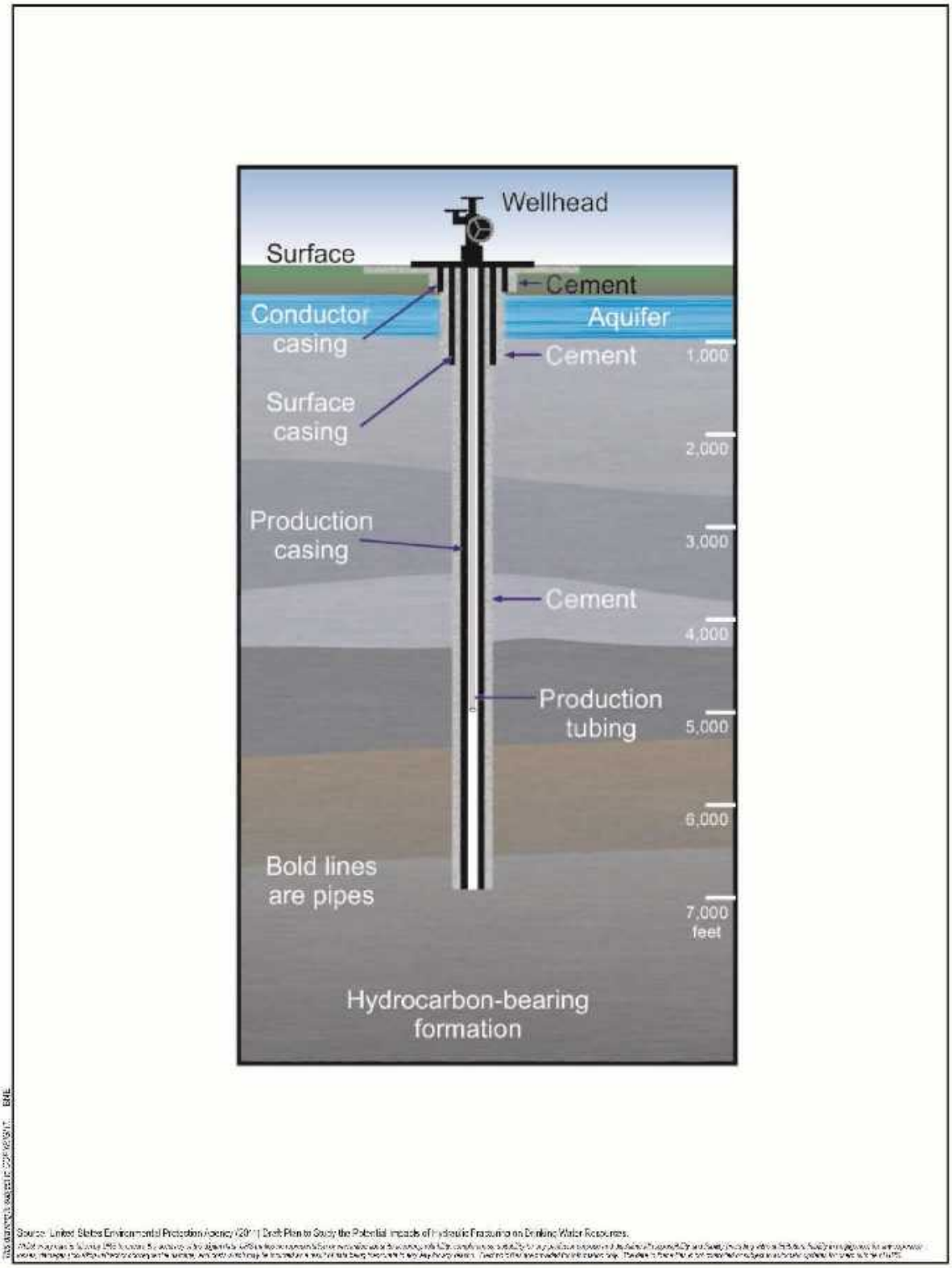


Figure 59. Schematic for a Typical Casing Installation for a Gas Well

Source: http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/upload/HFStudyPlanDraft_SAB_020711-08.pdf

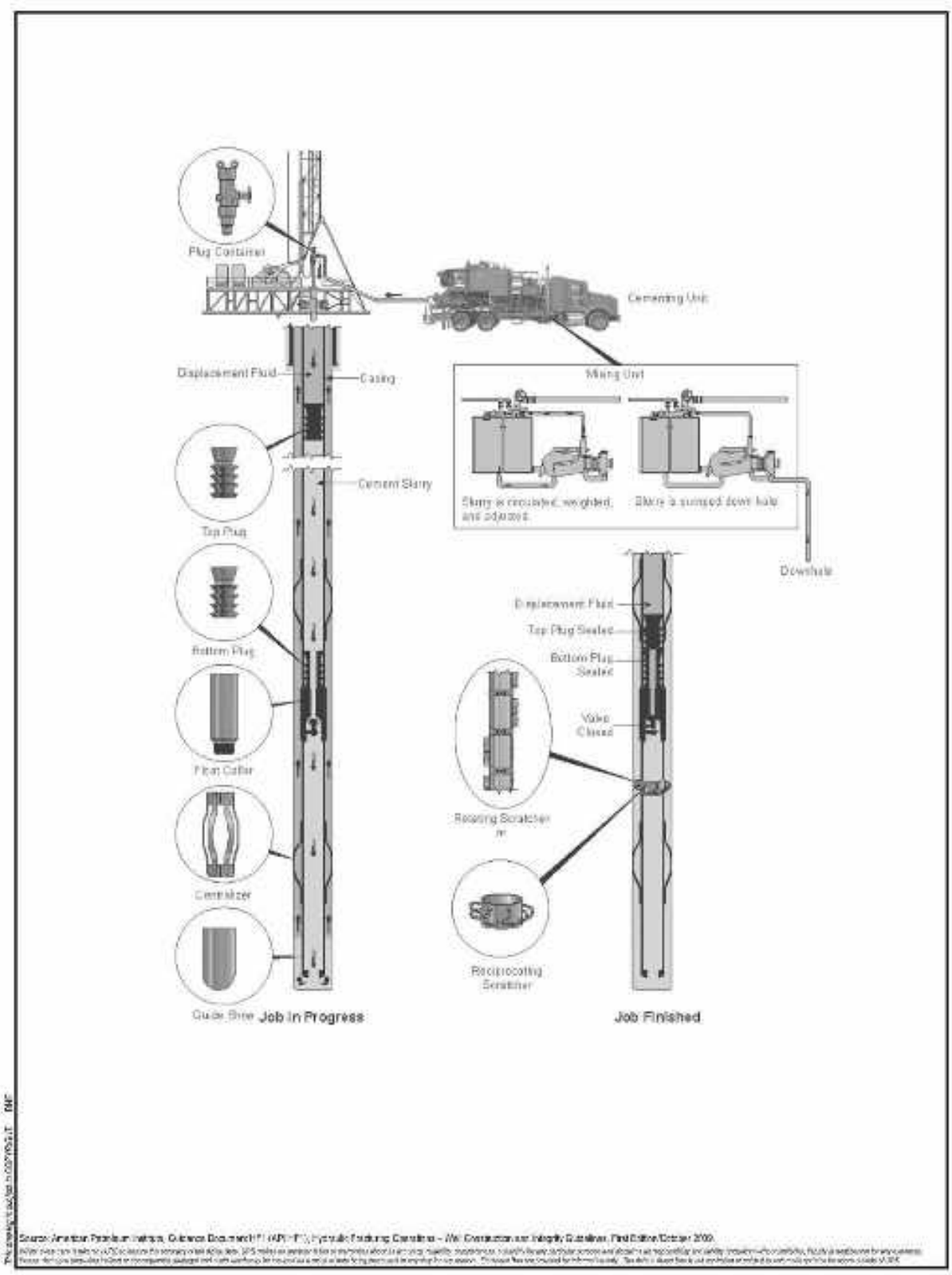


Figure 59. Equipment Used to Ensure Performance During Cementing Activities

Source: API HF1

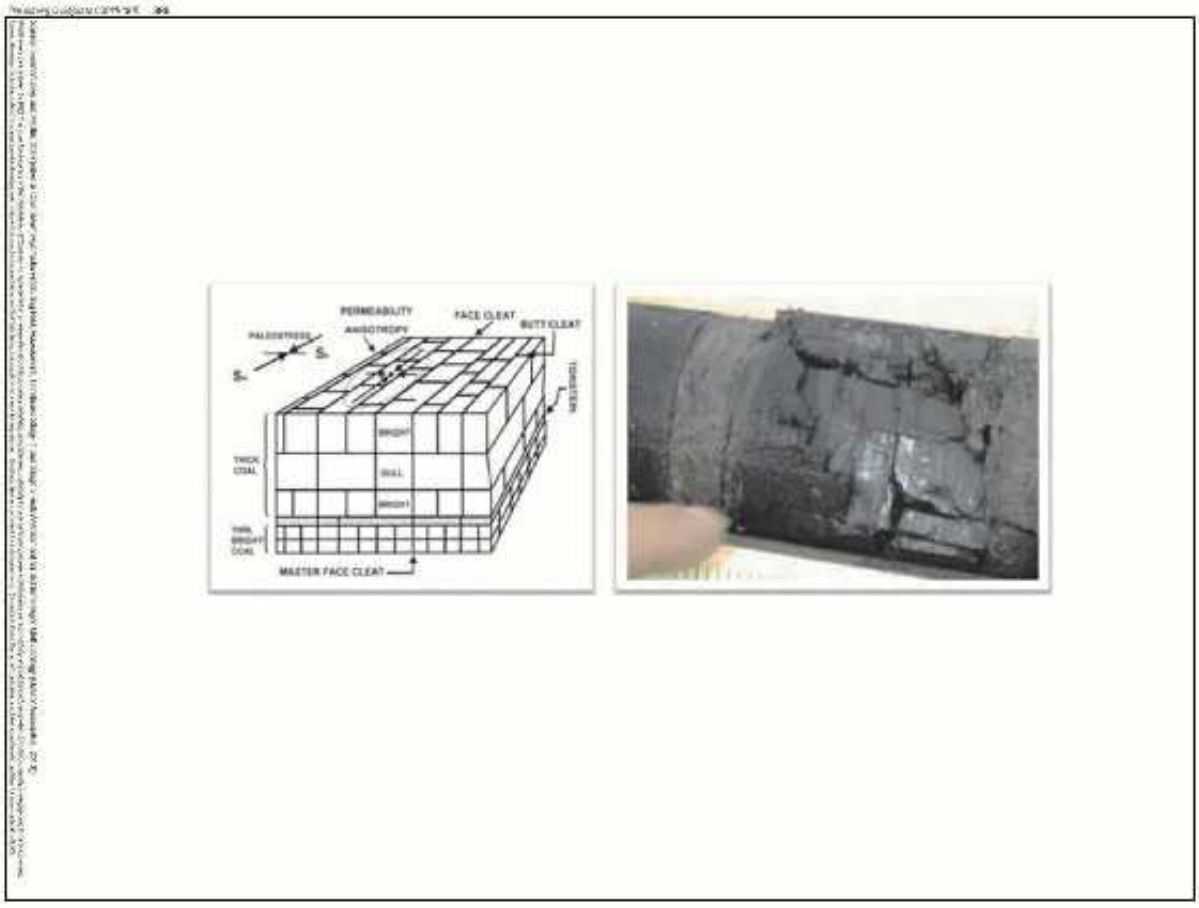


Figure 60. Conceptual and Actual Illustration of 'Butt Cleats' and 'Face Cleats'

Source: Economides and Martin 2007

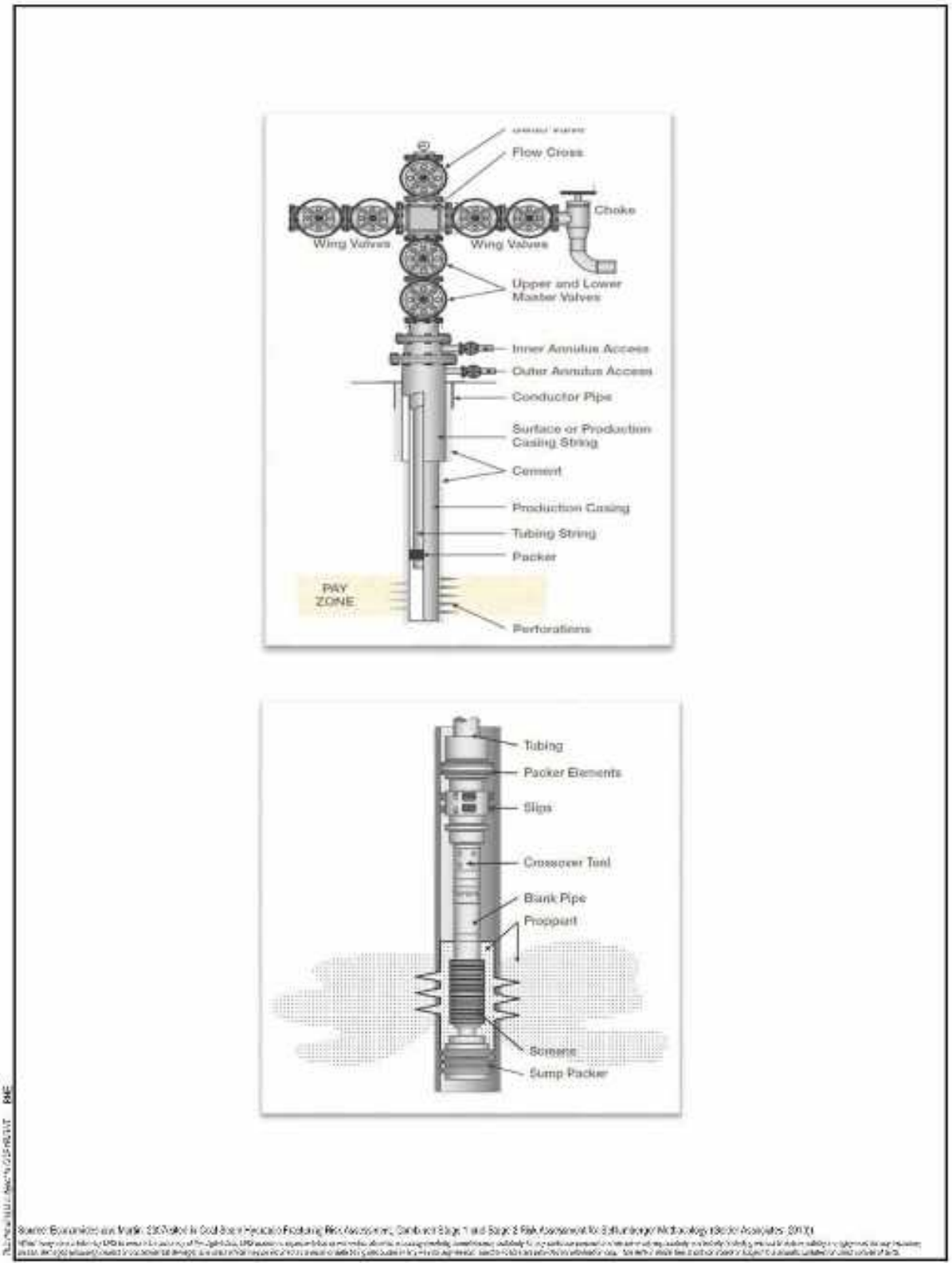


Figure 61. Typical Hydraulic Fracturing Wellhead Fixture and Components of a 'Frac-Pack' Fitting

Source: Economides and Martin, 2007

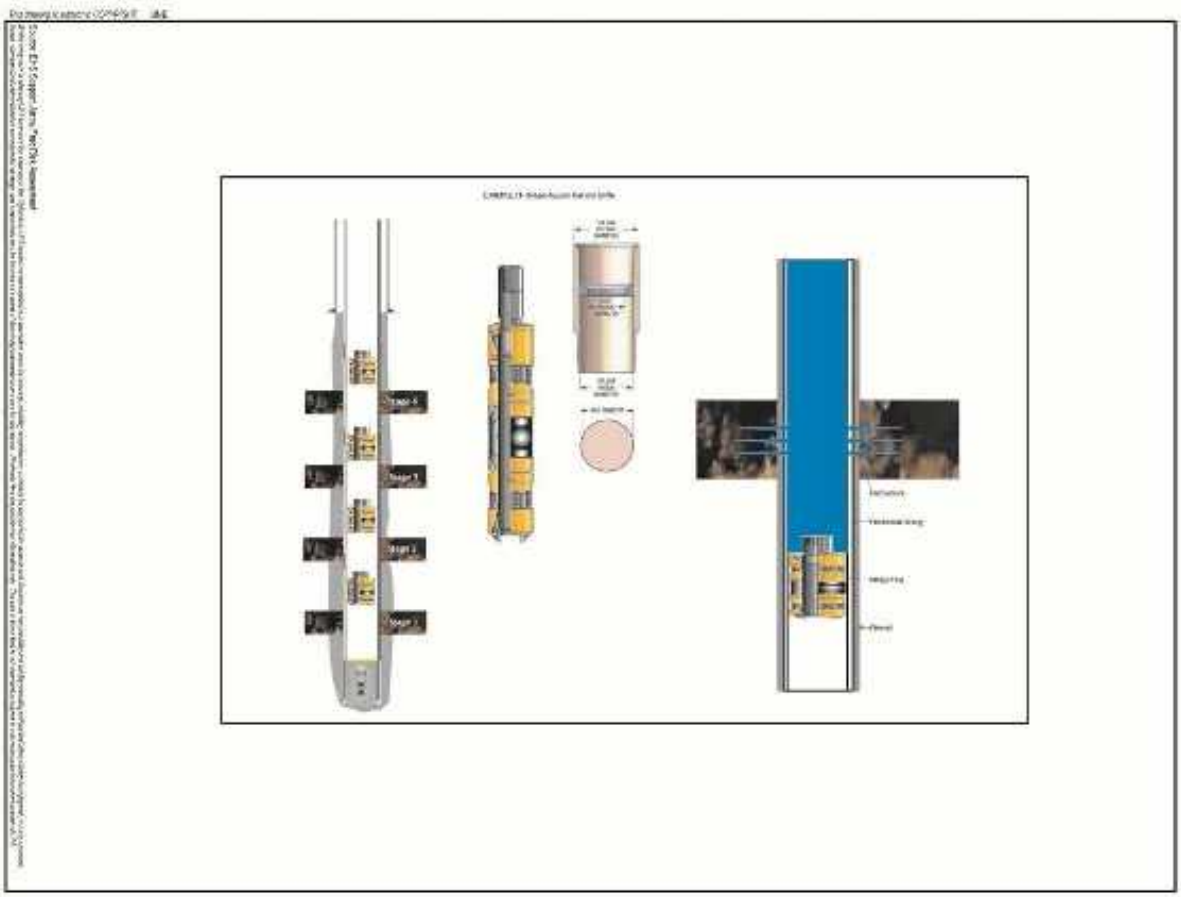


Figure 62. Illustration of the Bridge Plug and Ball and Baffle

Source: EHS Support, 2012

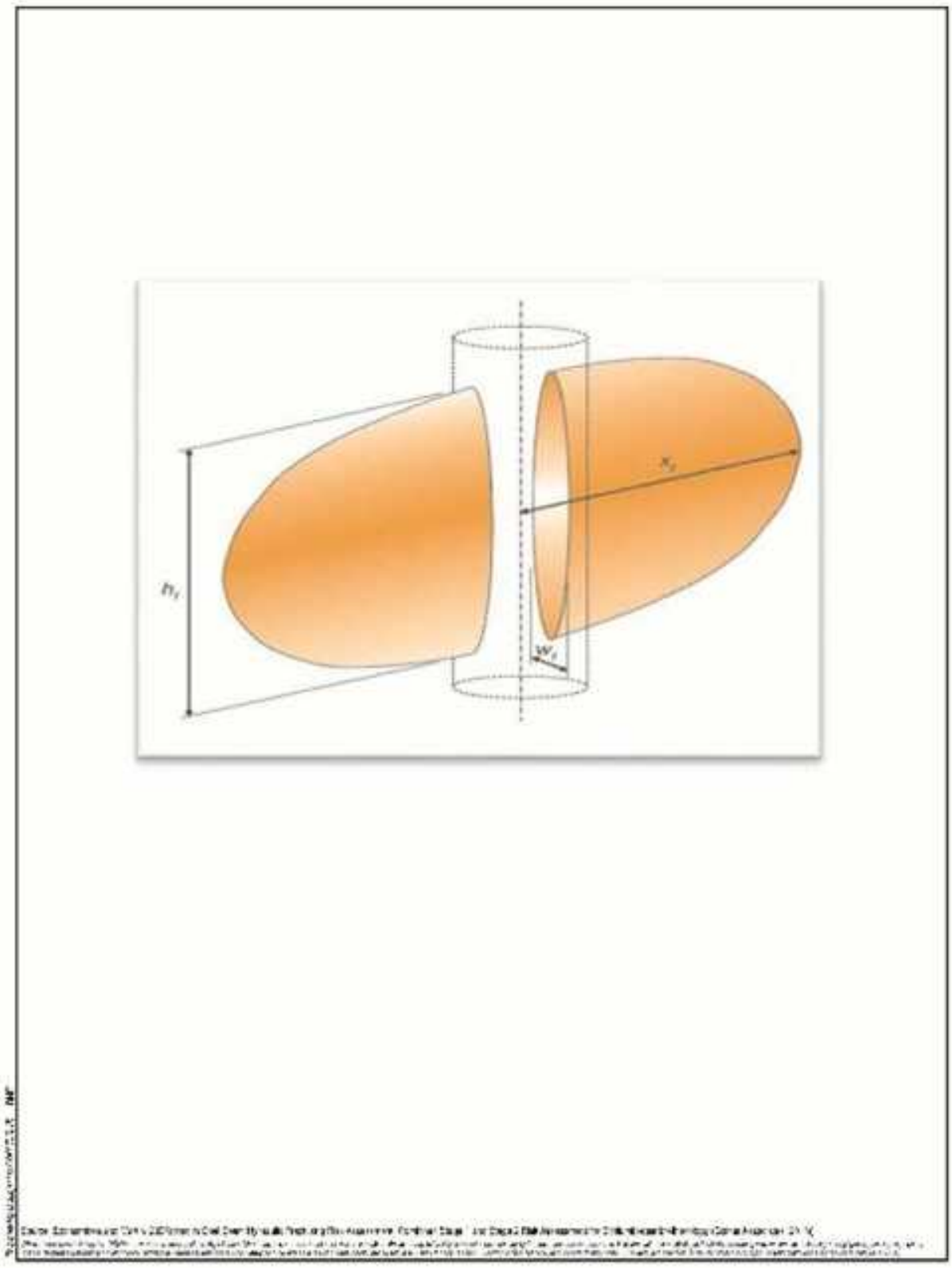


Figure 63. Conceptualised Shape of Hydraulic Fracturing Zone of Influence

Source: Economides and Martin, 2007

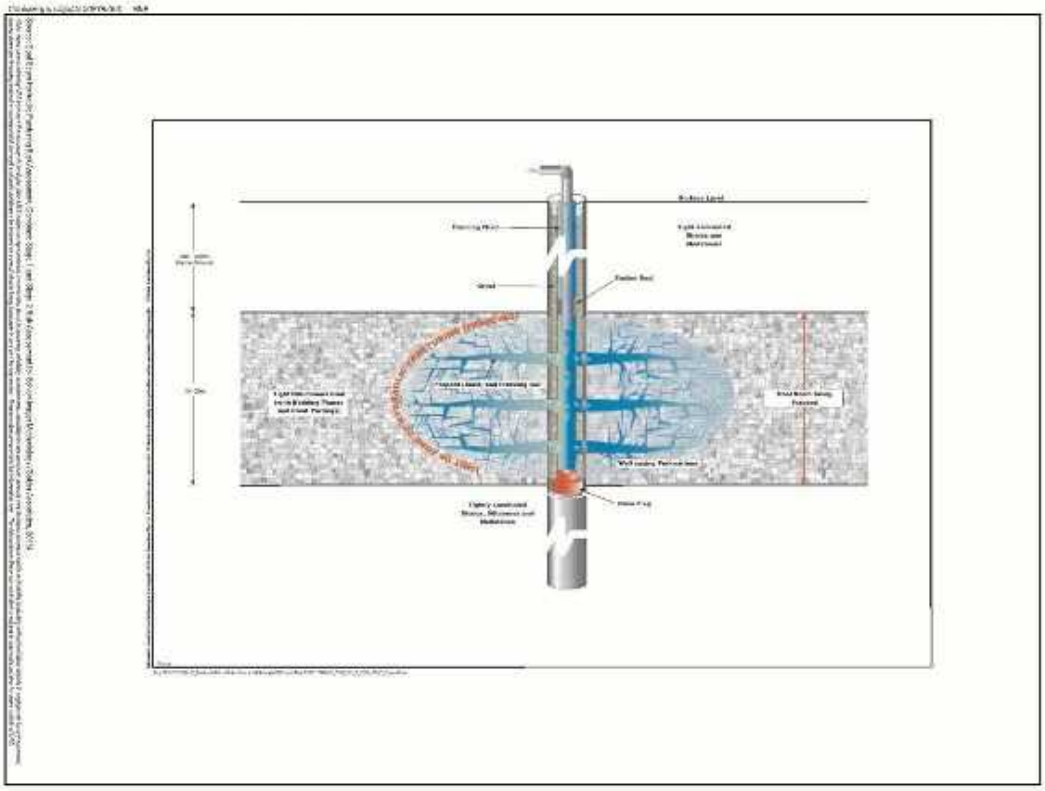


Figure 64. Conceptual Configuration of Hydraulic Fracturing

Source: Golder, 2013a

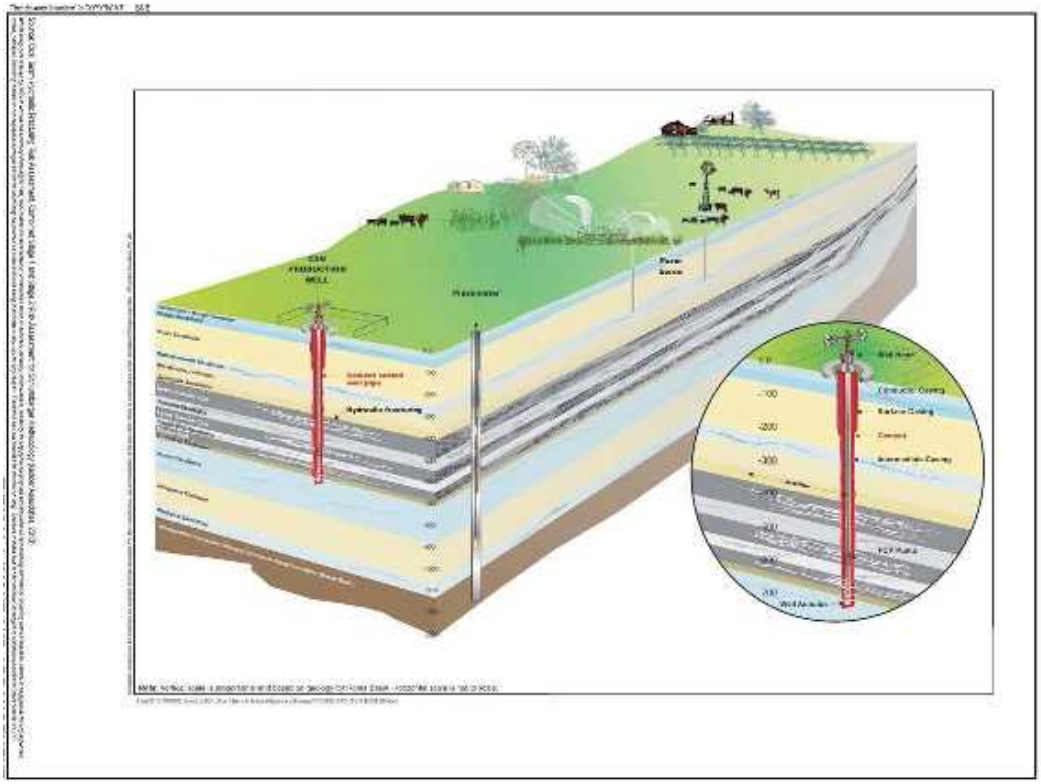


Figure 65. Typical Layout and Arrangement of a CSG Well Showing Conceptual Hydraulically Fractured Coal Seams

4.4.5 Infrastructure and Equipment Used

A hydraulic fracturing setup typically consists of the following key pieces of equipment (see **Figure 66** and **Figure 67**):

- 'Clean Fluids' Pit or Turkey's nest or Frac Tanks– Water for hydraulic fracturing is either stored in a clean fluids pit (a lined excavation such as a turkey's nest) or in Fracc Tanks/Concept Tanks. The water used for hydraulic fracturing is usually untreated groundwater pumped from the coal seam/s or blended water from a water management facility. A biocide (bacteriacide) is added to this water to eliminate and settle out algal growth prior to the hydraulic fracturing process. The lined pond or tanks provide temporary storage of the water used in production of the hydraulic fracturing fluid mixes used during the various stages of hydraulic fracturing.
- Hydration Units – water from the pond is pumped into a blending device where it is mixed with a guar gum powder/solution. The blend is then sent to the hydration unit where guar gum hydrates (absorbs water) over a period of several minutes. This produces the 'guar slurry' which is the prime constituent of the hydraulic fracturing fluid (aside from water and sand).
- Sand Trailer Unit – which is a large sand trailer that holds the 'proppant' (fine graded quartz beach sand) and delivers it to the blender unit in a measured rate when it is required in the second stage of hydraulic fracturing.
- Blender Unit – mixes the hydraulic fracturing fluid ingredients 'on-the-fly' (OTF) and, later, the hydraulic fracturing fluid chemicals plus sand proppant.
- High Pressure Pumps – draw in the specific hydraulic fracturing fluid mixtures from the downhole blender unit and then pressurises this fluid mix prior to injecting it into the particular coal seam being fractured.
- Control or 'Data' Unit – is the central control room from which all the hydraulic fracturing equipment is electronically controlled (it is provided for the automated preparation of the hydraulic fracturing mixtures and injection pumps).
- 'Coil Tubing' Unit – remains sited over the well installation to provide the means of precisely injecting the hydraulic fracturing fluids. This comprises a crane or similar to support a coil of steel tubing, which is uncoiled and/or lowered down the well to facilitate the hydraulic fracturing. This equipment supports the packer system, which isolates the specific coal seam proposed for hydraulic fracturing).
- Wireline Unit - provides a means of running isolation plugs and perforating zones.
- Flowback Tanks – acts as a receiving pit for the initial flow-back of fluids leaving the well annulus during and immediately after the hydraulic fracturing process. It is typically put in place to provide a recirculation and sedimentation pit for the drilling fluids during the well borehole-drilling phase of the well construction and is reused during hydraulic fracturing. Once the initial flow back is removed, the production water (also referred to as Associated Water) is pumped from the well and directed to the frac tanks for re-use (in its untreated form) or treated in an on-site Water Treatment Plant (WTP) for beneficial reuse or directed to the conveyance network for management within the coal seam water scheme.

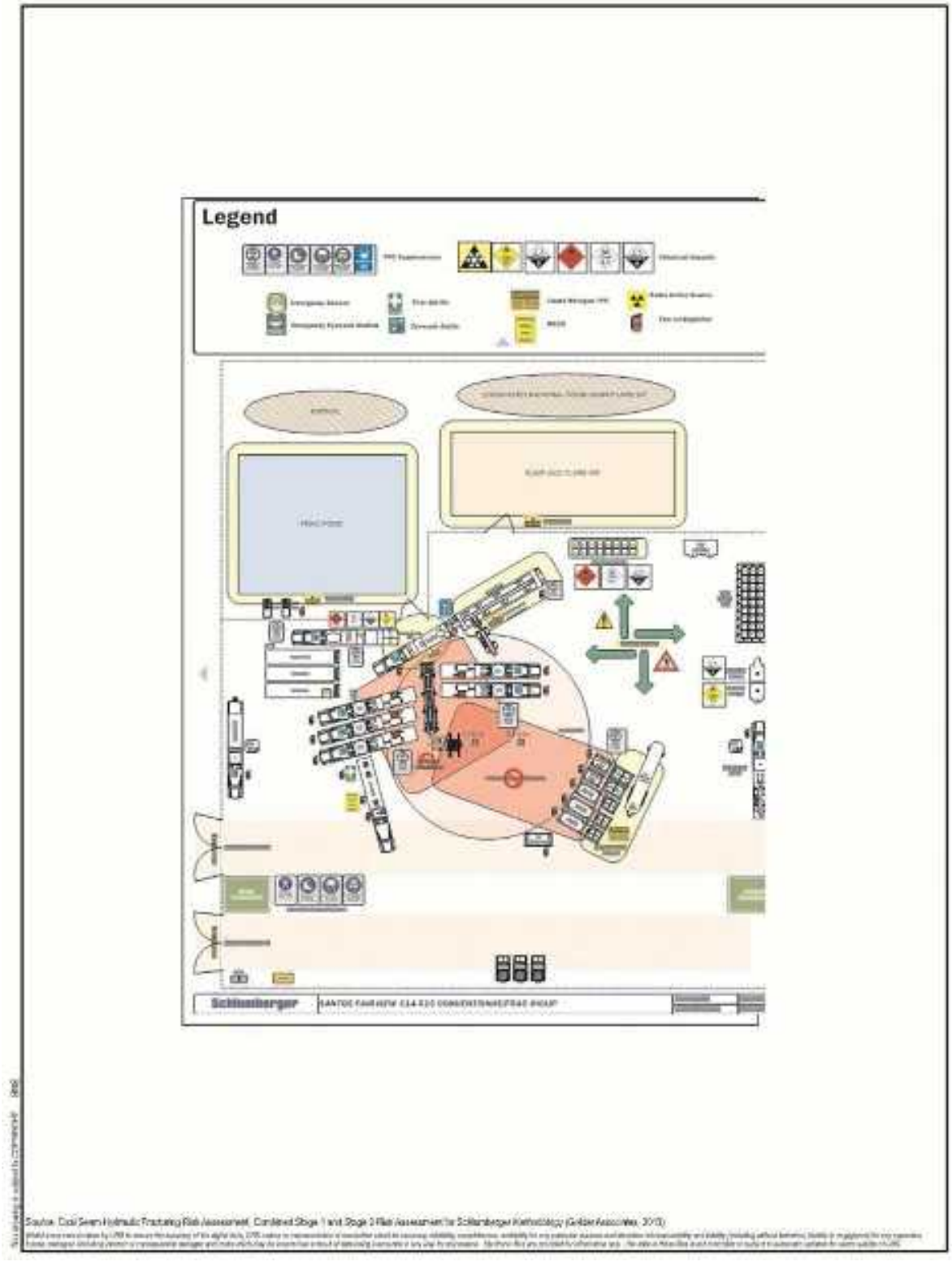


Figure 66. Diagrammatic Layout of a Typical Hydraulic Fracturing Operation on a Well Lease[2]

[2] Note: In CSG operations, frac ponds and flare pits have been largely replaced by frac tanks and flowback tanks, respectively.

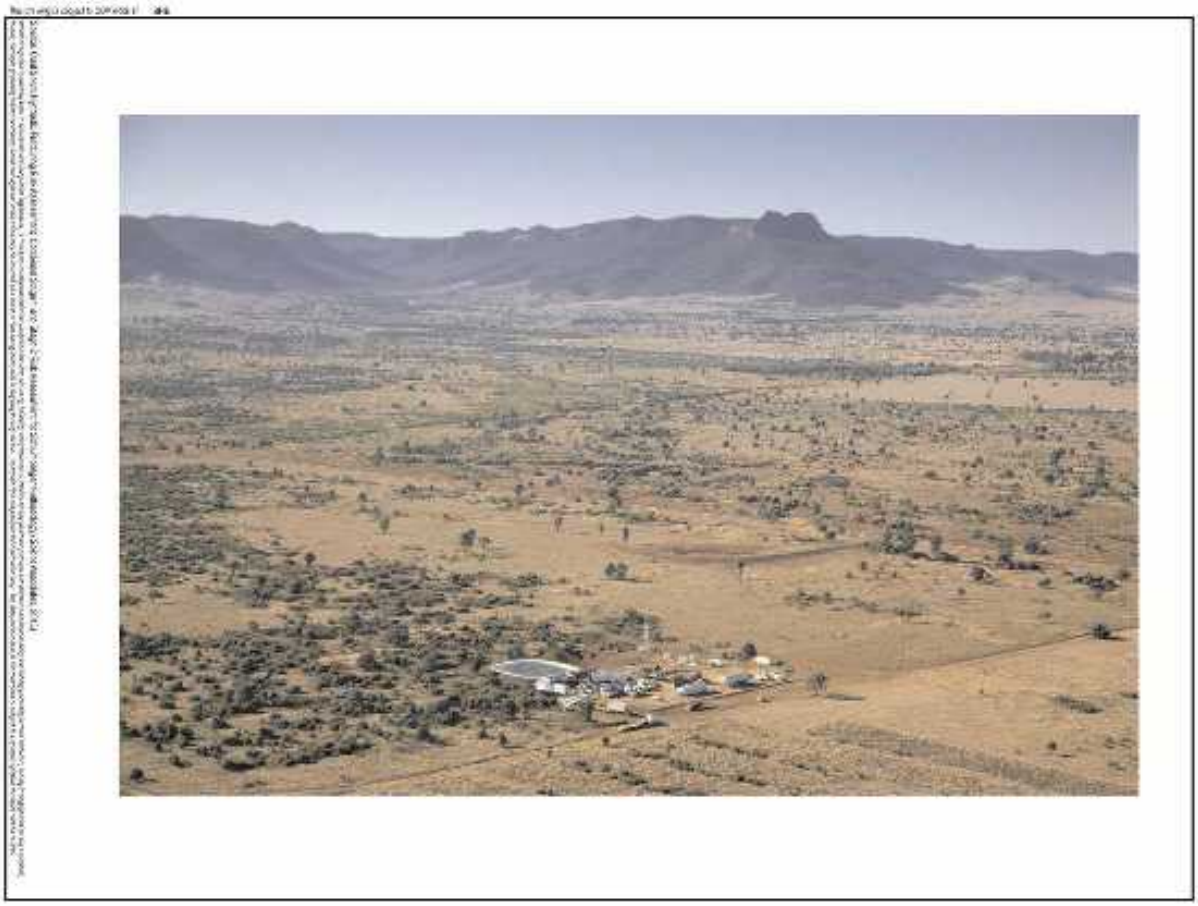


Figure 67. Photograph of a Typical Hydraulic Fracturing Setup Operation on a Well Lease

4.5 Stages of Hydraulic Fracturing

Hydraulic fracturing events are individually designed in detail as part of the well completions design process described in **Section 4.2.** The design input parameters are described in that section.

As part of the hydraulic fracturing process detailed fracture modelling is intermittently performed to refine field designs using computer modelling methods.

- Equipment requirements (depth, pressures and water requirements) and personnel
- Fracture fluid type/s and volumes required
- Likely fracture pressure profile (for real-time comparison with that monitored in the field during the fracturing event)
- Fluid pumping and staging
- Flowback design and prediction
- Logistics for materials procurement, handing, transport, site management, site mobilisation and demobilisation.

4.5.1 Well Perforation

Holes are created in the well casing pipe at locations, which align to the centre of the coal seams targeted for gas production; these are referred to as ‘perforations’. A section of the casing pipe approximately 1 m long is selected for perforation to allow the well to discretely access the coal seam. They are generally aligned slightly below the midpoint of the coal seam being fractured to accommodate the tendency for upward propagation of the fracture, in the direction of least stress.

The perforations are created by one of two methods. The first method used small explosive devices which blast a hole, approximately 10 mm in diameter, at a density of 6 shots per foot of well casing.

The second method used is referred to as 'water' or 'sand jetting' and involves blasting a jet of water or of fine sand and water mix at high pressure at the well pipe wall to abrade a hole in the pipe. Both methods penetrate the steel casing and the cement layer, and into the coal seam by up to a metre.

4.5.2 Acid Injection (if required)

If the coal seam cleats are found to be naturally filled with calcite mineral (calcium carbonate) then a dilute acid mix can be injected through the perforation holes into the coal seam to dissolve the calcite away prior to hydraulic fracturing. This is rarely performed. It is carried out after completion of the well casing and perforations, but prior to hydraulic fracturing. The selected coal seam can be pressurised with a 15% solution of hydrochloric acid (with preservatives).

It is noted that acid injection also results in some degree of aggressivity towards the cement in the bore annulus within the injection zone. However, given the relatively short duration of the acid injection the potential impact to the annular seal integrity is likely to be minor and localised to the immediate vicinity of the well perforations.

4.5.3 Pad Volume Injection

Pad volume injection is the initial hydraulic fluid mix being pumped down to the targeted coal seam stages. The pad volume is mixed on the surface prior to being injected down the casing, tubing or coiled tubing to the selected section of perforated well casing (adjacent to the coal seam being fractured) where coal fracturing is to occur.

The process of mixing additives is automated and is prepared dynamically (OTF) within specialised mixing equipment. The pad volume slurry comprises a mix of water (typically 99.5% by volume and usually comprises groundwater obtained from the coal seams) drawn from the frac tanks together with several preservatives and stabiliser chemicals. This system can comprise fluid systems as simple as water and weak organic acids through to complex gel-based systems. Gel based systems are typically preferred in settings where the coals are potentially more transmissive and/or fractured to minimise the amount of fluid loss and increase pressure of the formation and facilitate more widespread fracturing.

Where gel-based systems are used these typically comprise dehydrated cellulose or guar gum-based systems. Where a cellulose and guar gum is used, this is allowed to hydrate in a baffled tank, referred to as the Hydration Unit, for several minutes prior to adding further ingredients, which stabilise and thicken prior to being diluted with the water. The viscosity of the fluid at this point is typically 3 centipoise (cP), marginally greater than that of water.

Guar gum is a vegetable product, which is ground into a powder and used to create a viscous liquid for hydraulic fracturing(Economides and Martin, 2007).

Simultaneously, additives including cross-linker, stabiliser and thickener ingredients are added to the guar gum hydraulic fracturing slurries used by Santos EQ, including:

- Borate may then be added to cross-link the guar gum (depending on coal seam properties), raising the viscosity from 3 to 300 centipoise (a gel consistency)
- A biocide is added to knock out bacteria which could destroy the gel
- A buffering agent (e.g., potassium carbonate) is added to keep pH above 8.

At this point, the guar gum and associated ingredients comprise approximately 0.050% by volume of the pad volume slurry with the viscosity of the final hydraulic fracturing fluid being typically up to 300 cP, which is essentially a gel consistency (refer to

Figure 68).

The viscous hydraulic fracturing fluid is then injected down into the coal seam at a rate of approximately 10-17 bbl/min, and a pressure of up to 6500 psi for coiled tubing fracs, or at a rate of approximately 10-40 bbl/min and a pressure of up to 8500 psi for plug and perf fracs. The injection pressure is a function of the formation properties and well construction. The injection process continues until pressure drops or stabilises, indicating that the coal seam has 'cracked' or fractured under the pressure. This progressively drives the pad volume further out into the coal layer propagating the fractures to a maximum distance of up to 200 m. At this point, the injection of the pad volume ceases, and the injection of the slurry volume commences in a continuous and uninterrupted fashion.

4.5.4 Slurry Volume Injection

Immediately after the coal has been fractured and the pad volume injection ceases, hydraulic fracturing immediately proceeds to injection of the slurry volume. The slurry volume differs only in its content from the pad volume by the higher measured quantities of specifically graded quartz sands or manufactured ceramic grains, referred to as the 'proppant'. The process may start with fine graded proppant, progressing to coarser grades of proppant as the slurry volume injection stage progresses. Typical proppant grades used in Santos EQ wells can include: 100 Mesh, 40/70, 30/50 and 20/40 (shown in **Figure 69)**.

On completion of the hydraulic fracturing program, a known volume of slurry has been injected into the fractured coal and the fracture stimulation ceases.

Where gel-based systems have been used, breaker compounds are added at progressively increasing concentrations throughout the slurry volume injection. The breaker comprises an oxidizer or enzyme compound that breaks the chemical bond of the gel reducing the viscosity. Water based systems do not require the use of breakers and enzymes.

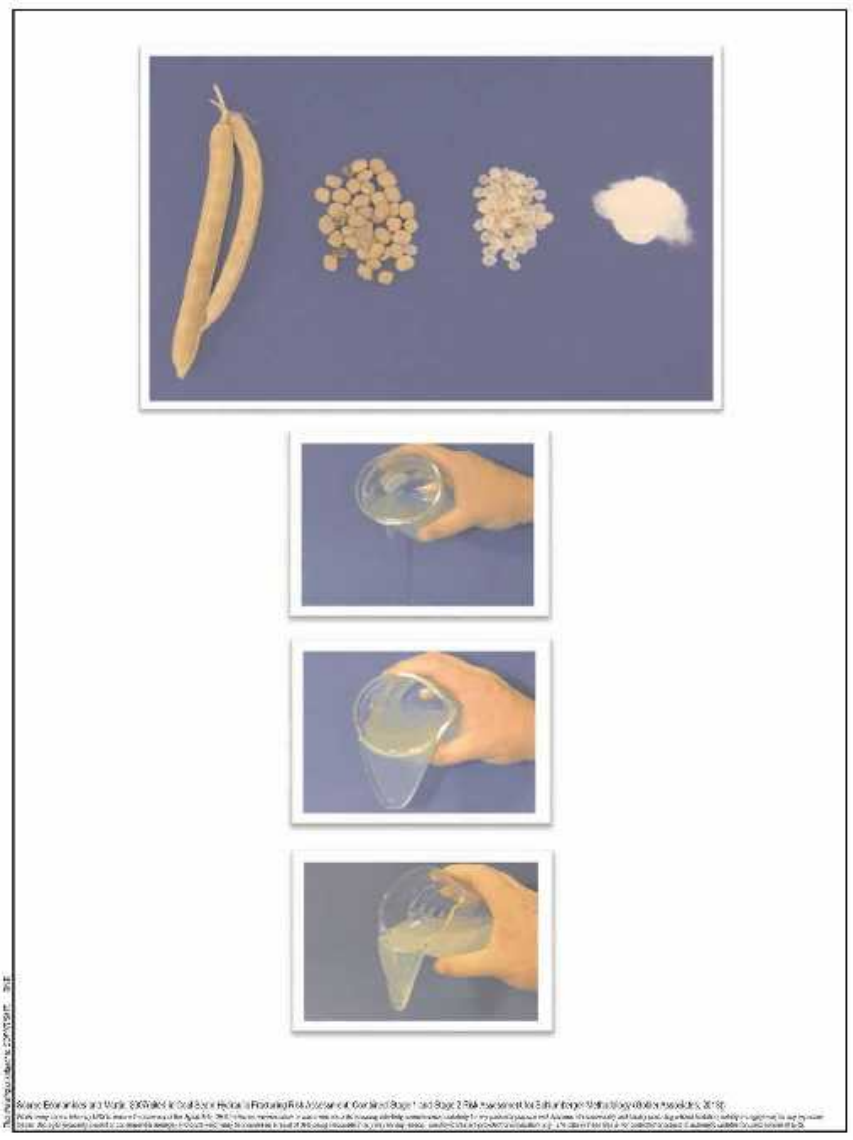


Figure 68. Guar Gum – Illustrating its Various Forms (Top) and Stages of Cross-Linking to Achieve 300 cP (Bottom)

The duration of the stimulation event and the slurry concentrations and volume are based on data from testing investigations on the coal seams (including drill stem tests and coal analysis data) and are tailored specifically to the coal seams and well characteristics as calculated using computer-based modelling.

The above procedure is carried out for each coal seam present in the target gas beds. In the case of Santos EQ's Project area, this equates to between three and twelve coal seams. Typically, up to 7,000 barrels (1,100 KL) of formation water carrying the hydraulic fracturing fluid is injected per well, with 600 to 1,400 barrels required per coal seam. Stimulation begins with the lowermost coal seam, working progressively upward through the various coal seams to be targeted. The well can be progressively perforated and fractured from the base of the well upwards. Composite plugs may be used to isolate the deeper sections after completion of the first fracture stage. This ensures that only the coal seam is pressurised during the hydraulic fracturing event for each seam.

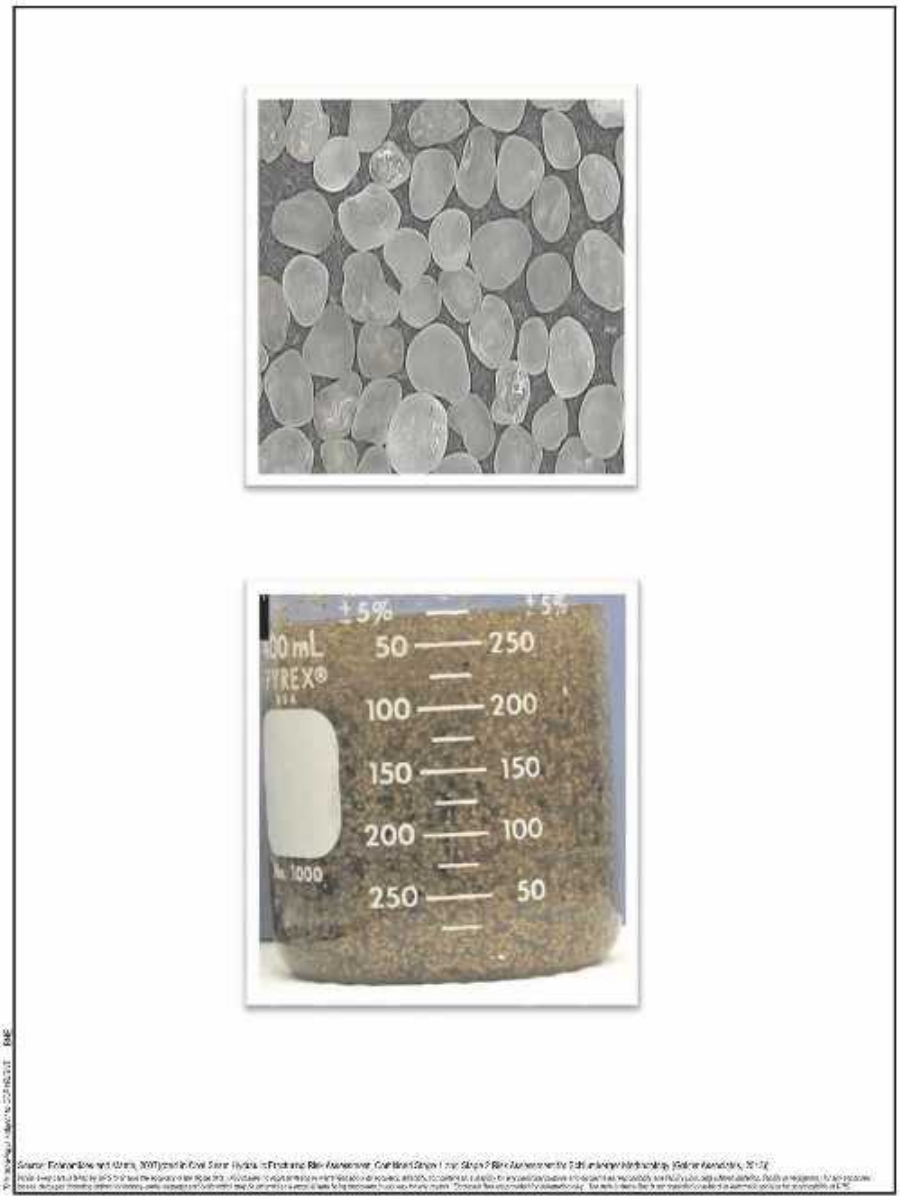


Figure 69. Typical 20-40 Grade Sand (Top) and Sand-guar Gum Fluid Mix (Bottom)

4.5.5 Flush Volume

Where required and between fracturing events a volume of hydraulic fracturing fluid, equivalent to the wellbore volume, or coiled tubing volume, down to the top of the perforations (20-100 barrels), is pumped to flush the slurry into the target formation. Since the coal seams are still pressurised following the final slurry volume injection, they are then allowed to depressurise. This allows residual fluids to flow to the surface under the residual pressure. These fluids are captured in the flowback tank and are recycled or disposed.

4.5.6 Initial Flowback and Well Completion

The initial flow back only occurs during removal of equipment and depressurisation of the well after hydraulic fracturing. Not all wells provide an initial flow back as insufficient pressure may exist for fluids to flow from the well. The flowback fluid is captured in tanks, the fluid consists of hydraulic fracturing fluid and potentially some solids (proppant, coal fines, etc.).

Hydraulic fracturing fluid not returned during initial flowback remains in the formation and is recovered during the production phase of the well. There is an indeterminate amount of hydraulic fracturing fluid lost in far reaching fractures that may never be recovered.

Once initial flowback is complete, typically a workover rig is used to drill out any plugs, clean out the wellbore and install the initial completion which typically consists of tubing, pump and rodstring.

4.5.7 Commissioning and Production

After the well has been completed with the required equipment, and gathering and surface equipment installed, the well is commissioned and put on production. Production pumping continues for the life of the well, with groundwater extraction over that period ranging from 2 ML to 25 ML. This flow is likely to flush all the available (mobile) components of the original hydraulic fracturing fluid, which may remain in the coal seam after flow-back.

The water produced during this phase is referred to as production or associated water and is not considered to be flowback. While low levels of chemicals associated with hydraulic fracturing may be detected in the water, the water quality reflects the general properties of CSG water. The pump will remain in the well in the long term for the purpose of pumping produced water. The associated water pumped from the well is of a quality suitable for management within the coal seam water management systems.

4.5.8 Timing of Hydraulic Fracturing Process

The hydraulic fracturing of a typical well of three to four seams takes two to four days to complete (noting that there are between 3 and 12 such coal seams in Santos EQ Project Area, this timeframe could extend up to 10 days).

The fracturing of each seam is carried out as a full sequence of each of the stages described above – the cycle being carried out to completion before moving to the next seam. Typically, seam fracturing is initiated with the lowermost seam planned for fracturing, moving progressively upward through the targeted seams.

The Well Completions Team then takes over to install the ‘completion’ equipment (pump, headworks and gas-water separator) and delivery pipelines (gas and coal seam water).

4.6 Program of Wells to be Fractured

Selected wells will be fractured prior to being brought into production, involving the various tasks described previously. Santos EQ has indicated that approximately 70% of wells will be fractured over the remainder of the field life in the Fairview, Denison, Scotia and Arcadia development areas and approximately 50% in the Roma development area. However, it is important to note that all wells have the potential to be hydraulically fractured at one or more point in time as operational requirements vary.

Once or twice during the life of the well, the wells may be subjected to additional hydraulic fracturing events, or the fractures may be ‘cleaned’ using nitrogen gas under high pressure. These processes are designed to open new pathways for gas and water to migrate to the well or flush out fine silts and clay particles which may contribute to clogging the fracture/s over time. Production wells in the Project area may require this re-fracturing.

According to information provided by Santos EQ, the average well spacing between gas wells is likely to range between 600 and 880 m.

Given the uncertainty in future hydraulic fracturing locations during field development planning, it has conservatively been assumed in this assessment that all gas well locations have the potential to be fractured; potential receptors for hydraulic fracturing operations (i.e., nearby water supply wells) have been assessed on this basis.

Santos implements the required notification and reporting requirements prior to the drilling of wells and the planning and execution of hydraulic fracturing activities. No hydraulic fracturing is conducted on a well without appropriate testing of the well, provision of well completion and testing records to the DNRME and the notification of proposed hydraulic fracturing (which includes the hydraulic fracturing design and proposed fluid systems). Further discussion is provided in the section below.

Based on the process of well drilling selection, no wells are established proximal to any structural faults or discontinuities that could lead to be vertical migration of fluids and gases into overlying aquifers, especially since the purpose of hydraulic fracturing is to facilitate gas recovery. Based on the Constraints Protocol (as described in **Section 1.3**) and stakeholder engagement, no wells are located within 500 m on potable bores and homesteads even where there is greater than 200 m vertical separation.

In accordance with the Code of Practice requirements, a risk evaluation is conducted for all wells and proposed hydraulic fracturing programs to ensure that areas where vertical migration into environmentally sensitive areas (eg. aquifers) could potentially occur and/or environmentally sensitive areas are avoided.

4.6.1 Regulatory Notification and Approval Process for Well Installation and Hydraulic Fracturing

As documented above, a Code of Practice and specific regulatory requirements for well completion and hydraulic fracturing are prescribed in Queensland. DNRME has rigorous requirements for notification and reporting which require the completion of numerous reports and the provision of completed registers. This process is designed to ensure that hydraulic fracturing is only conducted on appropriately constructed and tested wells which have been completed in approved areas of the Basin away from faults and other structural features that may impact on well performance and/or potential impacts to overlying aquifer systems.

The formal reporting process includes the development of prescribed assessments and reports that must be formally lodged online (http: geolodgement.drme.qld.gov.au). The specified reports include:

1. Prenotification of drilling and well installation activities
2. Prenotification of hydraulic fracturing activities (including landowner notifications)
3. Regulatory Notification of Completion of Hydraulic Fracturing – This comprises submission of DNRME Form PGGD-04 immediately on completion of the hydraulic fracturing activity.
4. Hydraulic Fracturing Activity Report – This report is filed online (typically within 90 days of completion the hydraulic fracturing event and includes the submission of:
    a. The Hydraulic Fracturing Vendors Hydraulic Fracturing Completion Report which documents:
        i. The well hydraulic stimulated, the stimulation method and chemicals
        ii. Pressure and flow monitoring data from the hydraulic fracturing event
        iii. Assessment and analysis of data to determine if the hydraulic fracturing activity was successful and if any matters of concern were identified during execution of the work.
5. Completion/Update of the DNRME submission template for each well including status and performance of:
    a. Tubing/Vasing
    b. Perforations
    c. Well Completion
    d. Additives/Chemicals Used
    e. Well Testing
    f. Well Treatments
    g. Water Analysis

4.7 Chemical Constituents in Hydraulic Fracturing Fluid Systems and Mass Balances

Several hydraulic fracturing vendors will potentially be undertaking hydraulic fracturing activities within the Santos EQ fields. These vendors all have multiple fluid systems with differing chemistries. The variability in fluid systems is primarily a function of the use of either water and gel-based systems and foam and non-foam versions. In addition, vendors use different biocides, breakers and enzymes in their gel-based systems.

The mass balance for these fluid systems including their respective Chemical Abstracts Service Registry Numbers (CASRN) is provided in the vendor specific Appendices (**Appendix C**). In addition, Toxicological Summaries are provided for the individual chemical compounds.

It should be noted that the information provided in the appendices will inevitably vary from, other published sources of hydraulic fracturing fluid compositions, as the specific hydraulic fracturing fluid mixtures are proprietary products of the hydraulic fracturing contractors and their product suppliers.

None of the fracturing fluid chemicals identified by the contractor contain benzene, toluene, ethylbenzene, xylenes (BTEX) or polycyclic aromatic hydrocarbons (PAHs). It is noted, however, that BTEX and PAHs occur naturally in coal, and it is possible that certain PAHs may naturally be present in the coal seam groundwater used in the hydraulic fracturing process. In terms of the reaction by products of these chemicals, none of the reaction by products is known to exhibit higher toxicity than the parent compounds. However, it is recognised that geochemical reactions in the formation are complex, and these will have to be assessed on a site-specific basis.

5 Risk Assessment Framework

The information provided in this section addresses the following EA approval requirements: conditions (q), (r) and (s).

5.1 Overview of Risk Assessment Process

A weight-of-evidence approach has been used by Santos EQ to evaluate the potential for human health and environmental (e.g., ecological) risks as a result of the hydraulic fracturing processes. In development of the risk assessment, the Site setting, landuse, hydrogeological conditions and beneficial uses of groundwater were considered.

The risk assessment involves a systematic assessment of the toxicity of the chemicals used in hydraulic fracturing and the potential for exposures to humans and ecological receptors. During this process, key constituents of potential concern are identified, and the effectiveness of exposure controls are considered. Through the process of evaluating potential exposure pathways, fate and transport modelling was also conducted to assess the mobility of chemicals within the coal seams. These components of work make up the qualitative component of the risk assessment.

The quantitative risk assessment utilised methodologies outlined in the National Water Quality Management Strategy (NWQMS), National Environment Protection (Site Assessment) Measure (NEPM) and enHealth methodologies. This risk assessment methodology evaluated the potential risks posed by the combined mixture of chemicals and where flowback data was available, the combined risks posed by hydraulic fracturing chemicals and naturally occurring geo-genic constituents.

Collectively the qualitative and quantitative assessment components make up the risk assessment methodology for the various fluid systems used in hydraulic fracturing. Details regarding the methodology of these components are discussed in the following sections with short salient summaries of their objectives as follows:

- **Section 6** – Qualitative Risk Assessment – a hazard assessment that includes a persistent bioaccumulative and toxic (PBT) substances assessment and defines which hydraulic fracturing fluids may potentially present a risk, based on the toxicity demonstrated in the PBT assessment, and the persistence and bioaccumulation that facilitates their potential for exposure by human and ecological receptors.
- **Section 7** – Exposure Assessment - involves the evaluation of the data available for the study, the details associated with the surrounding environment, the nature of the exposure identified and the potential mobility of the COPC to identify potential complete exposure pathways and receptors.
- **Section 8** – Quantitative Risk Assessment– includes the quantitative calculations for the exposure assessment and risk characterisation, and toxicity estimates for the hazard assessment, by incorporating exposure models to evaluate potential exposures to human and ecological receptors and estimated the potential risks to these receptors from the exposures.
- **Section 9** – Other Risks – assessment of risks from modifications of previously assessed fluid systems and proppants, as well as the assessment of potential risks not directly related to the COPCs in the fluid systems including noise, vibration, air quality, and radiological exposures.

The general findings from the risk assessments are provided in **Section 10**. The detailed assessment and results for individual hydraulic fracturing fluid systems are summarised in **Appendix C**. These summaries have been set up with headings based on the various assessment methodologies described above.

It should be noted that **Sections 6** and **7** make up the qualitative components of the risk assessment. The exposure assessment conducted as part of the qualitative assessment serves as the basis for the quantitative risk assessment, with assessment only completed on potential exposure pathways.

5.2 Tiered Framework Process

For chemicals used in stimulation activities since January 2020, a tiered assessment approach has been employed to streamline the risk assessment process. This process, hereafter referred to as the Chemical Risk Assessment Framework (CRAF), aligns with chemical assessment guidance provided by NICNAS and approach

used for industrial chemicals and aligns with Commonwealth Approval requirements. This allows for a defined and streamlined process to:

- Identify low hazard chemicals that can be addressed simply through a hazard assessment process;
- Identify higher hazard chemicals that should be assessed through completion of a quantitative risk assessment;
- Identify very high hazard chemicals that should be encouraged not to be used as part of the process;
- Identify very high hazard chemicals that cannot to be used as part of the process; and
- Incorporate the outcomes of the assessment into environmental mitigation and management controls.

This approach incorporates best practice risk assessment methodology to evaluate potential risks and effects of chemicals used during stimulation activities to environmental values and demonstrate that potential risks to environmental values have been eliminated or reduced as much as reasonably practicable. The methods used for qualitative risk assessment, toxicological assessment and the quantitative risk assessment align with the best practices referenced in the previous methodology with the only difference being that assessment is completed on a chemical-specific basis. On the basis that the potential risk in a fluid system is driven by higher Tier chemicals (Tier 3 and 4) this methodology is considered to effectively evaluate potential human health and ecological risks. Tier 5 chemicals will not be used.

This assessment process is designed to align with national guidance and other regulatory frameworks and assesses the full lifecycle of chemicals that are stored, handled, used and/or disposed of during or following hydraulic stimulation activities and in the treatment of produced formation water. Accidental release scenarios are not included.

The framework involves a two-step process:

- Step 1 – classification of chemicals (**Section 5.2.1**).
- Step 2 – assessment of chemicals (**Section 5.2.2**).

5.2.1 Classification of Chemicals

In accordance with the CRAF, chemicals are classified into five Tiers (Tier 1 through 5) based on the following criteria:

- Assessment of whether chemicals are identified on chemical databases used by NICNAS as indicators that these chemicals are of concern. These included:
  - European Union Substance of Very High Concern (EU SVHC).
  - US National Toxicology Program (US NTP) Report on Carcinogens or International Agency Research on Cancer (IARC) Monographs.
  - European Commission Endocrine Disruptors Strategy - list of Category 1 substances with endocrine disrupting capacity.
  - Chemical Substances Control Law of Japan (CSCL) Class I and II Specified Chemical.
  - Polymers identified as of low concern by NICNAS
- Completion of a formal PBT substances assessment (using environmental reference values contained within the categorisation guidelines) and the factors discussed in the meeting to develop the tiered framework.
- Evaluation of any other concerns associated with persistence in the environment (especially for inorganics) which is not captured in the PBT assessment but may be a consideration in the context of project activities (for example, irrigation of produced water).

The criteria to be used in the chemical category classification within this framework is provided as **Appendix D.1**.

A low-risk chemical is defined as a chemical that is not identified as a PBT chemical and is not listed as a chemical of concern on the following databases:

- EU SVHC.
- US NTP Report on Carcinogens or IARC Monographs.

- European Commission Endocrine Disruptors Strategy - list of Category 1 substances with endocrine disrupting capacity.
- CSCL Class I and II Specified Chemical.

A high-risk chemical is defined as a chemical that is identified as a PBT chemical, or a chemical which exhibits toxicity of potential concern, or is listed as a chemical of concern on the following chemical databases:

- EU SVHC.
- US NTP Report on Carcinogens or IARC Monographs.
- European Commission Endocrine Disruptors Strategy - list of Category 1 substances with endocrine disrupting capacity.
- CSCL Class I and II Specified Chemical.

For the purposes of the CRAF, chemicals categorised as Tier 1 or Tier 2 chemicals are designated as 'low risk' chemicals. Chemicals categorised as Tier 3, Tier 4 or Tier 5 chemicals are designated as 'high risk' chemicals. Tier 5 chemicals will not be used.

5.2.2 Assessment of Chemicals

Based on the category classification of the chemical (and its potential toxicity, persistence and bioaccumulation potential in the environment), different levels of assessment are conducted with the most robust assessment conducted on the highest classification (**Table 15**).

Table 15. Risk Assessment Requirements

Tier	Risk Category	Screening Assessment and Categorisation	Toxicological Profile)	Qualitative Risk Assessment)	Quantitative Risk Assessment	Site-Specific Assessment	Prohibited from Use on Project
1	Low Risk	X	X				
2		X	X	X			
3	High Risk	X	X	X	X		
4		X	X	X	X	X	
5		X					X

Consistent with the screening matrix in **Appendix D.1** and **Table 15**:

- Tier 1 chemicals, which are effectively low toxicity and therefore low hazard, would be subject to only the screening assessment.
- Tier 2 chemicals, in addition to the screening assessment, will be subjected to a qualitative risk assessment.
- Tier 3 and Tier 4 chemicals, in addition to the screening assessment and qualitative risk assessment, will be subject to a quantitative risk assessment with Tier 4 chemicals requiring an additional site-specific risk assessment.
- Site-specific risk assessment for Tier 4 chemicals will require site-specific per use approval by the Minister.
- Tier 5 chemicals will not be used.

Toxicological profiles (risk assessment dossiers) are developed for all chemicals. Depending on the category of the chemical being assessed (i.e., Tier 1, 2, 3 or 4), the toxicological profiles (dossiers) include chemical identification, physical and chemical properties, environmental fate properties, human health and environmental hazard assessments, derivation of non-cancer and cancer screening levels, a PBT assessment and regulatory status.

The qualitative and quantitative assessments are undertaken in accordance with best practice risk assessment methodologies including those contained within the international standards and Australian risk assessment guidance documents referenced in **Section 8**.

In the assessment of exposure pathways and risks, only authorised operational activities are considered (i.e., activities that are authorised in the respective EA and Commonwealth Approval). Where activities are specifically

precluded (e.g., release or disposal of wastes to surface or ground waters are explicitly not authorised), these are not considered in the risk assessment.

Further the qualitative risk assessment considers management plans developed as part of Commonwealth and State approvals, which have been developed to avoid, mitigate, manage and monitor potential impacts.

Based on the outcomes of the *National Assessment of the Chemicals used in Coal Seam Gas in Australia* (DoEE, 2016), hypothetical accidental releases associated with delivery truck rollovers, including into watercourses, represented the greatest potential risk to environmental values. Given the highly regulated nature of transportation of chemicals (at both a Commonwealth and State level), transport related scenarios and assessment will not be incorporated into the risk assessment process. However, the outcome of the assessment should be used to inform emergency response actions.

The chemical risk assessment qualitatively assesses the potential for one or more hazards associated with the chemicals used in hydraulic fracturing to impact environmental values. Further, the assessment of cumulative impacts to environmental values is evaluated for Tier 3 and Tier 4 chemicals only due to their potential persistence and/or potential to bioaccumulate.

Hydraulic stimulation fluid systems and chemicals evaluated in the tiered assessment approach for this report are tabulated in **Appendix D.2**. The table provides the chemical assessed, the associated fluid system and the classification tier determined. An example for a pre-2020 fluid system (Halliburton Hybor DFS-BGB) is also included for comparison. A detailed mass balance of the composition of the new (post-2020) fluid systems and associated CAS numbers are included in **Appendix D.3.** The findings of the screening assessment based on the tiered classification assessment is included in the Registry of Assessed Chemicals (discussed in **Section 5.2.3**).

5.2.3 Register of Assessed Chemicals

A Register of Assessed Chemicals is published and maintained on the Santos website (https://www.santos.com/about-us/corporate-governance/public-notices/) and full access will be provided to DES to review information contained within the register.

The Register of Assessed Chemicals will, for each published chemical, provide a summary of the outcomes of the screening assessment, including the Tier (and Risk Level) categorisation, the activities the chemical has been assessed for (i.e., hydraulic) and the assessed end use /fate of the chemical. The Register for Assessed Chemicals includes the following document control information, where required (typically by Commonwealth Approval):

- date of Register of Assessed Chemical publication;
- date of chemical assessment;
- date of independent chemical risk assessment expert review (Tier 1 and 2 chemicals only);
- date of notification to Commonwealth Environment Department (Tier 1 and 2 chemicals)/date of lodgement to Commonwealth Environment Department (Tier 3 and 4 chemicals);
- date of approval from Commonwealth Environment Minister; and
- date of chemical re-evaluation (only if chemical is still in use).

Supporting information (i.e., dossiers, qualitative and quantitative risk assessments) for each assessed chemical are made readily accessible via the Register of Assessed Chemicals.

5.2.4 Review Process

Where required by Commonwealth Approval conditions, the Tier 1, 2, 3 and 4 risk assessment information for chemicals still in use is to be re-evaluated and peer reviewed every five years by a chemical risk assessment expert. Peer review is only required for chemicals that are still in use.

Typically the 5-year review process will be provided with a statutory declaration provided by an independent suitably qualified person.

6 Qualitative Assessment Methodology

The information provided in this section addresses the following EA approval requirements: conditions (s) and (q).

The qualitative assessment methodology provides a hazard assessment of the hydraulic fracturing fluids used in the assessed fluid systems. The methodology includes a PBT substances assessment based on the Australia and EU Reach Criteria methodology.

The approach presented in the following paragraphs is an assessment of hazard, rather than environmental risk. Risk assessment of chemicals in the environment is based on a comparison between the levels to which an organism in a particular environmental compartment (e.g., water) is exposed, and a maximum level, which an organism can tolerate, based on a defined exposure scenario in an environmental compartment without significant adverse effect. The environmental hazard assessment presented herein, is not a risk assessment per se because it does not consider likely exposure concentrations for most of the hydraulic fracturing chemicals. However, it does define which hydraulic fracturing fluids may potentially present a risk, based on the toxicity demonstrated in the PBT assessment, and the persistence and bioaccumulation that facilitates their potential for exposure by human and ecological receptors.

6.1 PBT Assessment Using Australia DotE / EU REACH Criteria

PBT substances are substances that are persistent (P), bioaccumulative (B) and Toxic (T). A PBT assessment is conducted because of specific concerns for substances that can be shown to persist for long periods in the environment, to bioaccumulate in food chains, and can give rise to toxic effects after a longer time and over a greater distance than chemicals without these properties. These effects may be difficult to detect at an early stage because of long-term exposures at normally low concentration levels and long lifecycles of species at the top of the food chain.

The properties of PBT substances lead to an increased uncertainty in the estimation of risk to human health and the environment when applying quantitative risk assessment methodologies (ECHA, 2008). A ‘safe’ concentration in the environment cannot be established using the methods currently available with sufficient reliability for an acceptable risk to be determined in a quantitative way (ECHA, 2008). Therefore, separate PBT assessments are conducted in conjunction with the quantitative risk assessments. **Appendix B** provides the methodology used to develop the necessary PBT information to conduct the assessment.

Assessments for PBT substances are conducted according to the criteria developed by DotE (formerly DEWHA) (2009). The criteria are presented in **Table 16**.

Table 16. DotE Persistence, Bioaccumulative, and Toxic (PBT) Criteria

Criterion	PBT Criteria		
Persistence	For PBT purposes a chemical is considered persistent in a particular media if its half-life in the media exceeds the following: Half life ($T_{1/2}$) >2 months in water Half life ($T_{1/2}$) >6 months in soil Half life ($T_{1/2}$) >6 months in sediment Half life ($T_{1/2}$) >2 days in air		
Bioaccumulative	For PBT purposes a chemical is bioaccumulative if it has a BCF/BAF of >2000, or in its absence of any BCF/BAF measurement a log K_{ow} >4.2.		
Toxic	For PBT purposes, in respect of aquatic toxicity, a chemical may be toxic under the following circumstances (corresponding to criteria for GHS chronic category 1:		
	Non-rapidly degradable substances for which there are adequate chronic toxicity data available	Chronic NOEC or EC_x (for fish)	<0.1 mg/L and/or
		Chronic NOEC or EC_x (for crustacea)	<0.1 mg/L and/or

Criterion	PBT Criteria		
		Chronic NOEC or EC_x (for algae or other aquatic plants)	<0.1 mg/L
	Rapidly degradable substances for which adequate chronic toxicity data are available	Chronic NOEC or EC_x (for fish)	<0.01 mg/L and/or
		Chronic NOEC or EC_x (for crustacea)	<0.01 mg/L and/or
		Chronic NOEC or EC_x (for algae or other aquatic plants)	<0.01 mg/L
	Substances for which adequate chronic toxicity data are not available (if criteria for P and B are met)	96 h LC_{50} (for fish)	<1 mg/L and/or
		48 h EC_{50} (for crustacea)	<1 mg/L and/or
		72 or 96 ErC_{50} (for algae or other aquatic plants)	<1 mg/L
		And the substance is not rapidly degradable and/or the experimentally determined BCF is >500 (or, if absent, the log K_{ow} is >4.2	
	Toxicity to other (terrestrial) organisms	Should be considered on a case by cases basis, compared with the highly toxic classifications DotE has developed for ag/vet chemicals	
	Long term toxicity or evidence such as endocrine disruption effects	Should be considered on a case-by-case basis.	

Notes:
BAF = Bioaccumulation factor
BCF = Bioconcentration factor

For substances where the available data may not allow a definitive conclusion on the PBT properties, screening criteria developed by the EU for REACH (ECHA, 2008) are used as surrogate information to decide whether a substance may potentially fulfil the PBT criteria. A summary of these screening criteria is provided in **Table 17**.

Table 17. EU REACH Persistence (P), Very Persistence (vP), Bioaccumulative (B), Very Bioaccumulative (vB) and Toxicity (T) Criteria

Type of Data	Criterion	Screening Assignment
Persistence		
Ready biodegradability test	Readily biodegradable	Not P and not vP
Enhanced ready biodegradability test	Readily biodegradable	Not P and not vP
Specified tests on inherent biodegradability		
Zahn-Wellens (OECD 302B)	>70% mineralization (dissolved oxygen carbon (DOC) removal) within 7 d; log phase no longer than 3 d; removal before degradation occurs below 15%; no pre-adapted inoculum	Not P
MITI II test (OECD 302C)	>70% mineralization (O_2 uptake) within 14 d; log phase no longer than 3 d; no pre-adapted inoculum	Not P
Biowin 2 (non-linear model prediction) and Biowin 3 (ultimate biodegradation time) or	Does not biodegrade fast (probability) and ultimate biodegradation timeframe prediction: >months (value <2.2) or	P

Type of Data	Criterion	Screening Assignment
Biowin 6 (MITI non-linear model prediction) and Biowin 3 (Ultimate biodegradation time)	Does not biodegrade fast (probability <0.5) and ultimate biodegradation timeframe prediction: >months (value <2.2)	P
Bioaccumulation		
Convincing evidence that a substance can biomagnify in the food chain (e.g., field data).	e.g., BMF >1	B or vB, definitive assignment possible
Octanol-water partition coefficient (experimentally derived or estimated by valid QSAR)	Log K_{ow} < 4.5	Not B and not vB
Toxicity		
Short-term toxicity aquatic toxicity (algae, daphnia, fish)	EC_{50} or LC_{50} <0.01 mg/L	T, criterion considered to be definitely fulfilled
Short-term toxicity aquatic toxicity (algae, daphnia, fish)	EC_{50} or LC_{50} <0.1 mg/L	T
Avian toxicity (subchronic or chronic toxicity or toxic for reproduction)	NOEC <30 mg/kilogram(kg) food	T

Note:
1 = Biowin is a biodegradable probability program that calculates the probability that an organic chemical will biodegrade rapidly (or slowly) under aerobic or anaerobic conditions, and only provides estimates of anaerobic biodegradation as either "biodegrades fast" or "does not biodegrade fast".
BMF = Biomagnification factor

6.2 Identification of COPCs from Combined Environmental (PBT) and Human Health Hazard Assessments

The hazard assessments from the environmental (PBT) provides criteria that evaluate substances that can be shown to persist for extended periods in the environment, bioaccumulate in food chains, and give rise to toxic effects after a longer time and over a greater distance than chemicals without these properties. This information is used in the overall identification of the COPCs.

A detailed discussion of the PBT process is provided in **Appendix B**, and the results of the assessments by fluid systems are included in **Appendix C**.

7 Exposure Assessment

The information provided in this section addresses the following EA approval requirements: conditions (j), (q), (r), (s), (v), (w), (y) and (aa).

The assessment of exposure involves the evaluation of the data available for the study, the details associated with the surrounding environment, the nature of the exposure identified and the potential mobility of the COPC.

For an exposure pathway to be complete there must be all the following:

- Source of COPC – how the chemical got into the environment and which environmental media are affected
- A transport media – how the chemical moves or migrates through the environment from one location to another, or from one environmental medium to another
- An exposure point – how organisms can come into contact with the chemicals (e.g., direct contact or via the food web)

- An exposure route – how the chemical could enter the organism (e.g., inhalation, ingestion or dermal contact).

If any one of these steps (source, transport media, exposure point or route) is not present, the exposure pathway is incomplete and further assessment of risks is not required. Thus, even if the COPC was a PBT, if there is no threshold concentration at the point of exposure, the potential risk to environmental and human receptors is considered acceptable and would not require mitigative measures.

7.1 Identification of Potential Exposure Pathways and Receptors

A detailed description of the EQ area environment is provided in **Section 2**. In general, the area is sparsely developed, and comprises rural communities and homesteads that are largely engaged in farming and livestock production.

The identification of exposure pathways and receptors has been split into those considered relevant for on-site (i.e., within the drill pad) and those relevant for off-site (i.e., anything beyond the drill pad boundary). A general description of the drill pad is provided in **Section 4**. Individual configurations of drill pads may change; however, the general layout is considered adequate for the identification of exposure pathways and receptors.

The environment surrounding the drill pad (i.e., off-site) may vary. To provide a conservative assessment, it has been assumed there is a homestead with a water supply bore located down gradient of the drill pad. It has also been assumed that a creek, livestock and native flora and fauna, are present in the surrounding environment. This hypothetical assumption was considered for the purposes of the exposure pathway assessment and may not actually occur in the vicinity of a hydraulically fractured well.

7.1.1 On-Site Exposure Pathways

A drill pad is a defined fenced area that contains all the equipment and infrastructure required to hydraulically fracture a well. While all drill pads are fenced, not all are secured with a locked gate. The entrance to some drill pads may have livestock grills rather than gates. A typical drill pad is described in **Section 4.4.5**. Of note for the exposure assessment are the turkey's nest, the blender unit and the mud pit.

As such, a drill pad is an occupational environment and accordingly it is unnecessary to consider any residential scenarios. Workers are typically housed in existing drill camps or camps specifically designed for hydraulic fracturing (frac camps). According to Santos EQ procedures (Hydraulic Fracture Stimulation Procedures, rev1 2005) '*The frac camp should not be located within one kilometre of operations*.' If a camp is located within 1 km, a risk assessment must be performed, and management approval obtained.

The environmental receptors on a drill pad are limited. Livestock and large native animals such as kangaroos are prevented from entering the pad by the fence. However, Santos EQ have indicated that cattle and kangaroos have been noted on drill pads on limited occasions when the fence has been removed for operational reasons (removal of site equipment).

Reptiles such as lizards and snakes are known to enter the pad and have the potential to be entrapped in the turkey's nest if no means of escape are provided. While no specific reports of birds in the drill pads have been noted, it is considered possible that birds may access the site.

As described in **Section 4**, the fracturing fluid is blended on site to the specific requirements of the fracture. The additives required for the fracture are brought onto site and stored in the blender unit and sand trailer, whilst the blending of the fluid is contained and completely automated. A typical fracturing operation is expected to be of limited duration (two to three days). As such, the chemicals are on site for a brief period of time. Any exposures associated with a spill of fracturing chemicals prior to injection is dealt with under appropriate occupational health and safety procedures and has not been considered further in this report.

The primary pathways for environmental and occupational exposures outside of spills are dermal, ingestion and inhalation of dust. Inhalation of volatile chemicals is of lesser concern as there are no indoor/enclosed environments with all activities conducted outside.

Typically, implemented measures to limit exposure include:

- Exposure by trespasses is limited through ensuring all drill pads are securely fenced. Signs are clearly displayed indicating water in the turkey's nest and mud pit is not potable and may contain contaminants.

- Exposure to livestock is limited through regular maintenance of fences.
- Exposures to sediments in the mud pit and turkeys' nest are limited by disposal or capping of sediments.

The main areas on site that are considered for occupational and environmental exposure are the turkey's nest and mud pit and these are discussed in more detail below.

7.1.1.1 Turkey's Nest

The turkey's nest is a lined (e.g., clay) storage area for the water used in fracturing. It can also be used to store the flowback water following temporary storage in the mud pit to allow sediment to settle. The turkeys nest typically has a 500 mm freeboard control requirement.

Occupational exposure to fracturing chemicals within the turkey's nest may occur from contact with the flowback water or from contact with sediments following drainage. Human exposure to the water in the turkey's nest during normal operation would be limited but may occur if the turkey's nest or liner becomes damaged and requires repair. Normal Occupational Health and Safety (OH&S) procedures are expected to limit workers exposure to flowback water under these scenarios. Human and/or ecological exposure may occur in the event of a flood where the freeboard is breached or if there is a breach of the walls.

The volume of sediment in the turkey's nest is expected to be small as the sediments are settled out of the fluid in the mud pit prior to storage in the turkey's nest. Alternatively, if the water has been sourced from offsite, there will not be any sediment in the turkey's nest.

Exposure to the sediment in the turkey's nest may occur if the turkey's nest is drained and the sediments dry out and contribute to wind borne dust. However, the small volume of dust from sediments is not likely to be of concern to human or ecological receptors and has not been considered further.

It is possible that trespassers may access the site if the pad is not fully secure, accidental and deliberate exposure to chemicals in the flowback water in the turkey's nest may occur. Ecological exposures to hydraulic fracturing chemicals within the turkey's nest may occur from contact with the flowback water or from contact with sediments following drainage. Ecological receptors may include stock animals, kangaroos and other native mammals, reptiles and birds.

7.1.1.2 Mud Pit

The mud pit is constructed during the well-drilling phase, to provide a recirculation and sedimentation pit for the drilling fluids. It is used during hydraulic fracturing as the first reservoir for flowback fluids once the first-flush fluids have been collected in tanks intended for off-site disposal. The fluid is held in the pit to allow the sediment to settle and until it meets the criteria for re-use or is sent for off-site disposal.

The occupational and ecological exposures to the chemicals in the mud pit are like those in the turkey's nest. Workers are expected to have limited contact with the flowback water during operational procedures.

Normal OH&S procedures are expected to limit worker exposure to flowback water in the event of a spill or if the mud pit becomes damaged and requires repair. Human and ecological exposure to the sediment may occur if the mud pit is drained and the sediments dry out and contribute to wind borne dust. The volume of sediments in the pit is considered to be small, unlikely to be of concern to either receptor group, and is not considered further in the exposure assessment.

Trespassers may access the site if the pad is not fully secure, and accidental or deliberate exposure to chemicals in the flowback water in the mud pit may occur. Ecological exposures to hydraulic fracturing chemicals within the mud pit may occur from contact with the flowback water or from contact with sediments following drainage. Ecological receptors may include stock animals, kangaroos and other native mammals, reptiles and birds.

7.1.2 Off-Site Potential Exposure Pathways

The off-site environment is considered anything outside the boundary of the drill pad. As discussed in **Section 1** and **Section 2,** the off-site environment is a sparsely developed with the predominant land use being the raising of livestock. For the purposes of developing a conservative worst-case scenario, of potential exposures, it has been assumed the environment surrounding a drill pad potentially could include:

- A homestead with a water supply bore. Adults and children living on the homestead and drinking water from the bore.

- A creek and associated ecosystems.
- Livestock with water provided by a water supply bore or the creek.
- Native flora and fauna.

The well pad sites where hydraulic fracturing will be conducted will be remote from water supply bores and not immediately adjacent to sensitive environments.

The possible exposure scenarios include receptors and exposure pathways considered relevant for off- site. The main possible sources identified are the hydraulic fracturing fluid, flowback water and gas. These are discussed in more detail below.

7.1.2.1 Exposure to Hydraulic Fracturing Fluid

Potential human and ecological exposures to fracturing fluid is unlikely but theoretically could occur due to casing failures or through fractures into surrounding aquifer. However, Santos EQ currently uses an extensive system of procedures to minimise the likelihood of the fracture (and then the fluid) leaving the target area and the loss of well integrity, as described in **Section 4**.

These systems include extensive testing programs, and operational and systems monitoring to ensure hydraulic fracturing activities are confined to the target units. If a loss of integrity is identified in a well immediate measures are employed to decommission the well or rectify the situation.

On this basis, there is an insignificant likelihood that exposure to fracturing fluids could occur due to the fluid escaping the target coal seam and contaminating overlying aquifers that are used for domestic or stock water supply or discharge into a creek. This conclusion is supported by a study completed by Osborn et al. (2011), which evaluated, aquifers overlying the Marcellus and Utica shale formations of north-eastern Pennsylvania and upstate New York. The study evaluated several issues associated with hydraulic fracturing including:

> 'Concerns for impacts to groundwater resources, from (i) fluid (water and gas) flow and discharge to shallow aquifers due to the high pressure of the injected fracturing fluids in the gas wells'.

The study evaluated groundwater from 68 private water wells, which ranged in depth from 36 to 190 m. The area of the study is undergoing an expansion of gas well drilling and hydraulic fracturing and is in an area with extensive fracture systems with several major faults and lineaments. The study found '*no evidence for contamination of the shallow wells near active drilling sites from deep brines and/or fracturing fluids*.'

A second source of possible human and ecological exposure to hydraulic fracturing fluids is the residual fluid in the coal seam. It is assumed that fluid may remain in the coal seam following fracturing. Exposure may occur if chemicals in the residual fluid migrate down gradient in the coal seam and into a natural spring or water supply bore in close vertical proximity to the coal seam. This pathway is evaluated through the fate and transport modelling provided below. However, migration of organic fracturing fluid chemicals in the coal seams is strongly attenuated by sorption to the carbon in the coal. In addition, the zone of hydraulic fracturing is less than 100 m, and all aquifers are identified within and beyond this zone in **Section 3.2.2**

7.1.2.2 Exposure to Sediments in the Turkey's Nest or Mud Pit

Potential off-site human and ecological exposure to the sediment from hydraulic fracturing could occur if the turkey's nest and/or mud pit is drained, and the sediments were left to dry out and contribute to wind borne dust.

The volume of sediments in the pit is considered to be small and unlikely to be of concern to either receptor group. Capping or disposal of the sediments (following drainage of the turkey's nest and mud pit) is conducted following the completion of drilling and removes the potential for off-site sediment exposure.

7.1.2.3 Exposure to flowback water

Potential off-site human and ecological exposure to chemicals in the flowback water could possibly occur under a range of conditions; however, the implementation of controls makes this the likelihood of this exposure minimal.

Exposure scenarios potentially could include:

- Releases of infiltration of flowback water into shallow aquifers that are used for domestic or stock water supply or which discharge to surface water.
- Direct releases to surface water.

However, for this exposure pathway to be complete there must be all of the following:

- A failure of the lining of the turkey's nest or mud pit.
- A high permeability unit beneath the drill pad that can transmit the flowback water to an underlying aquifer.
- A shallow aquifer located in the subsurface beneath the drill pad that either is used as water supply or discharges into a creek.

If any of the above conditions are not present, no exposure will occur. As previously noted, water supply bores are present in the shallow alluvium throughout the Santos EQ area. It is therefore considered possible that a high permeability unit and a shallow aquifer with a downgradient water supply bore may be present under the drill pad.

The concentrations of hydraulic fracturing chemicals in the flowback water are lower than those injected due to the capture of first flush, and the toxicity of those chemicals is expected to rapidly decrease due to the relatively rapid biodegradation, short biotransformation half-lives, and volatilisation of many of the chemicals. The concentrations of chemicals are also expected to be reduced along the flow path of the coal seam through degradation adsorption and dissolution. The likelihood of exposure to fracturing chemicals under this scenario in concentrations likely to be of concern is considered to be low.

7.1.3 Spills and Overflows from the Turkey's Nest of Mud Pit

Potential off-site human and ecological exposure to flowback water could possibly occur in the event of a spill or overflow from the turkey's nest or mud pit. However, the turkey's nests have been designed to exclude stormwater and will be operated with a 500 mm freeboard to limit the potential for overflow. On this basis, a release could only occur during a prolonged period of heavy rainfall. The probability of a spill or overflow event occurring is further reduced by minimising the duration that flowback fluids are stored in the pit or turkey's nest. In addition, the toxicity of the chemicals in the flowback fluid is likely to be rapidly reduce based on the dissociation of the inorganic chemicals, and the relatively rapid biodegradation, short biotransformation half-lives, and volatilisation of most organic chemicals. In the event of a release, human and ecological receptors could possibly be exposed however sampling of soil, groundwater and surface water (if relevant) in the affected area would be required to determine if unacceptable exposures had occurred.

7.1.4 Management Measures to Reduce Off-Site Exposure

Management measures that are implemented to reduce the potential for off-site exposure or assess the potential for exposure include:

- Lining of mud pits and turkey's nests to prevent seepage of flowback water into underlying aquifer.
- Capping or removal and disposal of the sediments immediately after drainage of the turkey's nest and mud pit.
- Fencing of well pads during drilling and hydraulic fracturing to preclude livestock and trespassers from the work area.
- Management of water levels in all dams prior to the onset of the wet season. This is consistent with the requirements contained within the each.
- Regular monitoring of water supply bores for fracturing fluid indicator parameters within 2 km of wells that are fractured. A stimulation impact monitoring plan has been developed to both identify potentially at-risk wells and undertake baseline and post hydraulic fracturing sampling.

7.2 Fate and Transport Assessment in Groundwater

Extraction bores represent a short circuit pathway for groundwater in the screened aquifer formations directly to the surface. Groundwater extraction through water supply bores represents a potential receiving environment. The types of environmental values potentially exposed to this groundwater may vary depending on the use of the bore, which can range from drinking water supply, irrigation, stock watering and industrial and commercial uses.

For this groundwater exposure pathway to be valid in the context of potential exposure to hydraulic fracturing fluids, a water supply well would need to be completed in close proximity (less than 100 m) to a gas production bore at which hydraulic fracturing had occurred, such that the capture zone of the well could conceivably include residual hydraulic fracturing fluid components from the coal seam. Realistically, this would require that the well be screened either within the coal seam itself, or in an aquifer formation immediately adjacent to the coal seams with the potential for inter-aquifer transfer to occur. Further, the well would need to be close enough to the area

affected by hydraulic fracturing fluids so that the chemical components did not have a chance to attenuate in the aquifer. It is noted that Santos EQ's procedures for selecting locations for gas production wells would preclude installation of a production well near an identified water supply bore. Further, there is no record of water supply wells screened within coal seams or near Santos EQ's petroleum lease areas. In many cases the salinity and presence of odoriferous compounds does not make the water conducive to potable uses.

To assess the fate and transports of hydraulic fracturing chemicals in the subsurface, Golder Associates (2010), as part of their hydraulic fracturing risk assessments, conducted fate and transport modelling. This modelling evaluated key constituents of interest within the fluid systems and provided the framework for assessing the potential mobility of all constituents used in hydraulic fracturing.

Based on the modelling and assessments described below, the selection of chemicals considered within the fate and transport modelling provides a broad range of physical properties which all assessment of varying physical properties on fate and transport.

In general, the model was not sensitive to the variability in physical properties of chemicals. The abundance of organic carbon within the coal seams and the generally low transmissivities (less than 10^5 m/s) preclude broad scale migration of constituents within the formation coals. Based on the broad range of physical properties assessed, the limited transport observed in the model and limited impact that physical properties have on transport distances, additional modelling for new fluid systems was not considered warranted.

Further details on the framework and general findings are provided below.

7.2.1 Subsurface Fate and Transport Considerations

The environmental mobility of COPC was considered for the scenario of fracturing fluid chemicals injected into coal seams. The approach to the assessment is described in the following sections.

7.2.2 Environmental Fate of Inorganic COPC

The inorganic chemicals with the highest hazards are either ionisable inorganic compounds (i.e., readily dissociate into simple salts) or have limited mobility in a coal seam environment due to their physical properties when hydrated (amorphous silica).

Given the fact that all of the inorganic COPC would either rapidly dissociate into simple ions or would have limited mobility based on physical properties when hydrated (i.e., form a gel consistency) it was considered unnecessary to attempt to model the migration of inorganic COPC within the coal seam. The likely result of the dissociation of inorganic compounds in fracturing fluid is a local change in the pH and total dissolved solids load in the immediate vicinity of the fracture zone. Given that the receiving coal seam groundwater is already brackish to saline, the incremental increase in dissolved salt load from dissociated inorganic COPC was considered to represent a low risk in an aquifer environment and did not warrant further assessment through modelling.

7.2.3 Fate and Transport Modelling of Organic COPC

A contaminant fate and transport model was developed to assess the potential for migration of organic COPC in groundwater based on the estimated concentrations in the hydraulic fracturing fluids. The objective of the modelling was to assess the migration potential of organic COPC of the residual hydraulic fracturing fluids remaining in the coal seam following the completion of the hydraulic fracturing process. Golder Associates (2011a) assessed the following organics for mobility in the environment through fate and transport modelling. These included:

Standard Schlumberger Fluid System

- Tetrasodium EDTA
- 5-chloro-2-methyl-4-isothiazolin-3-one
- 2-methyl-4-isothiazolin-3-one
- Vinylidene chloride.

Standard Halliburton Fluid System

- Fatty acid ester
- 1,2 benzisothiazolin -3-one
- Alkylated quaternary chloride

- Sweet orange oil
- Polyethlyene glycol oleate ester.

This selection of organic chemicals provides a broad range of physical properties with the biocides and fatty acids providing the highest potential mobility.

Acetic acid was not considered for fate and transport modelling. This simple organic acid is added to fracturing fluids for pH adjustment and is rapidly buffered in the system. Hence, similar to the inorganic COPC, it is likely to be rapidly consumed within the fracturing radius yielding simple by-products (ultimately carbon dioxide and water). Hence modelling the migration of acetic acid in an aquifer in unreacted form was considered to be unrealistically conservative and accordingly was not considered further from a fate and transport perspective.

7.2.4 Methodology

A one-dimensional fate and transport model, ConSim version 2.5 (Golder, 2010), was used to assess the potential extent of migration of organic COPC in groundwater. The software is based on a probabilistic methodology using a Monte Carlo simulation technique that allows for specification of a range of values for each input parameter rather than a single number. Each simulation comprises multiple iterations of the model run, with input parameters selected from within the range specified for each, to provide a range of modelling results, which reflect the uncertainty inherent in the input values. The modelling results are presented as charts of the statistical probability of a given chemical concentration reaching a specified distance from a gas well at specified time intervals.

The modelling results for chemical concentrations have been reported as both the 50% and 95% confidence limit values generated by the Monte Carlo simulator. The 50% value should be considered as a median, or most likely, value, while the 95% value is conservative (i.e., there is only a 5% chance that the 95% confidence limit value would be exceeded based on the range of model input parameters).

7.2.5 Input Parameters and Model Assumptions

A fate and transport model was developed to simulate the major physical, chemical and biological processes that would influence the transport of residual COPC in the coal seam following hydraulic fracturing. The model considered the scenario of a single gas well, to function as a proxy for evaluating potential exposure pathways for each gas production well that could potentially be subject to hydraulic fracturing. The details regarding parameter selection and model assumptions are summarised in the following sections and chemical information sheets are provided in **Appendix E**.

Table 18. Summary of ConSim Input Parameters

Parameters	Data Distribution	Distribution Parameters			Comment
		Minimum	Maximum	Likely Value	
Hydraulic parameters					
Hydraulic conductivity (m/s)	Log triangular	5 x10-10	1.2 x 10-5	1.0 x 10-6	Data from pumping test (Matrixplus, 2009)
Hydraulic gradient	Uniform	0.002	0.004	-	Estimated from Surat North
Effective porosity (fraction)	Uniform	0.02	0.11	-	Estimated 2% for coal seam and 11% for fractures, modelled as a range
Estimated plume length (m)	-	20	-	-	-

Parameters	Data Distribution	Distribution Parameters			Comment
		Minimum	Maximum	Likely Value	
Initial dispersivity (m)					
Longitudinal	Uniform	2.9	5.0	-	Calculated based on the estimated plume length of 20 m using equation Xu and Eckstein (1995), or estimated as 10% of the plume length
Transverse	Uniform	0.3	0.5	-	10% of the longitudinal dispersivity
Aquifer properties					
Dry bulk density (g/cm3)	Single	-	-	1.3	Published value for bituminous coal (Allen- King et al, 2002)
Organic carbon content (%)	Triangular	56	72	65	Published data for Walloon Subgroup (Scott et al., 2007)
Source concentrations (mg/L)					
Schlumberger fluid system – key constituents					
Tetrasodium EDTA	Triangular	4	12	8	Calculated from mass fraction information provided by the contractor
5-chloro-2-methyl-4-isothiazolin-3-one	Triangular	2	6	4	Calculated from mass fraction information provided by the contractor
2-methyl-4-isothiazolin-3-one	Triangular	0.5	1.5	1	Calculated from mass fraction information provided by the contractor
Vinylidene chloride	Triangular	9	27	18	Calculated from mass fraction information provided by the contractor
Halliburton fluid system – key constituents					
Fatty acid ester	Triangular	141	422	281	Calculated from mass fraction information provided by the contractor

Parameters	Data Distribution	Distribution Parameters			Comment
		Minimum	Maximum	Likely Value	
1,2-benzisothiazolin-3-one	Triangular	1	3	2	Calculated from mass fraction information provided by the contractor
Alkylated quaternary chloride	Triangular	1.35	3104	2069	Calculated from mass fraction information provided by the contractor
Sweet orange oil	Triangular	47	141	94	Calculated from mass fraction information provided by the contractor
Source dimensions					
Thickness (m)	Uniform	0.8	6.3	-	Thickness of coal seams in the study area (Matrixplus, 2009)
Area (m^2)	31,415	-	-	-	Assumes a radial fracture distribution around injection point approximately 200 m in diameter
Partitioning coefficient Koc (kg/L)					
Schlumberger fluid system					
Tetrasodium EDTA	Single		-	-	312.7
5-chloro-2-methyl-4-isothiazolin-3-one	Single	-	-	19.38	Estimated using episuite v.4.0, USEPA
2-methyl-4-isothiazolin-3-one	Single	-	-	12.08	Estimated using episuite v.4.0, USEPA
Vinylidene chloride	Single	-	-	64	Estimated using episuite v.4.0, USEPA
Halliburton fluid system					
Fatty acid ester	Single		-	-	2,423
1,2-benzisothiazolin-3-one	Single		-	-	34.5
Alkylated quaternary chloride	Single		-	-	8.2
Sweet orange oil	Single		-	-	1,119
Polyethylene glycol oleate ester	Single		-	-	3,321

7.2.5.1 Source Specification and Concentrations

The source was the residual hydraulic fracturing fluid components associated with a single gas well. It has been assumed that:

- Injection of the hydraulic fracturing fluids into coal seams creates a source zone with a typical maximum radius of 100 m around the injection well which penetrates the whole thickness of the coal seam. This is conservative in that typically only discrete, thin fractures are created, rather than full penetration of the coal seam.
- The source of dissolved chemicals was conservatively assumed to be infinite (no recovery or biodegradation) releasing constant dissolved chemical concentrations (no dilution) over the simulated period (up to 1,000 years).
- Natural groundwater flow conditions have been established immediately following the injection of hydraulic fracturing fluids, which would only apply to the limited duration between completion of the fracturing event and the gas well being brought into operation.

The estimated concentrations of the hydraulic fracturing fluid additives were calculated from mass balances provided for the various fluid systems. These mass balances for the Halliburton and Schlumberger fluid systems modelled are provided in **Appendix C**.

7.2.5.2 Aquifer Properties

It has been assumed for this modelling that the fractured coal seam can be represented as an equivalent porous medium. Aquifer property data was based on reported values in Matrixplus (2009) (see **Figure 70**) and URS (2011). Porosity data obtained from field measurements followed a polynomial distribution. Therefore, a uniform distribution ranging between 2% and 11% was estimated for this parameter. A log triangular distribution was assumed for hydraulic conductivity. A triangular data distribution is generally applied where, in addition to minimum and maximum values, it is possible to identify a value that is likely to occur; the use of a log triangular distribution prevents a bias towards the larger values. The range of hydraulic conductivity values varied between $5.0x10^{-10}$ m/s to $1.2x10^{-5}$ m/s with the most likely value corresponding to $1.0x10^{-6}$ m/s. The hydraulic gradient was estimated from previously reported groundwater elevation data (Golder, 2009) for the Surat 5 (Surat North1) GMU. The estimated hydraulic gradient ranged between 0.002 and0.004 across this GMU.

A coal seam bulk density of 1.3 grams per cubic centimetre (g/cm^3) was adopted from published data on volatile bituminous coals (Allen- King et al., 2002).

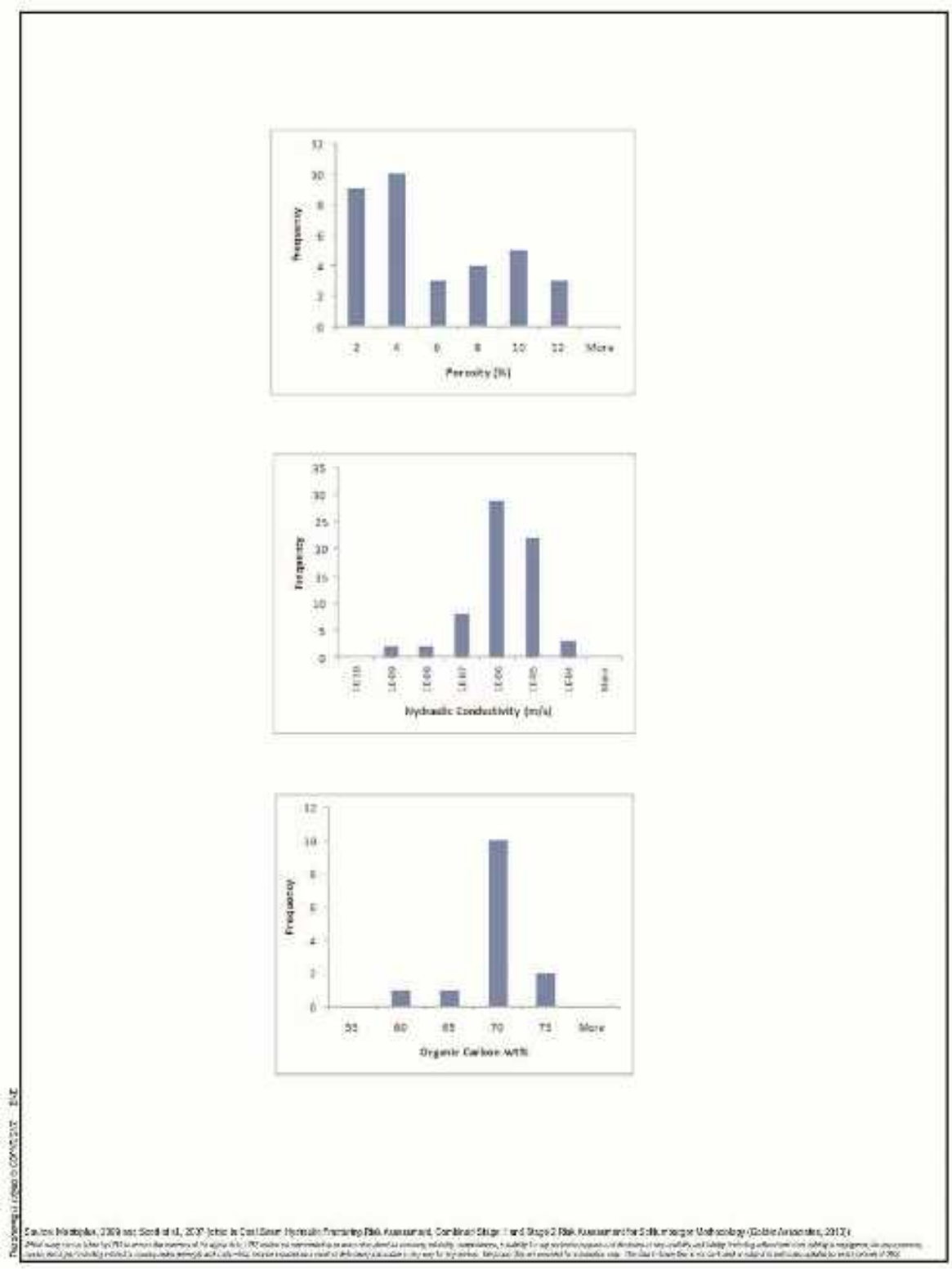


Figure 70. Histogram of Coal Seam Aquifer Porosity and Hydraulic Conductivity

Source: Matrixplus, 2009

7.2.6 Adsorption

7.2.6.1 Fraction of Organic Carbon

The organic carbon content of an aquifer is considered the principal factor contributing to the sorption of dissolved organic compounds in groundwater. Based on published studies by Scott et al. (2007) the middle Jurassic coals of the WCM in the Surat Basin are classified as highly volatile bituminous coals with high carbon content [50-70 weight percent (wt%)] and a moderate to high ash content (approx. 30 wt%). The distribution of organic carbon data was assumed to be triangular within the defined range from 56 wt% to 72 wt% and the most likely value corresponding to 67 wt% (Golder, 2011a).

7.2.6.2 Organic carbon partitioning coefficient (K_{oc})

The organic carbon partitioning coefficient (K_{oc}) is a measure of a chemical's affinity for adsorption to organic matter in soils, where higher values correspond to higher retention in organic matter. Only a single value was used for each of the COPC considered.

Uniform data distributions were assigned to the K_{oc} values for all modelled hydraulic fracturing fluid components.

7.2.7 Conservatism of Modelling Assumptions

A significant degree of conservatism was incorporated into the modelling assumptions to represent a worst-case scenario. The model is conservative in terms of the following assumptions:

- An infinite and constant source for each chemical (i.e., no degradation or depletion of chemical concentrations in the source over time).
- Dispersion and sorption were the only processes simulated (i.e., biodegradation was not considered).
- Natural groundwater flow conditions prevail at the site (i.e., no additional capture of residual hydraulic fracturing fluid due to groundwater extraction during gas production).

7.2.8 Results

The modelling provided unretarded travel times as a basis for comparison to the influence of the physical and chemical processes that retard the migration rate of hydraulic fracturing fluid chemicals relative to the groundwater flow velocity. The simulated unretarded travel times at different distances downgradient from the source are presented in **Table 19.** The simulated unretarded travel time to reach a monitoring point located 20 m down hydraulic gradient from the source ranged from 2 to 35,000 years, which reflects the large range of potential hydraulic conductivity values reported for the coal seams (i.e. five orders of magnitude). The minimum travel times can be considered as the most conservative in this case (i.e., fastest migration rate), while the 50th percentile values can be considered the median or most likely travel times to reach the various distances.

Table 19. Unretarded Travel Time (years)

Distance down hydraulic gradient from the source	Min	Max	50th percentile	95th percentile
5 m	0.5	22,000	45	3,245
20 m	2.0	35,000	85	5,530
50 m	3.0	61,750	155	10,760
100 m	5.0	107,700	280	19,900

7.2.9 Tetrasodium EDTA

The model results presented in **Table 20** below suggest that the mobility of tetrasodium EDTA is extremely low, with a maximum estimated concentration of $3x10^{-11}$ mg/L reaching 5 m beyond the fracturing radius after 1,000 years (i.e., undetectable by analytical laboratories).

Table 20. Predicted Tetrasodium EDTA Concentrations in Groundwater Down Hydraulic Gradient from Hydraulically Fractured Area (Dispersion and Sorption)

Distance from the source	Range of 50th, 95th percentile concentrations					
	Predicted concentrations at 20 years (mg/L)		Predicted concentrations at 100 years (mg/L)		Predicted concentrations at 1000 years (mg/L)	
	50th	90th	50th	90th	50th	90th
5 m	< LOR	< LOR	< LOR	< LOR	< LOR;	< LOR
20 m	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR
50 m	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR
100 m	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR

Note: Typical conservative LOR for organic chemicals was assumed to be 0.001 mg/L.

7.2.10 5-chloro-2-methyl-4-isothiazolin-3-one

The model results presented in **Table 21** below suggest that the mobility of 5-chloro-2-methyl-4- isothiazolin-3-one is extremely low, with a maximum predicted concentration of 0.02 mg/L reaching 20 m beyond the fracturing radius after 1,000 years.

Table 21. Predicted 5-chloro-2-methyl-4-isothiazolin-3-one Concentrations in Groundwater Down Hydraulic Gradient from Hydraulically Fractured Area (Dispersion and Sorption)

Distance from the source	Range of 50th, 95th percentile concentrations					
	Predicted concentrations at 20 years (mg/L)		Predicted concentrations at 100 years (mg/L)		Predicted concentrations at 1000 years (mg/L)	
	50th	90th	50th	90th	50th	90th
5 m	< LOR	<LOR	< LOR	< LOR	< LOR	1.09
20 m	< LOR	< LOR	< LOR	< LOR	< LOR	0.02
50 m	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR
100 m	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR

7.2.11 2-methyl-4-isothiazolin-3-one

The model results presented in **Table 22** below suggest that the mobility of 2-methyl-4-isothiazolin-3- one is extremely low, with a maximum predicted concentration of 0.08 mg/L reaching 20 m beyond the fracturing radius after 1,000 years.

Table 22. Predicted 2-methyl-4-isothiazolin-3-one Concentrations in Groundwater Down Hydraulic Gradient from Hydraulically Fractured Area (Dispersion and Sorption)

Distance from the source	Range of 50th, 95th percentile concentrations					
	Predicted concentrations at 20 years (mg/L)		Predicted concentrations at 100 years (mg/L)		Predicted concentrations at 1000 years (mg/L)	
	50th	90th	50th	90th	50th	90th

Distance from the source	Range of 50th, 95th percentile concentrations					
	Predicted concentrations at 20 years (mg/L)		Predicted concentrations at 100 years (mg/L)		Predicted concentrations at 1000 years (mg/L)	
5 m	< LOR	< LOR	< LOR	< LOR	< LOR	0.56
20 m	< LOR	< LOR	< LOR	< LOR	< LOR	0.08
50 m	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR
100 m	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR

7.2.12 Vinylidene Chloride

The model results presented in **Table 23** below suggest that the mobility of vinylidene chloride is extremely low, with a maximum predicted concentration of 0.56 mg/L reaching 5 m beyond the fracturing radius after 1,000 years, and concentrations below the assumed reporting limit at 20 m beyond the fracturing radius after 1,000 years.

Table 23. Predicted Vinylidene Chloride Concentrations in Groundwater Down Hydraulic Gradient from Hydraulically Fractured Area (Dispersion and Sorption)

Distance from the source	Range of 50th, 95th percentile concentrations					
	Predicted concentrations at 20 years (mg/L)		Predicted concentrations at 100 years (mg/L)		Predicted concentrations at 1000 years (mg/L)	
	50th	90th	50th	90th	50th	90th
5 m	< LOR	< LOR	< LOR	< LOR	< LOR	0.54
20 m	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR
50 m	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR
100 m	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR

7.2.13 7.2.13 Fatty Acid Ester

The model results presented in **Table 24** below suggest that the mobility of fatty acid ester is extremely low, with a maximum predicted concentration of 8.7×10^{-15} mg/L reaching 5 m beyond the fracturing radius after 1,000 years.

Table 24. Predicted Fatty Acid Ester Concentrations in Groundwater Down Hydraulic Gradient from Hydraulically Fractured Area (Dispersion and Sorption)

Distance from the source	Range of 50th, 95th percentile concentrations					
	Predicted concentrations at 20 years (mg/L)		Predicted concentrations at 100 years (mg/L)		Predicted concentrations at 1000 years (mg/L)	
	50th	90th	50th	90th	50th	90th
5 m	< LOR	< LOR	< LOR;	< LOR	< LOR	< LOR
20 m	< LOR	< LOR	< LOR;	< LOR	< LOR	< LOR
50 m	< LOR	< LOR	< LOR;	< LOR	< LOR	< LOR
100 m	< LOR	< LOR	< LOR;	< LOR	< LOR	< LOR

Note: Typical conservative LOR for organic chemicals was assumed to be 0.001 mg/L.

7.2.14 1,2-benzisothiazolin-3-one

The model results presented in **Table 25** below suggest that the mobility of 1,2-benzisothiazolin-3-one is extremely low, with a maximum predicted concentration of 0.39 mg/L reaching 5m beyond the fracturing radius after 1,000 years.

Table 25. Predicted 1,2-benzisothiazolin-3-one Concentrations in Groundwater Down Hydraulic Gradient from Hydraulically Fractured Area (Dispersion and Sorption)

Distance from the source	Range of 50th, 95th percentile concentrations					
	Predicted concentrations at 20 years (mg/L)		Predicted concentrations at 100 years (mg/L)		Predicted concentrations at 1000 years (mg/L)	
	50th	90th	50th	90th	50th	90th
5 m	< LOR	< LOR	< LO	< LOR	< LOR	0.39
20 m	< LOR	< LOR	< LOR	< LOR	< LO	0.0004
50 m	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR
100 m	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR

7.2.15 Alkylated Quaternary Chloride

The model results presented in **Table 26** below suggest that the mobility of alkylated quaternary chloride is limited. Despite having the lowest Koc value of the COPC evaluated, the upper end concentration predicted to reach 20 m beyond the fracturing radius after 100 years is still less than one part per billion (i.e., below the standard laboratory limit of reporting (LOR) for most organic chemicals).

Table 26. Predicted Alkylated Quaternary Chloride Concentrations in Groundwater Down Hydraulic Gradient from Hydraulically Fractured Area (Dispersion and Sorption)

Distance from the source	Range of 50th, 95th percentile concentrations					
	Predicted concentrations at 20 years (mg/L)		Predicted concentrations at 100 years (mg/L)		Predicted concentrations at 1000 years (mg/L)	
	50th	90th	50th	90th	50th	90th
5 m	< LOR	< LOR	< LOR	12	0.2	1,766
20 m	< LOR	< LOR	< LOR	< LOR	< LOR	1,155
50 m	< LOR	< LOR	< LOR	< LOR	< LOR	69
100 m	< LOR	< LOR	< LOR	< LOR	< LOR	0.0007

Note: Typical conservative LOR for organic chemicals was assumed to be 0.001 mg/L.

7.2.16 7.2.16 Sweet Orange Oil

The model results presented in **Table 27** below suggest that the mobility of sweet orange oil is extremely low, with a maximum predicted concentration of $2x10^{-11}$ mg/L reaching 5 m beyond the fracturing radius after 1,000 years.

Table 27. Predicted Sweet Orange Oil Concentrations in Groundwater Down Hydraulic Gradient from Hydraulically Fractured Area (Dispersion and Sorption)

Distance from the source	Range of 50th, 95th percentile concentrations					
	Predicted concentrations at 20 years (mg/L)		Predicted concentrations at 100 years (mg/L)		Predicted concentrations at 1000 years (mg/L)	
	50th	90th	50th	90th	50th	90th
5 m	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR
20 m	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR
50 m	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR
100 m	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR

Note: Typical conservative LOR for organic chemicals was assumed to be 0.001 mg/L.

7.2.17 Polyethylene Glycol Oleate Ester

The model results presented in **Table 28** below suggest that the mobility of polyethylene glycol oleate ester is extremely low, with a maximum predicted concentration of $7x10^{-16}$ mg/L reaching 5 m beyond the fracturing radius after 1,000 years.

Table 28 . Predicted Polyethylene Glycol Oleate Ester Concentrations in Groundwater Down Hydraulic Gradient from Hydraulically Fractured Area (Dispersion and Sorption)

Distance from the source	Range of 50th, 95th percentile concentrations					
	Predicted concentrations at 20 years (mg/L)		Predicted concentrations at 100 years (mg/L)		Predicted concentrations at 1000 years (mg/L)	
	50th	90th	50th	90th	50th	90th
5 m	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR
20 m	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR
50 m	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR
100 m	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR

7.2.18 Summary of Groundwater Fate and Transport Modelling

The modelling results suggest that organic COPC in the hydraulic fracturing fluid will be strongly attenuated within the coal seam, predominantly by adsorption. The extent of sorption of organic chemicals in aquifers depends on the content as well as nature of the organic carbon. The natural attenuation potential for organic chemicals within coal seam is significantly higher than that of natural soils due to the high content of organic carbon (50-70%).

Previous published studies have demonstrated that the presence of thermally altered carbonaceous materials such as coals, chars, and kerogen in soils, sediment and rocks has a significant influence on sorption even when present in small fractions (Allen-King et al., 2002). The model simulations suggested a strong attenuation capacity for all organic COPC considered. Sorption was predicted to significantly limit the transport of all constituents with the exception of the alkylated quaternary chloride. Even with the adoption of source concentrations one to three orders of magnitude above the estimated solubility limits for the chemicals no inherent transport was observed.

The exception was alkylated quaternary chloride, for which the upper end modelling predictions suggest migration of detectable concentrations to between 50 and 100 m beyond the fracturing radius after 1,000 years. It is reiterated, however, that the modelling excluded biodegradation as an attenuation process for the sake of conservatism, and assumed a constant mass in the source zone, both of which result in unrealistically conservative migration estimates over long timeframes. The dissolved plumes associated with each of the organic COPC would reach equilibrium with respect to the attenuation capacity.

Further, the assumption of the residual hydraulic fracturing fluids being subject to a natural groundwater flow field is also very conservative, as hydraulically fractured gas wells are typically brought into production within approximately one year after the hydraulic fracturing process and are typically operated for five to thirty years.

During gas production, groundwater is extracted from the gas well to depressurise the coal seam, which creates a significant inward hydraulic gradient that would likely act to prevent migration and capture and remove most of the residual hydraulic fracturing fluid mass over the operational lifespan of the gas production well.

In summary, the modelling results suggest that the strong sorption capacity of the coal seam aquifers will significantly limit the transport potential of the organic hydraulic fracturing fluid components. Migration of most of the organic COPC was predicted to be less than 5 m beyond the hydraulic fracturing radius of influence over 1,000-year simulation. On this basis, migration of constituents in groundwater to potential receptors is not considered a potentially complete exposure pathway.

7.3 Identification of Complete Exposure Pathways

The potential for exposures has been assessed qualitatively and through groundwater fate and transport modelling. These are summarised below separately for on-site and off-site receptors.

7.3.1 On-Site Exposure Pathways

The most likely potential exposures were evaluated for workers, trespassers, native fauna and stock animals. Based on information provided by Santos EQ, there does not appear to be complete exposure pathways identified for on-site workers under normal circumstances, provided the following conditions are met:

- Adequate OH&S procedures are adhered to that prevent direct contact with chemicals during spills and when handling flowback water or sediments.
- Sediments in the mud pit and turkey's nest are disposed of appropriately or capped immediately following drainage.

Exposure by trespassers is considered to be an unlikely occurrence. Exposure to sediments or flowback water is a complete exposure pathway (ingestion, dermal and inhalation) if trespassing occurs on unsecured sites. Exposure will be limited through ensuring all drill pads are securely fenced with signage clearly displayed to indicate that the water in the turkey's nest and mud pit is not potable and may contain contaminants.

Exposure pathways to the flowback water in the turkey's nest and mud pit for large native fauna (i.e., kangaroos) and stock animals can be considered incomplete on the basis of the fencing that Santos EQ will establish and maintain around the well pads, during operations and while back flow water is stored on-site. Exposure pathways (direct contact) for small native fauna (i.e., small mammals, snakes, lizards and birds) is considered complete for exposure to the flowback water in the turkey's nest and mud pit, with practical measures implemented by Santos EQ to minimize potential exposures.

7.3.2 Off-Site Exposure Pathways

Four possible sources were identified:

- Hydraulic fracturing fluids
- Sediments from mud pit or turkey's nest
- Flowback water
- Gas (methane).

Exposures were considered unlikely for all scenarios based on the engineering (liners/stormwater diversion) and operational controls that are being implemented by Santos EQ. In the unlikely event that an uncontrolled release was to occur, potential exposures could include direct contact and inhalation exposures for residents, stock animals, native flora and fauna and aquatic ecosystems. The probability of a release from a pond or turkeys nest occurring can be reduced through minimising the duration of flowback fluid storage. In addition, the concentrations of chemicals in flow back water are likely to be considerably less than in the injected fluid and the toxicity of the chemicals in the flowback fluid are likely to rapidly reduce through dissociation of organic chemicals and the relatively short biotransformation half-lives of the majority of the organic chemicals. Sampling would be required to characterise exposure should a release occur.

8 Quantitative Risk Assessment Methodology

The information provided in this section addresses the following EA approval requirements: conditions (q), (s), (x) and (aa).

The methodology used in the Qualitative Risk Assessment included quantitative calculations for the exposure assessment and risk characterisation, and toxicity estimates for the hazard assessment. This methodology taken to the quantitative assessment of human health and environmental risks is in accordance with guidelines/protocols provided by enHealth. These guidelines draw on, and are supplemented by, those provided by NWQMS and National Health and Medical Research Council (NHMRC), as well as international human health and environmental risk agency guidance such as the US Environmental Protection Agency (USEPA).

Information presented in the qualitative risk assessment was reviewed for applicability in the quantitative risk assessment, and was either incorporated into the quantitative risk assessment, or was replaced with an alternative methodology.

The risk assessment process in the quantitative risk assessment included a comprehensive assessment of both the theoretical and empirical concentrations of hydraulic fracturing fluids in the flow back water. A robust toxicity assessment was conducted that develops both human health and ecological toxicity criteria utilizing extensive toxicological databases, industry toxicological assessments not available to Golder (2011a) and less reliance on toxicological modelling methodologies. The quantitative risk assessment extends the qualitative risk assessment presented in **Section 6** by incorporating exposure models to evaluate potential exposures to human and ecological receptors and estimated the potential risks to these receptors from the exposures. Based on the risk characterisation, existing operational control activities are in place that will limit the potential risks.

8.1 Exposure Assessment

This section identifies the organisms or group of organisms (receptors) which may be exposed to the COPCs identified for the study and outlines the mechanisms (exposure pathways) by which these receptors may be exposed.

The assessment of exposure involves the evaluation of the data available for the study, the details associated with the surrounding environment, the nature of the exposure identified and the potential mobility of the COPC.

For an exposure pathway to be complete there must be all of the following:

- Source–COPC - how the chemical got into the environment and which environmental media are affected.
- A transport–media - how the chemical moves or migrates through the environment from one location to another, or from one environmental medium to another.
- An exposure–point - how organisms can come into contact with the chemicals (e.g., direct contact or via the food web).
- An exposure–route - how the chemical could enter the organism (e.g., inhalation, ingestion or dermal contact).

If any one of these steps (source, transport media, exposure point or route) is not present, the exposure pathway is incomplete and further assessment of risks is not required. Thus, even if the COPC was a PBT, if there is no threshold concentration at the point of exposure, the potential risk to environmental and human receptors is considered acceptable and would not require mitigative measures.

8.2 Identification of Exposure Pathways and Receptors

A detailed description of the EQ study area environmental values is provided in **Section 3**. In general, the area is sparsely developed, and comprises rural communities and homesteads that are largely engaged in farming and livestock production. The identification of exposure pathways and receptors has been split into those considered relevant for on-site (i.e., within the drill pad) and those relevant for off- site (i.e., anything beyond the drill pad boundary) as identified in **Section 7**. The general drill pad includes a cleared area with drilling mud pits, flare pits and turkey nests (water storage dams) constructed in designated areas. Individual configurations of drill pads may change; however, the general layout is considered adequate for the identification of exposure pathways and receptors.

Consistent with the assumptions made in the Qualitative Risk Assessment, the environment surrounding the drill pad (i.e., off-site) may vary. In order to provide a conservative assessment, it has been assumed there is a homestead with a water supply bore located down gradient of the drill pad. It has also been assumed that a creek, livestock and native flora and fauna, are present in the surrounding environment. This hypothetical assumption was considered for the purposes of the exposure pathway assessment and may not actually occur in the vicinity of a hydraulically fractured well. Onsite and off-site exposure pathways were presented previously in **Sections 7.1.1** and **7.1.2**.

8.3 Exposure Point Concentration – Theoretical and Empirical

Two datasets were evaluated in the quantitative risk assessment: a theoretical dataset and an empirical dataset. The theoretical dataset calculated exposure point concentrations (EPCs) based on theoretical calculations of exposure using the mass-balance data for each vendor's hydraulic fracturing fluid system. The EPCs for the empirical dataset are limited to the Schlumberger fluid system which has been widely used and has sufficient monitoring data from the SIMP.

8.4 Human Health Risk Assessment

The enHealth (2012) human health risk assessment (HHRA) process involves three components:

- Hazard assessment
- Exposure assessment
- Risk characterisation

The hazard assessment includes:

The hazard identification, which is the characterisation of the exposure data, and the statistical evaluation of the exposure data; and

The toxicity assessment, which defines the relationship between the potential extent of exposure and the toxicological effects of the exposure and is estimated for each COPC. For the HHRA, the COPC-specific toxicity criteria are presented (when available), including:

  - Cancer slope factors (CSFs) or unit risk factors (URFs) for carcinogens, genotoxics (where a non-threshold dose-response approach is appropriate).
  - Reference doses (RfDs) (or acceptable/tolerable daily intakes RfDs acceptable daily intakes (ADIs) or tolerable daily intakes (TDIs) or reference concentrations (RfCs) or tolerable concentrations (TCs).

In the exposure assessment, the potential human receptors are identified and their potential for exposure to COPCs is characterized. Potential exposure pathways are evaluated to determine which, if any, are potentially complete. Next, the EPCs of COPCs in the flow-back water exposure areas are calculated and are used in conjunction with exposure assumptions to determine systemic doses for the applicable potential receptors. Finally, the magnitude, frequency and duration of these potential exposures are integrated to calculate estimates of daily intakes over a specified exposure period.

Integration of the results of the toxicity assessment and the exposure assessment to derive quantitative estimates of human health risks is accomplished in the risk characterisation for COPC evaluated based on a threshold and/or non-threshold approach. Finally, the level of uncertainty relevant for the completion of the risk assessment is evaluated.

The approach taken to the quantitative assessment of human health risks is in accordance with guidelines/protocols provided by enHealth (2012). In addition to these guidelines, the following documents provided supplemental guidance for the quantitative HHRA:

- The NEPM [2013], (Schedule B(4) Guideline on Health Risk Assessment Methodology, Schedule B(6) Guideline on Risk Based Assessment of Groundwater Contamination, Schedule (7a) Guideline on Health-Based Investigation Levels, Schedule B (7b) Guideline on Exposure Scenarios and Exposure Settings and Schedule (5) Guideline on Ecological Risk Assessment).
- 'The Health Risk Assessment and Management of Contaminated Sites' (CSMS, 1991, 1993, 1996 and 1998 and enHealth, 2012).
- Australian Drinking Water Guidelines (ADWG) (2011) National Water Quality Management Strategy. ADWG, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.
- USEPA, 2002. A Review of the Reference Dose and Reference Concentration Processes. External
- Peer Review Draft. USEPA, Washington, D.C. EPA/630/P-02/002A.
- Environmental Risk Assessment Guidance Manual for Industrial Chemicals, Australian Environmental Agency Pty, Ltd., Commonwealth of Australia, 2009.
- European Commission, Technical Guidance Document on Risk Assessment, 2003.

8.4.1 Hazard Assessment

The purpose of the hazard assessment is to summarize the environmental data and to address the toxicological assessment of the COPCs that will be further evaluated in the quantitative risk assessment process. The environmental media data used in the HHRA will be managed in an electronic database and compiled by constituent, medium and sample location, if applicable. All descriptive and statistical analyses of the data will be

performed using ProUCL Version 4.1 that was developed for the USEPA (2010). Both the theoretical and empirical sampling data will be included in the electronic database.

8.4.2 Toxicity Assessment

The toxicity assessment was conducted to determine the relationship between the dose of a COPC taken into the body and the probability that an adverse effect will result from that dose.

Quantitative estimates of the potency of COPCs include two sets of toxicity values, one for genotoxic carcinogens and one for other non-genotoxic carcinogens and non-carcinogenic effects. For the assessment of genotoxic carcinogenic effects, a non-threshold toxicological mechanism was assumed and there was no level of exposure that does not pose a probability that an adverse effect will result from that dose. For toxicity criteria for other, non-genotoxic carcinogens and non-carcinogenic effects, it was assumed that there is a threshold effects level, below which adverse health effects are not expected to occur.

The assessment of carcinogenic effects was conducted following the review of the available data utilising a weight-of-evidence approach in relation to genotoxicity. Genotoxic carcinogens were evaluated based on a non-threshold dose-response relationship, quantified using a URF for inhalation exposures and/or slope factor (SF) for oral and dermal exposures. The URF (expressed as 1/(µg/m^3)) or SFs (expressed as 1/(mg/kg/day)) evaluated were upper-bound estimates of the excess cancer risk due to continuous exposure to a COPC averaged throughout the course of a 70-year lifetime. The referenced bases of URF and SFs were data from lifetime animal bioassays, although human data are used when available.

Where carcinogenic effects were associated with a non-genotoxic mode of action (or where insufficient weight of evidence was available to support a genotoxic mode of action), these effects were characterized based on a threshold. Other non-carcinogenic effects, such as organ damage or reproductive effects, were evaluated based on a threshold. These threshold values were defined as RfC or TCs for inhalation exposures and RfDs or ADIs/TDIs for oral and dermal exposures. These threshold values may be available for different durations of exposure ranging from acute to chronic exposures), with the focus of the assessment presented in this report on chronic exposures. A chronic RfC/TC or RfD/ADI/TDI was defined as the concentration or intake that all members of the public may be exposed to every day for a lifetime with no adverse health effects.

The threshold value was commonly derived from a point of departure (POD), defined as the lowest concentration that is associated with no (or the lowest) observed adverse health effects (no observed adverse effect level [NOAEL] or lowest observed adverse effect level [LOAEL] or a benchmark dose), determined from experimental animal studies (most common) or human studies (less common). The POD was then divided by a safety/uncertainty factor to obtain the threshold toxicity value. Uncertainty factors were typically factors of 10 that account for interspecies variation and sensitive human populations. Additional factors of 10 were included in the uncertainty factor if the RfC is based on the lowest observed adverse effect level instead of the NOAEL, or an experiment that included a less-than- lifetime exposure.

The assessment of toxicity of the COPCs was used to develop initial screening criteria for human health exposure scenarios.

8.4.2.1 Toxicological database and literature review

The following toxicity-based screening guidance's were used to develop the necessary toxicity assessment information used in this quantitative risk assessment:

- Australian and New Zealand Environment Conservation Council (ANZECC) (2000) and Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG) (2018) guidelines for fresh and marine water quality.
- National Health and Medical Research Council and National Resource Management Ministries Council (NHMRC/NRMMC) 2011 ADWG for physical and chemical characteristics. World Health Organization (WHO) 2011 Guidelines for Drinking-water Quality (Fourth Edition).
- USEPA. 2009a. National Recommended Water Quality Criteria (2009) for protection of aquatic life and human health.

If no relevant guidelines exist, other applicable international guidelines have been used for the screening process (or risk screening values derived) to ensure that all chemicals are adequately considered.

The following is a list of resources that have potentially been queried:

- Chemical Risk Information Platform (CHRIP) [Japan] Information on Biodegradation and Bioconcentration of the Existing Chemical Substances Database (http://www.safe.nite.go.jp/english/db.html).
- European Chemicals Agency (ECHA) public database of Registration, Evaluation, Authorization and Restriction of Chemical Substances (REACH). Registered substances (ECHA CHEM) (http://apps.echa.europa.eu/registered/registered-sub.aspx).
- European Commission (EC) Joint Research Centre (JRC) Institute for Health and Consumer Protection - European Chemical Substances Information System (ESIS) (http://ecb.jrc.ec.europa.eu/esis).
- USEPA High Production Volume Information System (HPVIS) (http://www.epa.gov/chemrtk/hpvis/index.html).
- New Zealand Environmental Protection Authority - New Zealand Hazardous Substances and New Organisms (HSNO) Chemical Classification Information Database (CCID) (http://www.epa.govt.nz/search-databases/Pages/HSNO-CCID.aspx).
- WHO International Programme on Chemical Safety (IPCS) Chemical Safety Information from Intergovernmental Organizations (INCHEM) (http://www.inchem.org/).
- Japan CHEmicals Collaborative Knowledge database (J-CHECK) (http://www.safe.nite.go.jp/jcheck/english/top.action).
- Japan Existing Chemical Data Base (JECDB) (http://dra4.nihs.go.jp/mhlw_data/jsp/SearchPageENG.jsp).
- Australian NICNAS Priority Existing Chemical (PEC) Assessment Reports (http://www.nicnas.gov.au/Publications/CAR/PEC.asp).
- Organisation for Economic Cooperation and Development (OECD) High Production Volume (HPV) Existing Chemicals Database (http://webnet.oecd.org/hpv/ui/Default.aspx).
- OECD Screening Information Dataset (SIDS) Database OECD Existing Chemicals Screening Information Data Sets (SIDS) Database (in IUCLID software) (http://oecdsids.jrc.ec.europa.eu:80/i5browser/Welcome.do).
- OECD Initial Assessment Reports for HPV Chemicals including Screening Information Data Sets (SIDS) as maintained by United Nations Environment Programme (UNEP) Chemicals (http://www.chem.unep.ch/irptc/sids/OECDSIDS/sidspub.html).

In addition, a general Google search by product name and CASRN was conducted, which is a basic requirement for programs such as REACH.

8.4.2.2 Derivation of oral reference dose and drinking water guideline values

Existing oral RfDs and drinking water guideline values were used when applicable. Otherwise, information on mammalian toxicity was acquired primarily from reported data that had already been through a screening process such as the OECD SIDS program, the U.S. Cosmetics

Ingredient Review or the EU Scientific Committee on Consumer Safety (SCCS). The data from these programs were considered sufficiently reviewed as to not require further evaluation. Data reported as part of other equivalent peer reviewed risk assessment programs (e.g., HERA (www.heraproject.com/); USEPA HPV Chemical Challenge Program) were also considered in a similar fashion, although a certain level of expert judgment was required to evaluate the quality of these programs.

Toxicity information was also obtained via the ECHA CHEM database. This database provides electronic public access to information on chemical substances manufactured or imported in Europe. The information originates from the registration dossiers submitted by companies to ECHA in the framework of REACH Regulation.

Where data was not available from the above sources or the available data were considered insufficient for the determination of oral RfDs and drinking water guideline values, then toxicity information on MSDSs was used, as well as read-across from available experimental data on a structurally related substances and predicted values from quantitative structure-activity relationship (QSAR) models.

With exception to the USEPA integrated risk information system (IRIS) values, the most appropriate or reliable NOAEL or LOAEL, if a NOAEL was unavailable and the critical effect were identified.

8.4.2.3 Oral reference dose derivation

The oral RfD was calculated using the following equation:

$$Oral\ Reference\ Dose\ =\ NOAEL\ /\ UF_{Total}$$

Where:

- NOAEL = No-Observed-Adverse-Effect
- UF_{Total} = Total uncertainty factors

Note that for NOAELs, when dosing regimens were 5 days/week, the NOAEL was adjusted to 7 days/week by multiplying the NOAEL by 5/7.

Uncertainty factors of 10 were used to account for:

- Variation in sensitivity among members of the human population, i.e., interindividual variability
- The uncertainty in extrapolating animal data to humans, i.e., interspecies uncertainty
- The uncertainty in extrapolating data obtained in a study with less-than-lifetime exposures, i.e., extrapolating from subchronic to chronic exposure
- The uncertainty in extrapolating from a LOAEL rather than from a NOAEL (USEPA, 2002).

8.4.2.4 Determination of drinking water guideline values

The ADWG values were used when applicable (2011). The WHO, and then USEPA, were also consulted for any additional drinking water standards when there were no ADWGs values. For the theoretical approach, limited additional drinking water standards were found that were applicable to the hydraulic fracturing chemicals used in this quantitative risk assessment.

For those chemicals where there are no regulatory drinking water guidelines, and for which a threshold exists, the guideline value was derived from animal toxicity data using the following equation (ADWG, 2011):

$$Guidance\ values = animal\ dose\ *\ human\ weight * proportion\ of\ intake\ from\ water\ volume\ of\ water\ consumed\ *\ safety\ factor$$

Where:

- Animal dose = NOAEL (or LOAEL)
- Human weight = 70 kg
- Proportion of intake from water = 10%
- Volume of water consumed = 2 L/day

As indicated above, the overall toxicity assessment used in this quantitative risk assessment included a more comprehensive review of the available literature and existing regulatory databases than provided in Golder (2011a). **Appendix F** and **Appendix G** includes the detailed toxicological profiles and supporting documents for the hydraulic fracturing chemicals.

8.4.2.5 Exposure equations and models

The following equations were used for calculating the intake of COPCs:

Ingestion of water:

$$Intake\ (mg/kg-day)\ =\ (CW\ x\ IR\ X\ EF\ X\ ED)\ /\ (BW\ x\ AT)$$

Dermal contact with water:

$$Intake\ (mg/kg-day)\ =\ (CW\ x\ IR\ X\ EF\ X\ ED)\ /\ (BW\ x\ AT)$$

Where:

- CW = concentration in water (mg/l)
- ET = exposure time (hr/day or hours/hours)
- EF = exposure frequency (day/year)
- ED = exposure duration (years)
- CF = correction factor (1 x 10^{-3} l/cm^3)
- AT = averaging time (days)
- IR = ingestion rate (l/hr)
- BW = body weight (kg)
- SA = skin surface area available for contact (cm^2/d)
- DP = dermal permeability factor (Kp – cm/hr).

The exposure assumptions to be used in the equations above for the human trespasser receptor was developed based on default (e.g., enHealth) or site-specific exposure assumptions including information contained in the Golder (2011a) risk assessment and the literature, as well as professional judgment. The human trespasser receptor exposure pathway includes a small child to teenager that may come in contact with the above grade water exposure scenario for approximately 20 days/year for a 10-year period with potential incidental ingestion (of 50 mL water) and dermal contact (e.g., swimming where the whole body gets wet) for a half hour. This assumption is consistent with the typical exposure assumptions utilized by USEPA (2009) for recreational exposure. This assumption also recognises that the storage of flowback water at individual well pad sites will be only a temporary activity, with operational controls and activities at the well sites likely limiting the occurrence of trespasser entry and exposures.

It is noted that the selected exposure assumptions are considered conservative because the above grade water would only be available in the flowback storage ponds for a maximum period of six to nine months based on the expected operational activities.

8.4.3 Risk Characterisation

The purpose of the risk characterisation is to provide a conservative estimate of the potential risk resulting from exposure to COPCs identified in the affected theoretical and empirical flowback groundwater at the site. Included in this section is a quantitative estimate of potential carcinogenic and non-carcinogenic risks for each complete exposure pathway for the human trespasser receptor.

8.4.4 Risk Estimation

For this risk assessment, carcinogenic risks were estimated in the HHRA by summing the excess lifetime cancer risk over all the COPCs, and comparing the total risk to a target risk range of one in ten thousand (1 x 10^{-4}) to one in one million (1 x 10^{-6}).

Carcinogenic risk less than 1x10^{-6} is considered acceptable, risks between 1x10^{-6} and 1x10^{-4} require best practice reductions and risks greater than 1x10^{-4} are not acceptable, consistent with the approaches commonly applied within Australia.

It should be noted that specific Australian guidance relating to an acceptable cancer risk threshold is not available in enHealth (2012), but the interpretation of cancer risk values in Australia is generally consistent with USEPA policy that adopts a risk value of 1 x 10^{-6} as representative of minimal risk, and a risk value of 1 x 10^{-4} as an action level. That is, where risk estimates are less than 1 x 10^{-4}, action is generally considered not to be warranted, but where action is warranted remediation goals are commonly based on a target cancer risk of 1 x 10^{-6}. However, an acceptable risk level in relation to exposure to site contamination issues of 1 x 10^{-5} is consistent with the approach in NEPM and enHealth guidance documents.

For the assessment of threshold effects, the individual hazard quotients (HQs) were summed for an overall HI. If the HI is less than or equal to one, then no adverse health effects are likely associated with exposures. However, if the total HI is greater than one, adverse health effects may be likely without control management measures currently in place.

8.5 Ecological Risk Assessment

An Ecological Risk Assessment (ERA) was conducted as part of the quantitative risk assessment to evaluate the potential for adverse ecological effects to terrestrial and aquatic ecological receptors that may be exposed to residual levels of hydraulic fracturing fluids in surface water used in the development areas. The approach for the ERA component of the quantitative risk assessment presented in this report provides a methodology for the assessment of the risks posed by mixtures. The quantitative risk assessment approach for the characterisation of potential risks to aquatic receptors has been conducted in accordance with the former ANZECC 2000 and ANZG 2018 guidelines and includes screening the individual constituents in the hydraulic fracturing fluids against trigger values contained within this guideline, or where no ANZECC/ANZG trigger values are available, relevant international screening values or conservatively derived chemical specific trigger values (i.e. for the theoretical hydraulic fracturing chemical fluid constituents). To address the potential for additive effects from the mixture of constituents in the hydraulic fracturing fluids, a cumulative risk characterisation will be conducted that incorporates the same risk assessment methodology used for the human health and terrestrial risk characterisation, and provides a margin of safety to ensure that the total ecotoxicological effects from the potential exposure to the hydraulic fracturing fluids are included in the characterisation of risks, consistent with guidance available from ANZECC (2000) and ANZG (2018). The NEPC (2013) addresses the mixture of constituents and has adopted the hazard quotient approach for the Guideline for ERA. This approach also has been used in other risk assessment frameworks (e.g., USEPA, 1998).

The first step in the ERA approach is to conduct a screening level ERA. The screening level ERA will compare water quality criteria to EPCs. Intake modelling will used for Level II ERA to evaluate exposure of terrestrial receptors to the fracturing water and the EPCs for the exposure scenarios.

The subsequent step in the ERA process is for the characterisation of the potential risks to terrestrial (wildlife and domestic livestock) receptors will follow the enHealth methodology (2012). This methodology includes the identification of the hazards of the constituents in the flowback water, compilation of the toxicity criteria for each constituent, development of exposure models to estimate the daily intake of the constituents, and calculations of individual constituent hazard quotients (daily intake divided by the toxicity criteria) and a cumulative constituent HI for each potentially complete exposure pathway for each human or terrestrial receptor.

8.5.1 Problem Formulation

As described in the NEPC (2013), the problem formulation establishes the goals and focus of the assessment. In addition, the problem formulation defines the conceptual model for the site that describes the current conditions, affected environmental media, ecological effects, potential receptors, complete exposure pathways and assessment endpoints. The problem formulation builds on the problem formulation defined in the PBT/Hazard assessment process by focusing on the site conceptual model and the additional site-specific information collected in the SIMP.

8.5.1.1 Ecological Habitats

As described in in **Sections 2** and **3**, the study area includes both the operational areas of the project and the land areas that immediately surround the operational areas. The objective of the ERA is to assess the typical potential exposures that may occur at any of the operational areas. Therefore, the exposure assumptions for aquatic and terrestrial ecological receptors were based on a typical operational layout, and adjacent land use that includes primary agricultural land and a flowing surface water body.

For the purposes of this ERA, the study area is divided into the operational area and the off-site agricultural area. Such division is relevant to discussions of wildlife habitat characteristics (e.g., land use, habitat fragmentation and anthropogenic effects) associated with the study area.

The operational area has minimal wildlife habitat to support a functioning aquatic or terrestrial ecosystem including foraging and breeding habitat. Normal operational activities and infrastructure and gravel and compacted soil cover on the well pad sites and around infrastructure would significantly inhibit establishment of the requisite wildlife habitat. In addition, as was presented in the HHRA, there are operational controls, security and management practices that would limit the exposure of ecological receptors to the hydraulic fracturing chemicals and fluids. Regarding exposure of potential ecological receptors, these controls and practices include installation and maintenance of fences around the gas pads, and implementation of spill containment and prevention procedures to minimize releases. However, as noted above, there are occasional incursions of wildlife on the operational areas, and these will be evaluated in the ERA.

The off-site agricultural areas do present a terrestrial and aquatic habitat that would support a functioning ecosystem, and therefore, would support a viable ecosystem with foraging and breeding habitat. The clearing and

farming practices pursuant to the extensive agricultural land use has diminished the overall habitat quality, which would potentially exist in an unaltered natural ecosystem. Therefore, the adjacent ecosystem to be evaluated in the ERA will be based on a rural agricultural terrestrial habitat and associated rural agricultural streams.

8.5.1.2 Ecological receptors

Potential ecological receptors are those species that are resident within the study area boundaries, or species resident to adjacent habitats that could be potentially exposed due to their foraging or migratory behavioural characteristics. Extensive ecological surveys were conducted for the Santos EQ Project Area that identified flora and fauna that may inhabit the local and regional environments. Potential ecological receptors include domesticated livestock, agricultural and native plants, local and regional wildlife, and aquatic fish and invertebrates. However, as previously noted, the objective of this ERA is to evaluate the potential risks from a typical gas well field in the Santos EQ Project Area; therefore, the selection of ecological receptors for this ERA is based on understanding that the selected ecological receptors all have an equal opportunity to be exposed to residual hydraulic fracturing flowback water.

8.5.2 Selection of Ecological Values

In accordance with NEPC (2013), ecological values are the actual assessment values that are to be protected from adverse effects on ecological receptors. The criteria for selecting ecological values or assessment endpoints are that they should be ecologically relevant, susceptible to the known or potential stressors and relevant to management decision-making. The ecological values must then be operationally defined. Two elements are required to define an assessment endpoint (USEPA, 1998): identification of the specific-valued ecological entity and a characteristic about the entity that is important to protect.

The Santos EQ Project Area is currently divided into an operational area and an agricultural land use area. The offsite agricultural area would support a limited (based on agricultural disturbance activities) habitat ecosystem, including an associated area for foraging of the selected ecological receptors. The operational area would provide an open area where domesticated and native wildlife may potentially occasionally occur from inadvertent entry, but one that would not be readily preferred due to operational activities and the absence of foraging habitat. Assessment endpoints were selected that were appropriate for these two land use scenarios. Selecting endpoints that are typical of a larger, more ‘natural’ ecosystem (e.g., a mature forested area or natural grasslands) would not contribute to the decision-making for this area. The assessment endpoints, or ecological values, described below are relevant to management goals for the study area. These assessment endpoints are all sensitive to the residual hydraulic fracturing flowback water COPCs identified and have the requisite toxicological and life history databases to support their use as representatives of the study area ecosystem. The assessment endpoints represent ecological receptors for both aquatic and terrestrial trophic levels within the area ecosystem. The selected assessment endpoints and their ecological relevance are:

Survival and reproduction of beef cattle – beef cattle were selected as representative of a large, domesticated livestock species that are known to inhabit the study area and may occasionally enter areas where hydraulic fracturing flowback water is stored on the well pad.

Survival and reproduction of kangaroo – kangaroo were selected as representative of a large wildlife species that are known to inhabit the study area and may occasionally enter areas where hydraulic fracturing flowback water is stored on the well pad.

Survival and reproduction of dingo – dingo were selected as representative of a small wildlife species that are known to inhabit the study area and may occasionally enter areas where hydraulic fracturing flowback water is stored on the well pad.

Survival and reproduction of aquatic invertebrates and fish – aquatic invertebrates and fish were selected as representative of the aquatic ecosystems that are known to exist within the study area. Whilst considered minimal, there is the potential for a release of stored hydraulic fracturing flowback water to surface water ecosystems located near the gas well pads in the situation of an accidental release, such as from piping or the flowback storage pond, especially due to a failure of a containment system during a flood event.

8.5.3 Characterisation of Ecological Effects

To evaluate the assessment endpoints and ecological values, measures of effects (or measurement endpoints) are developed that represent the COPC exposure levels that are conservative thresholds for adverse ecological effects. An effects evaluation was not conducted on the potential ecological effects of landscape maintenance activities, such as mowing, vehicle travel or farming. Physical stressors unrelated to the COPCs in the hydraulic fracturing flowback water are not the focus of this ERA. To evaluate the potential for adverse ecological effects, toxicity reference values (TRVs) are selected as measurement endpoints for the ERA that will be used in the risk

analysis. The TRVs are based on COPC levels that imply no adverse effects or levels that represent the lowest concentration at which adverse effects may occur. The ERA used two types of TRVs. The first TRV is a concentration-based TRV to evaluate the concentration of the selected COPC in the surface water and direct exposure by the aquatic ecological receptor. The second TRV is a dose-based TRV to evaluate the intake dose of the selected COPC from exposure to surface water by ingestion.

The Toxicological Database and Literature Review includes the sources for ecotoxicological information used in the ERA. A hierarchy was used to compile the TRV information as follows:

- ANZECC (2000) and ANZG (2018) guidelines for fresh and marine water quality.
- Western Australia (WA) Department of Environment and Conservation. Assessment Levels for Soil, Sediment and Water. February 2010. Contaminated Site Management Series.
- Department of Environmental and Resource Management. Approval of Coal Seam Gas Water for Beneficial Use. Environmental Protection (Waste Management) Regulation 2000. Queensland Government. March 2010.
- International Guidance including USEPA, American Petroleum Institute and Oak Ridge National Laboratory/Risk Assessment Information System (ORNL/RAIS).

8.5.3.1 Concentration- based TRV

Where possible, existing water quality guidelines for protection of aquatic life were researched and compiled using the hierarch outlined above. If water quality guidelines are available, information on aquatic toxicity was acquired from reported values that had already been through a screening process such as the OECD-SIDS program or through a European Union (EU) existing substances risk assessment. The data from these programs were considered sufficiently reviewed as to not require further evaluation. Data reported as part of other equivalent peer reviewed risk assessment programs (e.g., HERA (www.heraproject.com/); USEPA HPVC Challenge Program) were also considered in a similar fashion, although a certain level of expert judgment was required to evaluate the quality of these programs.

Aquatic toxicity information was also obtained via the ECHA CHEM database. This database provides electronic public access to information on chemical substances manufactured or imported in Europe. The information originates from the registration dossiers submitted by companies to ECHA in the framework of REACH Regulation.

If no data were available from the above sources or the available data were considered insufficient for TRV determinations, then toxicity information on MSDSs were used, as well as read-across from available experimental data on a structurally related substances and predicted values from QSAR models.

Calculation of PNEC for freshwater

The determination of TRVs for freshwater will be conducted according to the predicted no-effects concentration (PNEC) guidance in the Environmental Risk Assessment Guidance Manual for Industrial Chemicals prepared by the Australian Environmental Agency (AEA, 2009).

The PNECs are determined by dividing the lowest toxicity value from a laboratory test by the relevant assessment factor. Results of long-term tests (expressed as the 10 percent effective concentration [EC_{10}] or no observable effects concentration [NOEC]) are preferred to those of short-term tests (50 percent effective concentration/lethal concentration [EC/LC_{50}]) because the results give a more realistic picture of effects on the organisms during their entire life cycle. In order to extrapolate from laboratory data to a multi-species ecosystem, the assessment factors reflect several uncertainties in the data including:

- Intra- and inter-species variations
- Intra- and inter-laboratory variation of toxicity data
- Short-term toxicity to long-term toxicity extrapolation
- Laboratory data to field impact extrapolation.

When only short-term toxicity data are available, an assessment factor of 1,000 was applied on the lowest EC/LC_{50} of the relevant available toxicity data, irrespective of whether the species tested is a standard test organism. This value was reduced to 100 if the following evidence was available:

- Availability of data from a wide variety of species including those considered to represent sensitive species
- Information from structurally similar compounds or QSAR, to suggest that the acute to chronic ratio is likely to be low

- Information to suggest that the chemical acts in a non-specific or narcotic manner, with little inter-species variation in toxicity
- Information to suggest that the release of the chemical is short-term or intermittent, and that the chemical would not be persistent in the environment.

When chronic toxicity data were available in addition to acute data, often an assessment factor from 10 to 100 was applied to the lowest NOEC, taking the following situation into account:

- If a chronic NOEC was available from one or two species representing one or two trophic levels (i.e., fish, *Daphnia* or algae), a factor of 100 or 50, respectively, was applied to the lowest NOEC. In this case, a PNEC value derived from chronic data should be compared to that derived from the lowest acute data. It is then the lowest value that is used in the assessment; and
- If chronic NOECs was available from three species representing three trophic levels (i.e., fish, Daphnia and algae), a factor of 10 was applied to the lowest NOEC. If there was convincing evidence that the most sensitive species for which acute toxicity data were available have been tested chronically, a factor of 10 may also be applied to the lowest NOEC from two species representing two trophic levels (i.e., fish and/or Daphnia and/or algae).

It should be noted that in the case of algae studies, which are actually multigenerational studies, it is generally accepted that a 72-hour (or longer) EC_{50} value may be considered as equivalent to a short- term result and that a 72-hour (or longer) EC_{10} or NOEC value can be considered as a long-term result.

It is preferable to use actual measured data in effects assessment and in estimation of PNECs. However, when limited or no data were available (e.g., data for only one test species) or when the measured data for a species were unacceptable, then estimation using QSARs was considered. With the exception of the $PNEC_{aquatic}$ value for nitrate (used for magnesium nitrate), the aquatic toxicity data sets for the chemicals were insufficient for using the species sensitivity distribution approach. In the case of nitrate, the ANZECC water quality guideline of 700 µg/L was used for the $PNEC_{aquatic}$; this value had been derived using the statistical distribution method.

8.5.3.2 Dosed-based TRV

The basic principles applied in human health toxicity assessments also apply to ecological toxicity assessments, however, carcinogenicity is rarely considered because of a lack of methodologies and the understanding of the modes of action of potential carcinogens on ecological receptors. For the ecological receptors, TRVs are developed based on adverse health effects. The sources of TRVs are from the published literature, or the application of dose-response equations incorporating the relationship of size of the selected receptor to the test species for the dose-response data.

For ecological receptors, the TRVs are calculated based on body weight (BW) scaling methodology that uses the NOAELs and LOAELs, which are daily dose levels normalized to the BW of the test animals (e.g., milligrams of chemical per kilogram BW/day). The use of toxicity data on an mg/kg/day basis allows the comparisons across toxicity tests and across test species with appropriate consideration for differences in body size. Studies have shown that numerous physiological functions such as metabolic rates, as well as responses to toxic chemicals, are a function of body size. Smaller animals have higher metabolic rates and usually are more resistant to toxic chemicals because of more rapid rates of detoxification. After a review of various dose-response models for wildlife, the allometric scaling method was developed using linear regression models of lethal dose versus body weight for a variety of chemicals to extrapolate toxicity between species (Sample and Arenal, 1999). To assess the sensitivity of the model, residuals from the allometric scaling were analysed using regression models. The patterns of sensitivity among mammalian species were relatively constant across chemical classes. The development of this new allometric scaling model improved the extrapolation of toxicity effects between species, thus providing a more accurate assessment of potential ecological risks when data are limited for the specific species being assessed. The allometric scaling method was used to estimate the population level effects on wildlife based on individual level of exposures (Sample et al., 1999).

For mammals, it has been shown that this allometric scaling relationship is best expressed in terms of BW raised to the ¾ power ($bw^{3/4}$). Therefore, the dose for the selected ecological receptor is a function of the BW of the test species divided by the BW of the selected ecological receptor to the ¾ power, and then is multiplied times the dose of the test species.

$$NOAEL_w = NOAEL_t \left(\frac{bw_t}{bw_w}\right)^{3/4}$$

The calculated TRVs for each of the mammalian ecological receptors evaluated in the ERA are presented in the species-specific ecological risk models. It is noted that the allometric scaling methodology was only used to calculate TRVs for terrestrial mammals. Aquatic receptors were evaluated using the $PNEC_{aquatic}$ values.

8.5.4 Characterisation of Exposure

As presented in the HHRA, the exposure scenarios for the ERA will be the same as the HHRA: theoretical exposure to the returning fracturing fluids used in the stimulation events.

8.5.4.1 Exposure Point Concentrations (EPCs)

EPCs for the exposure assessment were calculated using the results of theoretical fate and transport modelling calculations for each fluid system (**Appendix C**). The potentially affected flowback water that represents complete exposure pathways for the ecological receptors includes the surface water systems (e.g., flowback storage ponds and mud pits) that were used to estimate the EPCs for the human health receptors (**Appendix C**). Similar to the EPCs for the human health receptors, the EPCs for the ecological receptors assumed various mass percentages returned in the flowback water, which were diluted within 150% of the injected volume of return water. These EPCs were then adjusted based on biodegradation rates to calculate the theoretical EPCs for the four exposure time periods (0, 30, 150, and 300 days).

8.5.4.2 Exposure Equations

The estimate for dose-based or intake rates for the assessment endpoints for wildlife representing domestic livestock and native mammalian species used the following general equation:

$$TI = Cwater \; x \; IRwater \; x \; EF \; x \; ED \; / \; BW \; x \; ED \; x \; 365 \; days/year$$

Where:

- TI = Total intake of COPC (mg/kg/day)
- Cwater = Concentration of COPC in water (mg/l)
- IRwater = Ingestion rate (litres/day)
- EF = Exposure frequency (days/year)
- ED = Exposure duration (years)
- BW = Body weight (kg).

Water ingestion and BW were obtained from the following: livestock cattle from API (2004); kangaroo from Dawson (1995); and dingo from Fleming et al. (2001). The water ingestion rate (IR) for kangaroo assumed that although they may go extended periods without water (getting water from the grasses they eat); they would conservatively take advantage of the presence

of surface water to replenish themselves, up to three litres per event. Dingoes in general drink one litre of water a day in the summer and about half a litre a day in winter (Dawson, 1995), a rate of 0.75 litres per day was selected as an average.

Exposure frequency and duration were based on professional judgment that incorporated operational considerations for the frequency and duration of the potential for exposure to the gas site in the three scenarios, and a conservative estimate of potential for domestic livestock and mammalian wildlife to be exposed. The use of EF and duration replaced the use of a home range ratio that is commonly used in intake modelling equations for ecological receptors. This was because the exposure of the domestic livestock and mammalian wildlife was not considered habitat-driven (they would normally forage and breed in the operational areas), but similar to a 'trespasser' exposure scenario used in the HHRA. As noted previously, the excluded ecological receptors (e.g., soil microbes, soil invertebrates, terrestrial plants, and localized smaller mammals) would have exposure that is habitat-driven (they would be limited to the unexposed surrounding lands). The exposure assumptions also recognizes that the storage of flowback water at individual well pad sites will be only a temporary activity, with operational controls and activities at the well sites likely limiting the occurrence of livestock and wildlife entry and exposures. In addition, it is not reasonable to assume that they would be exposed to multiple gas well sites that are located miles apart. Therefore, the receptors were assumed to obtain drinking water from the flowback water only on occasions when they inadvertently entered on to the operational area of a unique modelled gas well site as follows:

- Livestock cattle – this receptor exposure pathway includes livestock cattle that may come in contact with the flowback storage pond water exposure scenarios for approximately 15 days/year for an 8-year period with the potential for incidental ingestion (watering).

- Kangaroo – this receptor exposure pathway includes kangaroos that may come in contact with the above grade water exposure scenarios for approximately 10 days/year for a 15-year period with the potential for incidental ingestion (watering).
- Dingo – this receptor exposure pathway includes dingos that may come in contact with the above grade water exposure scenarios for approximately 10 days/year for a 15-year period with the potential for incidental ingestion (watering).

8.5.5 Risk Characterisation

In accordance with NEPC (2013) and USEPA guidance (1997), the risk characterisation integrates the information obtained in the ecological effects and exposure phase and provides an estimate of risk to those ecological entities included in the assessment endpoints. After the risk estimates are calculated, they are placed in the context of the significance of any adverse effects and lines of evidence supporting their likelihood, and associated uncertainties are described.

8.5.5.1 Estimation of Risk

Risks are estimated by comparing the EPC (for aquatic receptors) to a concentration-based TRV and the estimated TI (for livestock and wildlife) to a dose-based TRV. This comparison provides a HQ, which represents a ratio of the exposure to the potential for toxicological adverse effects.

The HQ estimate for concentration-based risks for the assessment points for aquatic receptors used the following general equation:

$$HQ = EPC / TRV$$

Where:

- HQ = hazard quotient
- EPC = COPC exposure point concentration in surface water (mg/l)

$$TRV = concentrat\text{-}on - based\ TRV\ (mg/l)$$

The HQ for intake-based risks for assessment endpoints for domestic livestock and mammalian wildlife used the following general equation:

$$TRV = concentrat\text{-}on - based\ TRV\ (mg/l)$$

Where:

- HQ = hazard quotient
- TI = total intake of COPC (mg/kg-day)
- TRV = dose-based TRV (mg/kg/day)

The resulting hazard quotient (HQ) must be less than or equal to one (rounded to one significant figure) for risks to be considered acceptable. If the quotient is greater than one, the exposure potentially may cause an adverse ecological effect and the substance is retained for further evaluation in the baseline ERA to refine the calculation of potential risks to exposed ecological receptors. If the hazard quotient is less than one, there is adequate information to conclude that ecological risks are negligible for that substance and, therefore, no further evaluation in the baseline ERA process is warranted.

8.6 Uncertainty Analysis

The procedures and inputs used to assess potential human health and ecological risks in this, and similar quantitative human health and ecological risk assessments are subject to a wide variety of uncertainties. In general, there are five main sources of uncertainty and variability in risk assessments of well-characterised sites:

- Environmental chemistry
- Environmental parameter measurements
- Fate and transport modelling
- Toxicological data and dose-response extrapolations

- Updated risk assessment methodologies, exposure assumptions, and toxicological data
- Combinations of the above.

Discussion regarding potential uncertainty inherent in the quantitative risk assessment process will be presented for each fluid system evaluated in **Appendix C**.

9 Other Potential Risks

The information provided in this section addresses the following EA approval requirements: conditions (u), (z)(2) and (aa).

Other potential risks associated with hydraulic fracturing were evaluated in the Golder Associated Stage 1 and Stage 2 Hydraulic Fracturing Risk Assessments (2011a). Evolution of the hydraulic fracturing process has also resulted in changes to the hydraulic fracturing methodologies and the proppants utilised.

Due to modifications to hydraulic fracturing systems and proppants, supplemental risk assessments have been completed including:

- A quantitative risk assessment conducted by EHS Support (2013a) on the use of radiological tracers and perforation balls
- A supplemental qualitative risk assessment conducted by Golder Associates (2013b) on the use of LiteProp 125 as an alternative to sand in the hydraulic fracturing process
- A supplemental qualitative risk assessment conducted by Golder Associates (2011b) on the substitution of potassium chloride for sodium chloride as a stabiliser in the drilling and hydraulic fracturing process.

The potential additional risks posed by these systems which may be used in any of the hydraulic fracturing processes and fluid systems are described below and further information is provided in **Appendix H**. It is anticipated that additional substitutions of chemicals, proppants, tracers and additives will be trialled over time and used as tools in the process. These supplement assessments (many of which are not part of fluid systems) will be simply added to the information provided in **Appendix H**.

9.1 Noise and Vibration

The Golder Associates (2011a) assessment considered the potential risks associated with noise, vibration and air quality. Key text from both of these documents is provided in the sections below.

The activities associated with hydraulic fracturing have the potential to generate noise or vibration that could potentially impact nearby receptors. Whilst the proposed activities will take place on a continuous basis, they will be undertaken sequentially for short periods of time at different sites over a wide area. As a result, individual sensitive receivers are only likely to be exposed to the effects of nose from these activities for a few weeks at a time. Such short-term noise and vibration effects can be considered to equate to construction works and may be evaluated and controlled accordingly.

In February 2012, the Queensland DEHP, formerly DERM, published the guideline Prescribing Noise Conditions for Environmental Authorities for Petroleum and Gas Activities (Noise Assessment Guideline) to supplement the application of EPP Noise in the administration of an EA for petroleum and gas activity projects.

This guideline applies to the Santos EQ Project Area as it specifies ‘best practice’ noise limits which are considered to protect the acoustic values of a noise receptor in rural or isolated areas and achieve acoustic quality objectives set out in the EPP Noise, whilst considering cumulative impacts and background creep.

The best practice noise emission limits are reproduced in **Table 29**. These best practice noise limits are applicable to noise emissions from both construction and operation, the duration and work hours of the activity determining the applicable noise limit for the activity.

Table 29. Best Practice Noise Limits

Time Period	Parameter	Noise Limit (dBA)[1]		
		Short-term[2]	Medium-term[3]	Long-term[4]
7:00 am – 6:00 pm	LAeq, adj, 15mins	45	43	40

Time Period	Parameter	Noise Limit (dBA)[1]		
		Short-term[2]	Medium-term[3]	Long-term[4]
6:00 pm – 10:00 pm	LAeq, adj, 15mins	40	38	35
10:00 pm – 6:00 am	LAeq, adj, 15mins	28	28	28
	Max LpA, 15 mins	55	55	55
6:00 am – 7:00 am	LAeq, adj, 15mins	40	38	35

[1] *Based on the deemed background noise levels.*
[2] *A short-term noise event is defined as a noise exposure lasting for no greater than eight (8) hours and does not reoccur for at least seven (7) days.*
[3] *A medium-term noise event is defined as a noise exposure lasting for no greater than five (5) days and does not reoccur for at least four (4) weeks.*
[4] *A long-term noise event is defined as a noise exposure lasting for greater than five (5) days, even when there are respite periods when noise is inaudible within those five (5) days. Almost all construction and operational scenarios will fall within this long-term noise event specification*

The Queensland Government's Environmental Protection Agency's Ecoaccess Guideline – Noise and vibration from blasting identifies a vibration performance human comfort criteria for blasting of 5 mm/s for nine out of ten blasts and a maximum limit of 10 mm/ s for any blast. Australian Standard AS 2670.1-1990 provides for generally higher standards for human comfort for continuous or extended transient periods. In the absence of an Australian Standard, the vibration criteria of BS 7385: Part 2:1993 and/or DIN 4150-Part 3:1999 are generally applied to protect building structures. These provide for similar standards of 5 mm/s for continuous vibration and 10 mm/s for transient vibration, except for heritage/vulnerable buildings where lower limits apply.

9.2 Qualitative Noise Assessment

Information regarding the main sources of noise associated with a typical hydraulic fracturing process was provided by Santos EQ and the individual source terms for each source (sound power levels – SWLs) have been calculated from this data to be:

- Annulus – 1 off – SWL 90.3 dB(A)
- Frac Van – 1 off – SWL 98.8 dB(A)
- Power Pack – 1 off – SWL 106.7 dB(A)
- High pressure pump – 4 off – SWL 104.7-107.6 dB(A) – average SWL 106.1 dB(A)
- Low pressure pump – 1 off – 99.5 dB(A)
- Downhole Blender – 1 off – SWL 105.4 dB(A)
- Sand trailer —1 off - SWL 100.2 dB(A)
- Pregel – 1 off – SWL 104.6 dB(A)
- LGC – 1 off – SWL 97.9 dB(A).

Adding all noise sources together provides a conservative estimate of the total noise emissions from the process plant of SWL 115 dB(A), assuming that all noise sources are operational at full load at the same time. On this basis under neutral meteorological conditions, assuming minimal ground attenuation and no topographic screening, noise levels in the region of 50 dB LAeq 1- hour could be expected at a distance of 500 m from the worksite, falling to about 45 dB LAeq 1- hour at 1 km, 40 dB LAeq 1- hour at 2 km and about 35 dB LAeq 1- hour at 4 km.

However, on the basis of the distance calculations for the 85 dB exclusion zone (where hearing protection is needed) in the information provided, it would appear that the quoted values are sound pressure levels (SPL) at an unspecified distance from the source and if this is the case the actual SWLs may well be up to 10 dB(A) higher, which could extend the separation distances required to achieve the identified noise levels by an order of magnitude.

The estimated noise levels over distance are based conservatively on the simultaneous operation of all noise sources, lower levels would be generated if some or all of the identified equipment were to be operated sequentially or intermittently. It should be noted that Hydraulic Fracturing operations are generally conducted during the day and as such the potential impacts from these short-term activities will be lower. Where potential impacts on sensitive receptors may occur a number of mitigation methods will be employed to dampen noise emissions and minimise nuisance to receptors.

9.3 Qualitative Vibration Assessment

The effects of ground vibration on receivers will depend upon the source strength, separation distance and the nature of the transmission pathway.

Typically, significant vibration effects are only likely within, at most, a few 100s of metres of the source and any potential adverse effects are, therefore, unlikely to extend as far as those arising from noise emissions.

SLR has undertaken vibration measurements adjacent to two Santos EQ employed drill rigs (Santos pers. comm). At both locations, the measured vibration levels (PPV) during air drilling operations were below 0.1 mm/s at the drill lease boundary. Based on the nature of hydraulic fracturing activities which have many similarities with drilling no vibration impacts are anticipated.

9.4 Air Quality

An assessment of potential air quality impacts was completed by Golder Associates (2011a) as part of the Stage 1 and Stage 2 Hydraulic Fracturing Risk Assessments. The basis and key findings from these assessments are described below.

9.4.1 Airborne Contaminants

Exposure to airborne contaminants has been evaluated through a review of chemicals considered volatile. In general, most chemicals used in hydraulic fracturing exhibit low volatility.

The volatility of individual chemicals within a water mixture can be assessed based on the Henry's law constant (KH). According to NEPC (2013) chemicals can be considered highly volatile if the KH value is >2.5 x 10-3, moderately volatile for a KH value between 2.5 x 10-7 and 2.5 x 10-3 and not volatile if KH value is < 2.5 x 10-7. The KH values included in the chemical information sheets indicate that most chemicals used exhibit low solubility. A number of chemicals do exhibit high or moderate volatility these include some of the organic acids, alcohols (e.g., ethanol) terpenoids and terpene alcohols, food-based oils and biocides.

In general, the use of these agents is at low concentrations and the environment on and off-site is predominantly outdoors and not enclosed areas, and as such, inhalation is considered to represent a minor exposure pathway. In addition, there are control measures to manage any potential risks to workers.

9.4.2 9.4.2 Dust Suppression

Certain chemicals within the fracturing fluid additives, for example crystalline silica, represent a potential human health risk related to inhalation of dust generated during storage, transport or handling of the product. This is principally an occupational health hazard that is controlled through existing operational management procedures relating to the handling and storage of the additives. Information provided by the service contractor indicates that a health and safety management system exists that specifically addresses hazards related to materials storage and handling. In addition, Golder understands that the hydraulic fracturing additives are blended into the fluid mixture in enclosed vessels, and therefore the inhalation risk related to dust particulates is considered to be low on the basis of the engineering controls in place.

9.5 Alternative Proppants and Hydraulic Fracturing Agents

As noted above, modifications to the hydraulic methodologies over time have result in the inclusion of alternative proppants, and agents in the hydraulic fracturing process. These agents while introduced into the well are not reactive chemicals and technically are not part of the fluid system, which must be assessed. Rather they act as either inert substances designed to fill induced fractures (proppants), provide mechanical isolation of intervals or act as a stabiliser in the fluid system.

The potential risks associated with these agents are only assessed through the PBT framework to determine whether they have any hazardous properties and demonstrate that they are inert and non- reactive.

The PBT assessments conducted on these agents (which are provided in **Appendix H**) demonstrate that these substances are inert and not considered PBT substances. The size and inert nature of agents such as the perforation balls and proppants and their insolubility in water prevent their uptake by aquatic or terrestrial organisms.

9.6 Radiological Exposures

The potential for radiological exposures associated with the use of radiological tracers during the hydraulic fracturing process was evaluated in a risk assessment completed by EHS Support (2013a). The risk assessment involved an assessment of the chemical and physical properties of the ProTechnics tracer beads, a literature review and review of quantitative risk assessment conducted by the supplier.

The ProTechnics zero wash beads are utilised in the hydraulic fracturing process to allow for tracing of vertical and lateral distribution of proppants in the formation. The tracer beads are manufactured using a process that binds the radioisotope to the carrier particle and prevents washout. The ceramic beads are not biodegradable and are persistent in the formation, the radioactive tracers used are short lived with half-lives of less than 90 days. No chemical exposures to organisms are anticipated based on the absence of reactivity of these compounds; however, radiological exposures may potentially exist and were evaluated further.

Exposure to radionucleides can increase the risk for human cancer because of their high-energy gamma radiation. Gamma radiation is high-energy electromagnetic radiation emitted by certain radionucleides when their nuclei transition from a higher to a lower energy value.

A quantitative radiological risk assessment was completed on the transportation, use and management (refer **Appendix H**). The assessment demonstrated that there are no adverse impacts from the use of radiological tracers with the resulting dosages similar to the magnitude of sources that people are exposed to in everyday life. On this basis, the existing exposure controls implemented by Santos EQ for hydraulic fracturing activities and management of flowback water are considered sufficient for management of potential impacts on human health and the environment.

9.7 Cumulative Underground Impacts

Cumulative underground impacts are not anticipated as part of the project based on the controls described above. Fracturing will be confined to the target formation and vertical fracturing into overlying aquifer units will not occur.

The only cumulative impacts associated with the development activities are associated with extraction of water from the coal sequences (after completion of the hydraulic fracturing activities) and depressurization of overlying aquifer systems. These cumulative impacts have been assessed separately and a groundwater monitoring and management plan developed which includes make good provisions for potentially affected bores which may see reductions in water levels and associated yield.

10 Risk Assessment Findings

As described in Section 5, a weight of evidence approach has been used to the risks associated with hydraulic fracturing. A combination of assessment methodologies and models has been used to assess the fate and transport of chemicals and their associated risks. The results for risk assessments completed on the individual hydraulic fracturing fluid systems is provided in **Appendix C**, with the summary of results mirroring the various steps in the assessment process.

The toxicity of the chemicals used in the hydraulic fracturing process has been assessed for PBT, terrestrial toxicity and human health toxicity. The qualitative risk assessment methodology in some cases has used a semi-quantitative ranking of the hazards. Through this assessment methodology it has been determined that the chemicals used in hydraulic fracturing fluid systems can be generally characterised as non-hazardous with no chemicals identified with no high hazard chemicals identified in the semi-quantitative assessments. Overall, the health concerns from these chemicals are limited with the primary concerns identified associated with potential risks to aquatic receptors.

Consistent with the NWQMS, the quantitative risk assessment evaluated the toxicity of the individual substances and characterised the cumulative risks of the total fluid to human receptors and ecological terrestrial and aquatic

receptors. The methodology incorporated an assessment of potential exposures to human and ecological receptors, with the following identified as the only potentially complete exposure pathways:

- Incidental ingestion and dermal contact by trespassers at well pads
- Livestock and native fauna exposure to flowback water (ingestion only) at the well pads
- Potential releases of water to aquatic environments.

Based on groundwater fate and transport modelling, no potentially complete exposure pathways were identified for groundwater.

EPCs were developed for each of the hydraulic fracturing fluid systems using a combination of theoretical calculations and the results of flowback sampling. It should be noted that theoretical calculations have been completed for each fluid system. However, sampling of the flowback from all fluid systems has not been conducted, with a number of fluid systems still to be used in the fields.

No carcinogenic compounds are used in any of the hydraulic fracturing fluid systems used by Santos EQ. The chemicals used in the hydraulic fracturing process do not contain BTEX or PAHs as additives, which are recognised carcinogens.

For the assessment of non-carcinogenic human health and ecological terrestrial and aquatic risks, the risks posed by the mixture were calculated. For the assessment of carcinogenic or threshold effects levels to human receptors, the actual uptake of COPCs by ingestion and dermal contact were compared to acceptable risk-based intakes to calculate an individual HQ and then summed for all constituents into a HI. Similarly, potential ecological risks were estimated by comparing the EPC (for aquatic and terrestrial receptors) to reference values to provide a HQ, which was cumulated for a HI of the mixture.

Consistent with risk assessment methodologies, if the HI is less than or equal to 1, then no adverse health effects are likely associated with exposures. However, if the total HI is greater than 1, adverse health effects may be likely, but the evaluation requires further evaluation to define the risk characterisation process.

On the basis of the risk evaluations, the exposure pathways were generally less than 1 for human health and terrestrial receptors. In a number of cases, only at high theoretical concentrations were potential unacceptable risks observed. However, sampling of flow-back from hydraulic fracturing completed to date has indicated that the concentrations observed in flowback are considerably lower than the theoretical concentrations and the theoretical assumptions are highly conservative and not representative of long-term EPCs.

The quantitative risk assessment identified potential impacts if releases of flow-back water were to occur to aquatic environments. The magnitude of the impacts on receiving water (surface water) would be determined by the magnitude of the release, the mixing and dilution within the receiving water, and the physical properties and conditions within the receiving water. Potential impacts occurred for all exposure biodegradation periods for both theoretical and empirical data sets.

Considering the findings of the hazard and exposure assessment and the controls implemented by Santos EQ, the overall risk to human health and environment associated with the chemicals involved in hydraulic fracturing is low and acceptable. These operational controls include:

- Compliance with all EA requirements on siting of well bores including the lateral and vertical separation of hydraulically fractured wells relative to landholder bores. EA requirements have been incorporated within Santos's constraints planning protocol which is used for siting of all wells.
- Continued conformance with the Code of Practice for well siting, well installation, testing and hydraulic fracturing of wells.
- Application of DNRME assessment, notification and reporting requirements to ensure that wells are appropriately installed, tested and hydraulically fractured. This is combined with Santos EQ operational procedures to ensure well integrity and design of fracture to stay within the target seam, which are included in all reports submitted to DNRME.
- OH&S procedures implemented during hydraulic fracturing operations to prevent workers from direct contact with chemicals during spills and when handling flowback water or sediments
- Implementation of spill containment procedures during operations to prevent migration of and exposure to chemicals
- Lining of mud pits and turkey's nests to prevent seepage of flowback water into underlying aquifers

- Disposal or capping of sediments contained within drained mud pits and turkey nests, to prevent exposure to contaminates in windborne dust
- Installation and maintenance of fences around the well pad to prevent access to the drill pad by livestock and large native fauna
- Santos EQ operational procedures to ensure well integrity and design of fracture to stay within the target seam

The adequacy and appropriateness of these exposure controls will be routinely evaluated by Santos EQ and modifications and revisions made, where necessary. This will be further supported by regular monitoring of water supply bores and surface water for hydraulic fracturing chemicals and routine audits and inspections to ensure that these operational and exposure controls are effectively implemented and maintained.

In addition to the potential hazards associated with the use of chemicals in hydraulic fracturing, an assessment of the potential impacts of noise and vibration from the process and the use of alternative proppants and radiological tracers was completed. No unacceptable risks to receptors were identified from noise and vibration during the hydraulic fracturing process. The additional risks were identified from the use of alternative proppants, with these proppants providing the benefit of reducing potential inhalation (siliceous) risks to workers. The use of radiological tracers, at the design concentrations and in accordance with manufacturer specifications provided no unacceptable risks. Risk Assessment summaries for the alternative proppants and radiological tracers are provided in **Appendix H**.

In addition, a tiered assessment approach (CRAF) was presented to streamline the risk assessment process. This assessment process is designed to align with state and national guidance and other regulatory frameworks and assesses the full lifecycle of chemicals that are stored, handled, used and/or disposed of during or following hydraulic stimulation activities and in the treatment of produced formation water. By using the CRAF, potential risks to environmental values associated with stimulation activities will be demonstrated to be eliminated or reduced as much as reasonably practicable.

Forty-eight (48) hydraulic fracturing chemicals were assessed as part of this tiered assessment approach:

- 38 chemicals were assessed as Tier 1 chemicals
- Seven (7) chemicals were assessed as Tier 2 chemicals
- Three (3) chemicals were assessed as Tier 3 chemicals
- No chemicals were assessed as Tier 4 or 5 chemicals

The chemical risk assessments completed for each chemical indicated no negligible risks and effects of chemicals used during hydraulic fracturing to environmental values when appropriate management and mitigation controls were in place. Should assessments of additional chemicals indicate additional management control, the associated management plans will be updated accordingly.

It is the intent of Santos EQ that this new methodology will be the process moving forward to assess new chemicals. As described in **Section 5.2.3**, the Register of Assessed Chemicals will, for each published chemical, provide a summary of the outcomes of the screening assessment, including the Tier (and Risk Level) categorisation, the activities the chemical has been assessed for (i.e., hydraulic) and the assessed end use /fate of the chemical. Supporting information (i.e., dossiers, qualitative and quantitative risk assessments) for each assessed chemical are also readily accessible via the published register. The dossiers that are published in the Register of Assessed Chemicals are considered the most up to date.

Based on this assessment of risk, stimulation impact monitoring will be conducted in accordance with the requirements specified in the EA. Monitoring of water quality in landholder bores should include the minimum parameter lists and standard reporting limits, with the exception of PAHs where ultra-low reporting limits are required to support comparison to relevant regulatory criteria. Based on the limited risks identified in the study (based on management and administrative controls) a reduced suite of analytes associated with operational requirements is recommended to address primarily operational requirements for water management and provide indicator/tracer compounds for technical assessments.

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APPENDIX A SUMMARY OF HYDRAULIC FRACTURING CHEMICALS

Santos

Schlumberger Guar Based Systems	
Chemical Name	**CAS No.**
Tetrasodium ethylenediaminetetraacetate (EDTA)	64-02-8
Carbohydrate polymer (guar gum)	9000-30-0
Hydrochloric acid	7647-01-0
Polypropylene Glycol	25322-69-4
Postassium Chloride	7447-40-7
Sodium Hydroxide	1310-73-2
Sodium Hypochlorite	7681-52-9
Nitrogen, liquid form	7727-37-9
Crystalline silica (cristobalite)	14464-46-1
Crystalline silica (quartz)	14808-60-7
Magnesium silicate hydrate (talc)	14807-96-6
Vinylidene Chloride/methylacrylate	25038-72-6
Non crystalline silica (amorphous silica surrogate)	7631-86-9
Diammonium peroxidisulphate (ammonium persulphate)	7727-54-0
Magnesium Chloride	7786-30-3
Diatomaceous Earth, calcined	91053-39-3
Alcohols C6-C10 ethoxylated (surrogate C6 - C12)	68439-45-2
Alkylaryl Sulfonate	25155-30-0
Timethylammonium chloride	8030-78-2
trimethyl-3-[{1-oxooctadecyl)amino]propylammonium methyl sulphate	19277-88-4
Propane 1,2 diol	57-55-6
Ammonium C6-C10 alcohol ethoxysulfate	68187-17-7
Carbonic acid, sodium salt	533-96-0

Assessment provided in Appendix C1

Santos

Halliburton Water and Guar Based Systems (Original DeltaFoam 140 Formulation)	
Chemical Name	**CAS No.**
Acetic Acid	64-19-7
Calcium chloride	10043-52-4
Coffee Extract	68916-18-7
Ethanol	67-17-5
Guar Gum	9000-30-0
Monoethanolamine borate	26038-87-9
Sodium chloride	7647-14-5
Sodium hydroxide	1310-73-2
Sodium sulfate	7757-82-6
Tetrakis (hydroxymethyl) phosphonium sulphate (THPS)	55566-30-8
Alkylated quaternary chloride (surrogate tetramethylammonium chloride)	75-57-0
Coco dimethylaminopropyl betaine	61789-40-0
Sodium sulfite	7757-83-7
Silica gel	112926-00-8
Crystalline silica	14808-60-7
Terpenes and terpenoids, sweet orange oil	68647-72-3
Terpene hydrocarbons by products™	68956-56-9
1,2 Benzisothiazolin -3-one	2634-33-5
Non-ionic surfactant mix™	-*
Surfactant mix™	-*
Fatty acid ester™	-*
Ethoxylated fatty acid ester™	-*
Enzyme™	-*
Sodium thiosulfate	7772-98-7
Bentonite	121888-68-4

** The CAS numbers for fatty acid ester, ethoxylated fatty acid ester, non-ionic surfactant mix, surfactant mix, terpene hydrocarbon by products and enzyme have not been included in this table due to commercial confidentiality.*

Assessment provided in Appendix C2

Santos

Halliburton CleanStimAUs System	
Chemical Name	**CAS No.**
Hemicellulase enzyme™	9012-54-8
Carbohydrate (Lactose)	63-42-3
Potassium chloride	7447-40-7
Polysaccharide (Sodium carboxymethyl cellulose)	9004-32-4
Fatty acid ester™ (Sorbitan, monododecanoate, poly(oxy-1,2-diethanediyl))	9005-64-5
Sulfuric acid	7664-93-9
Sodium lauryl sulfate	75-57-0
Tri tetradecyl phosphonium chloride (TTPC)	81741-28-8
Cyrstalline silica, quartz	14808-60-7
Talc	14807-96-6
Saccharide (Maltodextrin)	9050-36-6
Inorganic salt (Aluminium sulfate)	10043-01-3
Food coating (Shellac, ammonium salt)	68308-35-8

Assessment provided in Appendix C3

ClearFrac	
Chemical Name	**CAS No.**
Cholinium chloride	67-48-1
Hydrochloric acid	7647-01-0
Propan-2-ol	67-63-0
Sodium chloride	7647-14-5
Acetic acid ethenyl ester, polymer with ethenol	25213-24-5
Cristobalite	14464-46-1
Cyrstalline silica	14808-60-7
Magnesium nitrate	13077-60-3
Magnesium silicate hydrate (talc)	14807-96-6
Vinylidene chloride/methalacrylate copolymer	25038-72-6
Magnesium chloride	7786-30-3
Diatomaceous earth, calcined	91053-39-3
2-methyl-2h-isothiazol-3-one	2682-20-4
5-chloro-2-methyl-2h-isothiazolol-3-one	26172-55-4
Erucic amidopropyl dimethyl betaine	149879-98-1
Benzenesulfonic acid, 4-ethenyl-, sodium salt, homopolymer	25704-18-1
Sodium chloroacetate	3926-62-3
Polyvinyl acetate, partially hydrolyzed	304443-60-5

Assessment provided in Appendix C4

Santos

Halliburton Alternative System (Delta 140 Formulation)	
Chemical Name	**CAS No.**
Acetic Acid	64-19-7
Hemicellulase enzyme	9012-54-8
Choline chloride	67-48-1
Ethylene glycol	107-21-1
Guar Gum	9000-30-0
Hydrochloric acid	7647-01-0
Monoethanolamine borate	26038-87-9
Sodium hydroxide	1310-73-2
Tetrakis (hydroxymethyl) phosphonium sulphate (THPS)	55566-30-8
Coco dimethylaminopropyl betaine	61789-40-0
Crystalline silica and Cyrstalline silica, quartz	14808-60-7
Coffee beans (green coffee bean extract; chlorogenic acid)	327-97-9
Coffee beans (caffeine)	58-08-2
Alcohols, C6-C-12, ethoxylated propoxylated	68937-66-6
Alcohols, C10-C16, ethoxylated propoxylated	69227-22-1
Maltodextrin	9050-36-6
Polyethylene glycol	25322-68-3

Assessment provided in Appendix C5

Schlumberger YF120 Flex with J318 System	
Chemical Name	**CAS No.**
Cholinium chloride	67-48-1
Glycerol	56-81-5
Guar gum	9000-30-0
Hydrochloric acid	7647-01-0
Potassium hydroxide	1310-58-3
2,2`,2"-nitrilotriethanol	102-71-6
Cristobalite	14464-46-1
Crystalline silica	14808-60-7
Magnesium nitrate	10377-60-3
Potassium borate	1332-77-0
Magnesium silicate hydrate (talc)	14807-96-6
Vinylidene chloride/methylacrylate copolymer	25038-72-6
Non-crystalline silica	7631-86-9
Diammonium peroxidisulphate	7727-54-0
Magnesium chloride	7786-30-3
Diatomaceous earth, calcined	91053-39-3
2-methyl-2h-isothiazol-3-one	2682-20-4
5-chloro-2-methyl-2h-isothiazolol-3-one	26172-55-4

Assessment provided in Appendix C6

Schlumberger Sapphire LF System	
Chemical Name	**CAS No.**
2-hydroxy-N,N,N-trimethylethanaminium chloride (Choline chloride)	67-48-1
Sodium carboxymethylcellulose	9004-32-4
2,2`,2"-nitrilotriethanol	102-71-6
Cristobalite	14464-46-1
Crystalline silica	14808-60-7
Magnesium nitrate	10377-60-3
Magnesium silicate hydrate (talc)	14807-96-6
Vinylidene chloride/methylacrylate copolymer	25038-72-6
Diammonium peroxidisulphate	7727-54-0
Magnesium chloride	7786-30-3
Diatomaceous earth, calcined	91053-39-3
2-methyl-2h-isothiazol-3-one	2682-20-4
5-chloro-2-methyl-2h-isothiazolol-3-one	26172-55-4

Assessment provided in Appendix C7

Halliburton Hydraulic Fracturing Fluid System - Well RM 08-14-3	
Chemical Name	**CAS No.**
Acetic acid	64-19-2
Hemicellulase enzyme	9012-54-8
Diethanolamine	111-42-2
Ethylene glycol	107-21-1
Lactose	63-42-3
Monoethanolamine borate	26038-87-9
Sodium carbonate	497-19-8
Sodium hydroxide	1310-73-2
Tributyl tetradecyl phosphonium chloride	81741-28-8
Hydroxypropyl guar	39421-75-5
Triethanolamine	107-71-6
Ulexite	1319-33-1
Crystalline Silica	14808-60-7
Silica dioxide	7631-86-9
Disodium octaborate tetrahydrate	12280-03-4

Assessment provided in Appendix C8

Fluorescein Dye Hydraulic Fracturing Fluid System	
Chemical Name	**CAS No.**
Potassium chloride	7447-40-7
Tributyl tetradecyl phosphonium chloride	81741-28-8
Sodium fluorescein	518-47-8

Assessment provided in Appendix C9

Santos

Condor Energy Hydraulic Fracturing Fluid System	
Chemical Name	**CAS No.**
2-Mercaptoethyl Alcohol	60-24-2
Polyacrylamide	25085-02-3
Acetic Acid	64-19-7
N-Benzyl-Alkylpyridinium Chloride	68909-18-2
Hemicellulase	9025-56-3
Choline Chloride	67-48-1
Ethylene Glycol	107-21-1
Polyoxyethylene-polyoxypropylene Block Copolymer	9003-11-6
Glutaraldehyde	111-30-8
Glycerol	56-81-5
Guar Gum	9000-30-0
Distillates, Hydrotreated Light	64742-47-8
HydroChloric Acid	7647-01-0
Isopropanol	67-63-0
Methanol	67-56-1
Potassium Chloride	7447-40-7
Potassium Hydroxide	1310-58-3
Sodium bisulfite	7631-90-5
Sodium Hydroxide	1310-73-2
Sodium polyacrylate	9003-04-7
Sodium erythorbate	6381-77-7
Diethylene Glycol	111-46-6
Cinnamaldehyde	104-55-2
Formic Acid	64-18-6
Ammonium Persulphate	7727-54-0
Alcohols, C9-11, ethoxylated	68439-46-3
Ethoxylated C11 Alcohol	34398-01-1
Ammonium Sulphate	7783-20-2
2-Propenoic acid, homopolymer, ammonium salt	9003-03-6
Potassium persulfate	7727-21-1
2-Ethoxy-naphthalene	93-18-5
Inorganic Salt	584-08-7
Sodium Tetraborate	1330-43-4
1,6-Hexanediol	629-11-8
Amylase, Alpha	9000-90-2
Sodium Benzoate	532-32-1
Pottasium Sorbate	24634-61-5
Polyoxyethylene nonylphenol ether	9016-45-9
Quaternary ammonium compounds, bis(hydrogenated tallow alkyl)dimethyl, salts with bentonite	68953-58-2
Water in Additive	7732-18-5
Tar Bases, Quinoline Derivatives, Benzyl Chloride-Quat	72480-70-7

Chemical Name	CAS No.
Castor Oil	61791-12-6
Pine Oil	8002-09-3

Assessment provided in Appendix C10

Santos

Halliburton Hybor and Delta Hyraulic Fracturing Fluid Systems (Hybor DFS-BCG-H)	
Chemical Name	**CAS No.**
Acetic acid	64-19-7
Alcohols, C12-15, ethoxylated	68131-39-5
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4
Butyl alcohol	71-36-3
Choline Chloride	67-48-1
Citric acid	77-92-9
Coffee Extract	68916-18-7
Diethanolamine	111-42-2
Ethanol	64-17-5
Ethylene glycol	107-21-1
Fatty acids, tall-oil, ethoxylated	61791-00-2
Glutaraldehyde	111-30-8
Hydrotreated light petroleum distillate	64742-47-8
Hydrochloric acid	7647-01-0
Methanol	67-56-1
Sodium bisulfite	7631-90-5
Sodium carbonate	497-19-8
Sodium Chloride	7647-14-5
Sodium hydroxide	1310-73-2
Sodium persulfate	7775-27-1
Sodium polyacrylate	9003-04-7
Sodium Sulfate	7757-82-6
Tributyl tetradecyl phosphonium chloride	81741-28-8
Hydroxylpropyl guar	39421-75-5
Triethanol amine	102-71-6
Silica dioxide	112926-00-8
Chlorous acid, sodium salt	7758-19-2
Disodium octaborate tetrahydrate	12008-41-2
Ulexite	1319-33-1
Crystalline silica, quartz	14808-60-7

Assessment provided in Appendix C11

Halliburton Hybor and Delta Hyraulic Fracturing Fluid Systems (DFS-BCG)	
Chemical Name	**CAS No.**
Acetic acid	64-19-7
Alcohols, C12-15, ethoxylated	68131-39-5
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-28-4
Butyl alcohol	71-36-3
Cellulase enzyme	9012-54-8
Choline Chloride	67-48-1
Citric acid	77-92-9
Coffee Extract	68916-18-7
Diethanolamine	111-42-2
Ethanol	64-17-5
Ethylene glycol	107-21-1
Fatty acids, tall-oil, ethoxylated	61791-00-2
Glutaraldehyde	111-30-8
Guar gum	9000-30-0
Hydrotreated light petroleum distillate	64742-47-8
Hydrochloric acid	7647-01-0
Lactose	63-42-3
Methanol	67-56-1
Monoethanolamine borate	26038-87-9
Sodium hydroxide	1310-73-2
Sodium persulfate	7775-27-1
Sodium Sulfate	7757-82-6
Tributyl tetradecyl phosphonium chloride	81741-28-8

Assessment provided in Appendix C11

Halliburton DFS-BGL Hydraulic Fracturing Fluid System	
Chemical Name	**CAS No.**
Acetic acid	64-19-7
Choline Chloride	67-48-1
Ethylene glycol	107-21-1
Guar gum	9000-30-0
Hemicellulase enzyme	9012-54-8
Lactose	63-42-3
Monoethanolamine borate	26038-87-9
Sodium hydroxide	1310-73-2
Sodium persulfate	7775-27-1
Sodium Sulfate	7757-82-6
Tributyl tetradecyl phosphonium chloride	81741-28-8

Assessment provided in Appendix D

Halliburton DFS-BGL Hydraulic Fracturing Fluid System 1	
Chemical Name	**CAS No.**
Acetic acid	64-19-7
Choline Chloride	67-48-1
Citric acid	77-92-9
Coffee Extract	68916-18-7
Ethylene glycol	107-21-1
Guar gum	9000-30-0
Hemicellulase enzyme	9012-54-8
Hydrochloric acid	7647-01-0
Lactose	63-42-3
Monoethanolamine borate	26038-87-9
Sodium hydroxide	1310-73-2
Sodium persulfate	7775-27-1
Sodium Sulfate	7757-82-6
Tributyl tetradecyl phosphonium chloride	81741-28-8

Assessment provided in Appendix D

Halliburton DFS-BGL Hydraulic Fracturing Fluid System 2A	
Chemical Name	**CAS No.**
Acetic acid	64-19-7
Citric acid	77-92-9
Coffee Extract	68916-18-7
Guar gum	9000-30-0
Hemicellulase enzyme	9012-54-8
Hydrochloric acid	7647-01-0
Lactose	63-42-3
Monoethanolamine borate	26038-87-9
Potassium chloride	7447-40-7
Sodium hydroxide	1310-73-2
Sodium persulfate	7775-27-1
Sodium Sulfate	7757-82-6
Tributyl tetradecyl phosphonium chloride	81741-28-8

Assessment provided in Appendix D

Halliburton DFS-BGL Hydraulic Fracturing Fluid System 2B	
Chemical Name	**CAS No.**
Acetic acid	64-19-7
Citric acid	77-92-9
Cocobetaine	61789-40-0
Coffee Extract	68916-18-7
Glycerine	56-81-5
Guar gum	9000-30-0
Hemicellulase enzyme	9012-54-8
Hydrochloric acid	7647-01-0
Lactose	63-42-3
Monoethanolamine borate	26038-87-9
Nitrogen	7727-37-9
Potassium chloride	7447-40-7
Sodium Chloride	7647-14-5
Sodium hydroxide	1310-73-2
Sodium persulfate	7775-27-1
Sodium Sulfate	7757-82-6
Tributyl tetradecyl phosphonium chloride	81741-28-8

Assessment provided in Appendix D

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Halliburton DFS-BGL Hydraulic Fracturing Fluid System 3	
Chemical Name	**CAS No.**
Acetic acid	64-19-7
Choline Chloride	67-48-1
Citric acid	77-92-9
Coffee Extract	68916-18-7
Ethylene glycol	107-21-1
Glycerine	56-81-5
Guar gum	9000-30-0
Hemicellulase enzyme	9012-54-8
Hydrochloric acid	7647-01-0
Lactose	63-42-3
Methanol	67-56-1
Methyl Acetate	79-20-9
Monoethanolamine borate	26038-87-9
Poly(vinyl acetate)-poly(vinyl alcohol) polymer	25213-24-5
Sodium Acetate	127-09-3
Sodium hydroxide	1310-73-2
Sodium persulfate	7775-27-1
Sodium Sulfate	7757-82-6
Tributyl tetradecyl phosphonium chloride	81741-28-8

Assessment provided in Appendix D

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Halliburton DFS-BCG Hydraulic Fracturing Fluid System 4	
Chemical Name	**CAS No.**
Acetic acid	64-19-7
Alcohols, C12-15, ethoxylated	68131-39-5
Alcohols, C12-16, ethoxylated	68551-12-2
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4
Amine oxides, cocoalkyldimethyl	61788-90-7
Benzaldehyde	100-52-7
Butyl alcohol	71-36-3
Chlorous acid, sodium salt	7758-19-2
Choline Chloride	67-48-1
Cinnamaldehyde	104-55-2
Citric acid	77-92-9
Crystalline silica, quartz	14808-60-7
Diethanolamine	111-42-2
Diethylene glycol	111-46-6
Disodium octaborate tetrahydrate	12008-41-2
Ethanol	64-17-5
Ethylene glycol	107-21-1
Fatty acids, tall-oil, ethoxylated	61791-00-2
Glutaraldehyde	111-30-8
Hydrochloric acid	7647-01-0
Hydrotreated light petroleum distillate	64742-47-8
Hydroxylpropyl guar	39421-75-5
Methanol	67-56-1
Silica dioxide	112926-00-8
Sodium carbonate	497-19-8
Sodium Chloride	7647-14-5
Sodium hydroxide	1310-73-2
Sodium iodide	7681-82-5
Sodium persulfate	7775-27-1
Sodium Sulfate	7757-82-6
Sodium Sulfite	7757-83-7
Sodium thiosulfate	7772-98-7
Tributyl tetradecyl phosphonium chloride	81741-28-8
Triethanol amine	102-71-6
Ulexite	1319-33-1

Assessment provided in Appendix D

APPENDIX B SUPPLEMENTAL INFORMATION FOR HAZARD ASSESSMENT APPROACH

B.1 Supporting Documentation

The environmental hazard assessment approach is consistent with national and international guidance for assessment of potential for PBT[1] in the risk assessment, classification, and regulation of chemicals. Physical and chemical properties that affect the fate and behaviour of chemicals in the environment, degradation rates, partition coefficients, and aquatic ecotoxicological data are used in assessment of environmental mobility and PBT potential.

The Australian National Framework for Chemicals Environmental Management (NChEM) guidance manuals were consulted in preparation of the environmental hazard assessment approach, namely:

- EPHC (2009a). Environmental Risk Assessment Guidance Manual for Industrial Chemicals; and
- EPHC (2009b). Environmental Risk Assessment Guidance Manual for Agricultural and Veterinary Chemicals.

These guidance manuals present the data requirements and methodology for assessment for environmental hazard and risk assessment of industrial and agriculture and veterinary chemicals, consistent with international best practice. NChEM guidance is prepared by the National Environment Protection and Heritage Council (EPHC) for the Minister for the Commonwealth Department of the Environment (DotE) (formerly Department of the Environment, Water, Heritage and the Arts [DEWHA]).

DEWHA undertakes environmental risk assessments of industrial chemicals for the National Industrial Chemicals Notification and Assessment Scheme (NICNAS) and of agricultural and veterinary chemicals for the Australian Pesticides and Veterinary Medicines Authority (APVMA).

The methodology used to develop the necessary PBT information to conduct the assessment is discussed herein.

B.1.1 Persistence

Persistence refers to whether, and how fast, a chemical degrades in the environment over time. Chemicals degrade in the environment in a variety of ways, and biotic (microbial) and abiotic transformation pathways should be considered. Abiotic pathways include degradation by hydrolysis, photolytic degradation and by reaction with atmospheric hydroxyl radicals.

The Stockholm Convention provides scientifically based criteria for identifying persistent organic pollutants (POP)[2]. The criteria for persistence in Annex D of the Stockholm Convention are expressed as single-media criteria, as follows:

- evidence that the half-life of the chemical in water is greater than two months, or that its half-life in soil is greater than six months, or that its half-life in sediment is greater than six months; or

[1] PBT substances are substances that are persistent (P), bioaccumulative (B) and Toxic (T).
[2] For further information on the Stockholm Convention see:
http://www.environment.gov.au/protection/chemicals-management/pops and
http://chm.pops.int/default.aspx.

- evidence that the chemical is otherwise sufficiently persistent to justify its consideration within the scope of the Convention.

Considerations under the second criteria may include, for example, where the chemical has a half-life greater than six months in anaerobic conditions but less than six months under aerobic conditions (DEWHA, 2009).

Australian threshold criteria for persistence are based on half-life data. Standard OECD guideline tests for half-life in various media are preferred where available. However, qualitative results from biodegradation studies may be used to perform persistence categorisation (DoEE, 2017).

B.1.2 Bioaccumulation

Assessment of bioaccumulation potential are evaluated for organic chemicals only. Bioaccumulation is not assessed for inorganic chemicals in accordance with guidance in Environment Canada (2003).

Bioaccumulation is discussed in terms of the bioconcentration factor (BCF) or the bioaccumulation factor (BAF) depending on the type of data available, and the predominant route of uptake. The BCF is defined as the ratio of the concentration of the chemical in an organism relative to the concentration in the surrounding medium, and only takes into account uptake from the medium in which the organism lives. For aquatic organisms, uptake from water is considered to be the predominant route of uptake unless the chemical is very hydrophobic, in which case, uptake from food becomes important. BAF measurements take dietary uptake into consideration in addition to uptake from the medium. BCF measurements are generally appropriate for chemicals with a log octanol / water partition coefficient (Kow) of less than 6. For highly lipophilic chemicals with with a log Kow of greater than 6, a BAF measurement is more appropriate than a BCF (DEWHA, 2009).

Several standard test guidelines are available for determining the BCF or BAF of a chemical, but the OECD 305 test guideline for bioaccumulation in fish is normally used. In the absence of measured BCF or BAF data, the log Kow may be used as a surrogate (DEWHA, 2009).

A discussion of secondary exposure through the aquatic food chain may also be appropriate. The biomagnification factor (BMF) describes the relative concentration of the chemical in a predatory animal compared with the concentration in its prey. A BMF of greater than 1 indicates that chemical has the potential to biomagnify in the food chain. Such a chemical is also classified as bioaccumulative. The BMF may be estimated from either the measured BCF or the measured log Kow using criteria set out by DEWHA (2009).

B.1.3 Toxicity

To assess the toxic (T) potential of the chemicals, readily available acute (i.e., predominantly L(E)C_{50}[3]) and chronic (i.e., no observed effect concentration [NOEC], lowest observed effect concentration [LOEC], maximum acceptable tolerable concentration [MATC] and EC_{50}) data for aquatic organisms are obtained from the following sources in order of priority:

- USEPA (2011) ECOTOXicology Database Version 4.0
- Australasian Journal of Ecotoxicology.

Where ecotoxicological data were not available for the chemicals of interest or a suitable surrogate, data were modelled using EPISUITE™ ECOSAR™ software. ECOSAR™ (stands

[3] Lethal (or effect) concentration that kills (or effects) 50% of the test population

for Ecological Structure Activity Relationships) estimates the toxicity of chemicals to fish, aquatic invertebrates and algae in water.

Toxic effect predictions are made using a set of quantitative structure-activity relationships (QSARs) models. QSARs predict the aquatic toxicity of untested chemicals based on their structural similarity to chemicals for which aquatic toxicity data are available. The toxicity data used to build the QSARs come from a database of publicly available and confidential data submitted to the US EPA New Chemicals Program. The QSARs used in ECOSAR™ correlate a compound's physicochemical properties and its aquatic toxicity within specific chemical classes, and applies rules for selecting the appropriate chemical class for the compound.

ECOSAR™ generates acute (short-term) toxicity and, when available, chronic (long-term or delayed) toxicity.

The trophic level groupings considered for aquatic organisms are plant, invertebrate and fish. As freshwater aquatic organisms are considered the receptor of concern for the hydraulic fracturing chemicals, freshwater ecotoxicological data are used in the assessment of toxic potential.

The downloaded data from USEPA ECOTOX database are screened. The following endpoints are selected: mortality (acute), growth (chronic) and reproduction (chronic) for plants, invertebrates and fish. Additional screening include the following: studies shorter than 24 hours are not considered; chronic mortality exposures are not considered; and $L(E)C_x$ endpoints other than $L(E)C_{50}$ are not considered, (e.g. EC_0, EC_{100}, EC_{10}, EC_{20})

Where modelled data were generated using EPISUITE™ ECOSAR™ software the chronic data do not specify the endpoint (i.e., it is not known if the endpoint is NOEC or LOEC/MATC, or EC_{50}.) The chronic data are assumed to be LOEC/MATC or EC_{50} endpoints which results in a higher (more conservative) hazard classification.

B.2 Exclusions and Limitations

The environmental hazard assessment is a relative assessment and not a comprehensive evaluation of environmental hazards. Below are the exclusion and limitations:

- The approaches consulted for assessment of PBT in devising the environmental hazard assessment approach are predominantly focussed on the assessment of organic chemicals. There is limited guidance for PBT assessment of inorganic chemicals;
- The environmental hazard assessment approach is subject to professional judgment and the evaluator's subjectivity in designating the parameter ranges for each parameter assessed;
- The environmental hazard assessment does not consider, inter alia:
  - Breakdown or reactive products of the chemicals that may pose more or less of an environmental hazard than the parent compound;
  - The quality, adequacy or accuracy of the available information sourced, noting that only sources considered to be reputable were used;
  - Endocrine disruption effects that are not assessed by standard ecotoxicological tests;
  - The combined effects of these chemicals when present in mixture.
- The data collated in the Chemical Information Sheets are treated the same regardless of whether the data are measured experimental values or estimated / calculated values;
- The test endpoint description in the (secondary) sources consulted are relied upon although it should be noted that true chronic and acute NOEC, LOEC, or L(E)C_{50} are dependent on a variety of factors such as test duration, species tested, stage in the life-cycle, etc. which can only be verified by review of the primary literature;
- It is noted in relation to the aquatic ecotoxicological data that the species *Daphnia magna* are a sensitive species, frequently displaying sensitivity to chemicals orders of magnitude greater than other invertebrate species;
- Sources of Australian aquatic ecotoxicological data are consulted but the information is very limited. Furthermore, many species reported in the Australian literature are not necessarily indigenous species;
- The environmental hazard assessment approach devised for this study will not adequately assess chemicals which are:
  - Hydrophilic i.e., are highly soluble and have low K_{ow}. Where aquatic ecotoxicological data are limited for these types of chemicals, toxicity may be underestimated because there is potential for these chemicals to be highly toxic;
  - Poorly biodegradable, have low acute toxicity, but are bioaccumulative (based on the BCF or K_{ow}). These chemicals may exert chronic toxicity.
- Use of surrogate toxicity data for hydraulic fracturing chemicals, which are best described as mixtures, may further bias the hazard assessment towards assessment of T potential. Where a highly toxic chemical is present in only small quantities the effect on the overall hazard assessment is greater compared to a chemical with lower toxicity.

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APPENDIX C ASSESSED HYDRAULIC FRACTURING FLUID SYSTEMS

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Appendix C1
Schlumberger Methodology – Guar Based Systems

C1.0 Introduction

As presented in **Section 5.0** of the Hydraulic Fracturing Risk Assessment, a weight-of-evidence approach was used by Santos to evaluate the potential for human health and environmental (e.g., ecological) risks as a result of the hydraulic fracturing processes.

Golder Associates (Golder), on behalf of Santos, completed a qualitative risk assessment (Golder, 2013c) that evaluated the nature of the geology in the areas undergoing stimulation, the potential for impacts on water resources, the process and chemicals used.

A Quantitative Risk Assessment (QRA), completed by EHS Support, LLC (EHS Support), supplemented the qualitative risk assessment (EHS Support, 2012). The QRA was conducted to meet Conditions 49e and 49f of the 2 October 2011 approval under the Environmental Protection and Biodiversity Conservation Act 1999 (EPBC 2008/4059) and the EA conditions to assess the toxicity of the mixtures.

Key reports and studies previously submitted for these fluid systems comprise:

- Golder Associates. (2013c). Coal Seam Hydraulic Fracturing Risk Assessment - Combined Stage 1 and Stage 2 Risk Assessment for Schlumberger Methodology. Revision 1. 14 March 2013.
- EHS Support (2012). Gladstone Liquefied Natural Gas (GLNG) Project. Coal Seam Gas Hydraulic Fracturing Quantitative Risk Assessment for Schlumberger Chemistry. EHS Support Report. 16 October 16, 2012.

The results and conclusions of the qualitative risk assessment components and the QRA are summarised below. Refer to the text of this report for detailed discussions on methodologies employed for each component; specific tables referred to in this summary are included for review with this document. Table numbers specific to the original reports were retained for consistency between documents.

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C2.0 Qualitative Risk Assessment and Evaluation

C2.1 Chemicals Evaluated

Three 'fluid systems' were assessed, each having a foamed and non-foamed version, for a total of six hydraulic fracturing fluid mixtures. Chemical constituents identified in each hydraulic fracturing fluid system were evaluated in the hydraulic fracturing risk assessments. The list of individual chemicals present within the three fluid systems is presented in Table 1 below. A mass balance of the chemicals within each of the hydraulic fracturing fluid systems is provided as **Appendix C1-1** (Table D-3; Golder, 2013c). Information regarding the chemical and physical properties of the individual chemicals listed below can be found in **Appendix E**.

It is noted, while none of the fracturing fluid chemicals identified contain benzene, toluene, ethylbenzene, xylenes (BTEX) or polycyclic aromatic hydrocarbons (PAHs), that PAHs occur naturally in coal and it is possible that certain PAHs may naturally be present in the coal seam groundwater used in the hydraulic fracturing process.

Table 1

Chemical	Cas Number
Carbohydrate polymer (guar gum)	9000-30-0
Polypropylene Glycol	25322-69-4
Alcohols C6-C10 ethoxylated (surrogate C6 - C12)	68439-45-2
Vinylidene Chloride/methylacrylate	25038-72-6
Tetrasodium ethylenediaminetetraacetate (EDTA)	64-02-8
Alkylaryl Sulfonate	25155-30-0
Timethylammonium chloride	8030-78-2
Nitrogen, liquid form	7727-37-9
trimethyl-3-[{1-oxooctadecyl)amino]propylammonium methyl sulphate	19277-88-4
Propane 1,2 diol	57-55-6
Magnesium Chloride	7786-30-3
Diatomaceous Earth, calcined	91053-39-3
Crystalline silica (cristobalite)	14464-46-1
Crystalline silica (quartz)	14808-60-7
Diammonium peroxidisulphate (ammonium persulphate)	7727-54-0
Ammonium C6-C10 alcohol ethoxysulfate	68187-17-7
Carbonic acid, sodium salt	533-96-0
Hydrochloric acid	7647-01-0
Magnesium silicate hydrate (talc)	14807-96-6
Sodium Hydroxide	1310-73-2
Non crystalline silica (amorphous silica surrogate)	7631-86-9
Postassium Chloride	7447-40-7
Sodium Hypochlorite	7681-52-9

C2.2 Risk Assessment Framework and Findings

As discussed in **Section 5.0** of the systematic weight of evidence approach was utilised to complete the risk assessment for the Schlumberger Fluid Systems. The work has involved the following evaluations:

Qualitative Assessment Methodologies

- Environmental Hazard Assessment
- Exposure Assessment including Fate and Transport Assessment in Groundwater
- Mass Balance of the fluid systems
- Groundwater Fate and Transport Modelling.

Quantitative Risk Assessment Methodologies

- Quantitative Human Health Risk Assessment
- Quantitative Ecological Risk Assessment for Terrestrial and Aquatic Receptors.

C2.3 Environmental Hazard Assessment

The environmental hazard assessment approach outlined in **Section 6.1** was undertaken to rank the hydraulic fracturing chemicals based on persistence (P), bioaccumulation (B) and toxic (T) potential (hereafter referred to as PBT).

A combination of data sets were used in the PBT assessment including chemical information sheets (**Appendix E** and **Appendix G**), the Hazardous Substance Database, and modelled data from USEPA (2009) EPISUITE modelling software, when data not available from other sources.

Of the 34 chemicals listed above, three were not considered for PBT ranking. Crystalline silica (quartz, 14808-60-7) and crystalline silica (cristobalite, 14464-64-1) relate to the sand used as the proppant and are therefore not considered to represent an environmental hazard. Similarly, amorphous silica is an inert element, also ubiquitous in the environment, and was therefore not considered further in the PBT ranking.

C2.4 Exposure Assessment

As discussed in **Section 7.0**, the exposure assessment identified receptors potentially exposed to COPCs identified for the study and outlines the exposure pathways by which the receptors may come in to contact with the COPCs.

C2.4.1 Onsite Exposures

Of the pathways evaluated, the onsite assessment indicated that the majority of exposures were unlikely or incomplete; given the application of operational controls by Santos. These operational controls include:

- Occupational health and safety procedures implemented during hydraulic fracturing operations to prevent workers from direct contact with chemicals during spills and when handling flowback water or sediments
- Implementation of spill containment procedures during operations to prevent migration of and exposure to chemicals
- Disposal or capping of sediments contained within drained mud pits and turkey nests, to prevent exposure to contaminates in windborne dust

- Fencing of drill pads to prevent trespassers and installation of signs to indicate that the water in the turkey's nest and mud pit is not potable and may contain contaminants
- Installation and maintenance of fences around the well pad to prevent access to the drill pad by livestock and large native fauna
- Mud pits and turkey's nests lined with clay or similar material to prevent seepage of flowback water into underlying aquifer.

Details regarding onsite exposure scenarios, receptors, and pathways evaluated are provided in Table 50 (Golder, 2013c) attached to this Appendix.

The following on-site pathways were determined to be potentially complete and were evaluated:

- Exposure to COPCs in mud pit and turkeys nest sediments:
  - Workers and trespassers via direct contact (ingestion and dermal contact).
- Exposure to COPCs in flowback water in turkey's nest and mud pit:
  - Workers while working with turkey's nest inlet/liner or drainage of turkey's nest or mud pit via direct contact
  - Trespassers after entry (accidental or deliberate) to turkey's nest or mud pit via direct contact
  - Native terrestrial fauna after entry (accidental or deliberate) to turkey's nest or mud pit via ingestion
  - Stock animals after entry (accidental or deliberate) to turkey's nest or mud pit via ingestion.
- Exposure to COPCs in flowback water released to environment (spill, leak, mud pit, turkey nest delivery system failure or overflow):
  - Workers, terrestrial fauna, terrestrial flora via ingestion, dermal contact and inhalation.

One potentially complete exposure pathway was identified, which is direct contact to the flowback water in the turkey's nest and mud pit for small native fauna (i.e., lizards and birds). All reasonable measures will be conducted to discourage entry of small native fauna into the well pad area during hydraulic fracturing operations.

C2.4.2 Offsite Exposure Pathways

Of the pathways evaluated, the following off-site pathways were determined to be potentially complete and were evaluated:

- Exposure to COPCs in flowback water released to environment (spill, leak, mud pit, turkey nest delivery system failure or overflow):
  - Residents, terrestrial fauna, terrestrial flora via ingestion, dermal contact and inhalation.

Details regarding offsite exposure scenarios, receptors, and pathways evaluated are provided in Table 51 (Golder, 2013c) attached to this Appendix.

Potential off site exposure pathways were evaluated for residents, stock animals, native flora and fauna and aquatic ecosystems. Four possible sources were identified, hydraulic fracturing fluids, sediments from mud pit or turkey's nest, flowback water and coal seam gas (methane). The exposure assessment concluded that with the implementation of operational controls including use of liners in turkey nests, well integrity testing, operational monitoring and capping and/or removal of sludge all off-site exposures are considered unlikely and incomplete.

C2.5 Mass Balance of Fluid System

A quantitative mass balance calculation was undertaken to identify the amount of each chemical additive of the hydraulic fracturing fluid in the following fluid systems:

- Waterfrac / Slickwater
- WF130 Linear Gel
- WF130 Linear Base Gel for Foam Fluid
- YF125LG Crosslinked Gel.

The results of the mass balance calculations are presented in the referenced Table D-3 (Golder, 2013c) which is included in **Appendix C1-1**.

C2.6 Fate and Transport Modelling

For the sake of conservatism, the fate and transport of the highest ranked and most mobile organic chemicals was further assessed. This included the following chemicals evaluated in this fluid system:

- Tetrasodium EDTA
- Vinylidene chloride.

Details on the fate and transport modelling methodology and results are provided in **Section 7.2** of the report. The modelling demonstrated that there is limited potential for chemicals to migrate within the coal seams.

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C3.0 Quantitative Risk Assessment

In accordance with the methodologies presented in **Section 8.0**, a QRA was conducted on both theoretical and empirical datasets for those chemicals identified in the Combined Stage 1 and 2 Risk Assessments (EHS Support, 2012). The QRA approach evaluates the toxicity of the individual substances and characterises the cumulative risks of the total effluent toxicity and ecotoxicity.

Generally, this methodology includes the identification of the hazards posed by constituents in the flowback water, compilation of the toxicity criteria for each constituent, development of exposure models to estimate the daily intake of the constituents, and calculations of individual constituent hazard quotients (daily intake divided by the toxicity criteria) and a cumulative constituent hazard index (HI) for each potentially complete exposure pathway for each human or terrestrial receptor.

Potential complete exposure pathways to the storage of flowback from hydraulically stimulated wells and potential risks to humans, terrestrial and aquatic receptors from the potential storage and accidental releases are evaluated in the QRA.

No further assessment of groundwater was determined to be necessary due to lack of potentially complete exposure pathways. Detailed operational procedures have been provided that are designed to contain the hydraulic fracturing fluids within the coal sequences, and no connection exists between groundwater in the coal seams and surface-water or springs (and therefore MNES). Further, the potential risks to workers involved with the hydraulic fracturing process were not considered as detailed Health and Safety (H&S) procedures are employed to manage exposures. The QRA considered the following specific exposure pathways:

1. Exposure of trespassers to flowback water contained within flowback storage ponds
2. Exposure of terrestrial receptors (e.g., livestock and wildlife) to flowback water contained within the flowback storage ponds
3. Exposure of aquatic receptors to flowback water in the situation of an accidental release, such as from piping or a release from the flowback storage pond. These potential releases could include a failure of containment systems, overtopping of the dam or in an extreme situation (considered highly unlikely) structural failure of the dam itself.

C3.1 Exposure Assessment

The purpose of the exposure assessment in the QRA was to predict the magnitude and frequency of potential human exposure to each COPC following the methodologies presented in **Section 8.1**. A conceptual site model (CSM) was developed which describes the potential receptors and exposure scenarios for the flowback water used in this exposure assessment. The potential exposures to receptors were evaluated based on the potential for a complete exposure pathway.

As discussed in **Section 8.3**, exposure point concentrations (EPCs) were derived for both the theoretical assessment and the empirical assessment. The EPCs for the theoretical assessment were calculated by estimating the mass and discharge flow of the COPCs from the flowback water monitoring data were used (**Appendix C1-2,** Table C-1**;** EHS Support, 2012). Operational data were utilized to assess the fate and transport of the constituents in the flowback storage ponds. Refer to Appendix C of the EHS Support QRA (**Appendix C1-2**, Tables C-2 through C-4) for the empirical data used in the QRA (EHS Support, 2012). The tables are included in this summary.

C3.2 Human Health QRA

A human health hazard assessment was conducted according to the methodologies presented in **Section 8.4**. The purpose of the hazard assessment process was to summarize the environmental data, and to address the toxicological assessment of the COPCs that will be evaluated further in the risk assessment process.

Exposure assumptions for the human trespasser scenario were developed based on default or site-specific assumptions (**Section 8.4**). This receptor exposure pathway includes a small child to teenager that may come in contact with the above grade water exposure scenario for approximately 20 days/year for a 10-year period with potential incidental ingestion (of 50 millilitre [mL] water) and dermal contact (e.g., swimming where the whole body gets wet) for ½ hour (Table 4; EHS Support, 2012, attached).

Calculation of intake of COPCs was performed using the equations presented below:

Ingestion of water:

$$Intake\ (mg/kg-day)\ =\ (CW\ x\ IR\ X\ EF\ X\ ED)\ /\ (BW\ x\ AT)$$

Dermal contact with water:

$$Absorbed\ dose\ (mg/kg-day)\ =\ (CW\ x\ SA\ x\ DP\ x\ ET\ x\ EF\ x\ ED\ x\ CF)\ /\ (BW\ x\ AT)$$

Where:

CW = concentration in water (mg/l)
ET = exposure time (hr/day or hours/hours)
EF = exposure frequency (day/year)
ED = exposure duration (years)
CF = correction factor (1 x 10-3 l/cm3)
AT = averaging time (days)
IR = ingestion rate (l/hr)
BW = body weight (kg)
SA = skin surface area available for contact (cm2/d)
DP = dermal permeability factor (Kp – cm/hr)

C3.3 Toxicity Assessment

A toxicity assessment was conducted to determine the relationship between the dose of a COPC taken into the body, and the probability that an adverse effect will result from that dose. Quantitative estimates of the potency of COPCs include two sets of toxicity values, one for genotoxic carcinogens and one for other non-genotoxic carcinogens and non-carcinogenic effects. As discussed in **Section 8.4,** detailed toxicological profiles were developed for the chemicals. The toxicological profiles are included as **Appendix F**.

The assessment of toxicity of the COPCs was used to develop initial screening criteria for human health exposure scenarios as discussed in **Section 8.4**. Refer to Tables 1, 2, and 3 of the QRA for details regarding the toxicity assessment of the COPCs (EHS Support, 2012).

C3.4 Risk Estimation

Risk estimation was performed in accordance with the methodologies outlined in **Section 8.4**. The total target risk range for carcinogens was 1 x 10^{-4} to 1 x 10^{-6}; the target hazard index (HI) for non-threshold effects is less than or equal to 1.0.

C3.4.1 Theoretical

No carcinogenic compounds are present in the stimulation fluids injected into the subsurface and as a result, only non-carcinogenic risks were calculated. The exposure scenarios include the specific fracturing fluids event from Table D-3 (Golder, 2013c), or the maximum of the fracturing fluids events, for the 20 and 80 percent (%) mass recovery from the fracturing fluid well flowback (**Appendix C1-1**). The modelled risks from injected chemicals in the flowback water were acceptable, with the trespasser for the maximum exposure to COPCs at the 80 % recovery indicating a potential risk below the HI of 1.0 (Tables 5 and 6; EHS Support, 2012, attached).

C3.4.2 Empirical

Two data sets, flowback storage ponds and untreated flowback, were used to characterize potential risks for the trespasser to COPCs. Trespasser exposure to water in flowback storage ponds did not have an unacceptable HI at either the mean or maximum concentrations; there were no carcinogens present (Tables 7 and 8; EHS Support, 2012).

While the mean scenario for the trespasser exposed to COPCs in pumped flowback did not have unacceptable levels of risk, the risk calculated using maximum concentrations did result in an unacceptable risk with an HI equal to 2.3 and an excess cancer lifetime risk of 5.1×10^{-7}.

C3.5 Ecological Risk Assessment

As discussed in **Section 8.5**, a screening level ecological risk assessment (ERA) was conducted to evaluate the potential for adverse ecological effects to terrestrial and aquatic ecological receptors that may be exposed to residual levels of hydraulic fracturing fluids in surface water used in the coal seam gas (CSG) fields.

Terrestrial receptors evaluated in the ERA include domesticated livestock, large mammalian wildlife and small mammalian wildlife. Beef cattle were used to evaluate domesticated livestock, kangaroos evaluated for large mammalian wildlife and dingos for small mammalian wildlife. Aquatic receptors evaluated included invertebrates and fishes.

Ecological effects were characterised following the methodologies outlined in **Section 8.5.3** (Table 9; EHS Support, 2012). Exposure scenarios were the same for ecological receptors as human receptors; EPCs were estimated in accordance with the methodology presented in **Section 8.5.4** (**Appendix C1-2**). Environmental fate information is provided in Table 10 (EHS Support, 2012).

Risks were characterised in accordance with the methodologies discussed in **Section 8.5.5**. The resulting ecological hazard quotient must be less than or equal to 1.0 for risks to be considered acceptable.

C3.5.1 Estimation of Risks

C3.5.1.1 Theoretical

Appendix C1-3 presents the calculated HI for flowback water (Appendix E, EHS Support, 2012). The HI calculated for flowback water for aquatic risk was elevated above the acceptable level for the majority of COPCs evaluated. Where large discharges of flowback water occur to surface water and/or flux dilution within the surface-water was insufficient, potential impacts on aquatic receptors could occur. As noted in the toxicity assessment section above, the lack

of a robust aquatic toxicological database resulted in aquatic screening values for the theoretical exposure scenario COPCs to be conservatively very low.

The modelled risks from injected chemicals in the flowback water were all acceptable for each of the ecological receptors modelled, with maximum HI ranging from 0.0034 (kangaroo) to 0.051 (cattle) (Tables 14 through 19; EHS Support, 2012, attached).

3.5.1.2 Empirical

Appendix C1-3 presents the calculated HI for flowback water (Appendix E, EHS Support, 2012). Aquatic life TRVs exceeded for the pump flowback water included toluene, xylene, C10-C36 Fraction (sum), aluminium, barium, boron, cadmium, chromium, copper, iron, lithium, manganese, molybdenum, nickel, strontium, tin, and zinc.

The modelled risks from the empirical exposure scenarios were all acceptable for each of the ecological receptors modelled, with the exception of the livestock cattle for the maximum exposure to COPCs in the flowback storage ponds and pump flowback, the HIs of 1.1 and 1.2, respectively, slightly exceeded the acceptable HI of 1.0 (Tables 20 through 25; EHS Support, 2012, attached). However, it is noted that this included a very conservative long-term exposure as compared to the typical duration that the flowback storage ponds surface water would be available for exposure.

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C4.0 Summary of QRA findings

The QRA was completed as discussed in **Section 8.0**, using two (2) independent assessments to develop a weight-of-evidence approach for potential human health and ecological risks. The first assessment was conducted using highly conservative theoretical calculations based on the chemicals utilized by Schlumberger in hydraulic fracturing. This assessment assumed that a range of theoretical percentages of injected chemicals would be present in the flowback water. The second assessment utilized empirical data collected as part of the Stimulation Impact Monitoring Program from hydraulic stimulation events conducted by Schlumberger.

Consistent with the risk assessment and groundwater fate and transport modelling conducted by Golder, no potentially complete exposure pathways were identified for groundwater. Potential exposures are limited to the aboveground storage and handling of flowback water as part of the CSG Water Management Plan (WMP). Management of CSG water involves the temporary storage of flowback water in flowback storage ponds.

On the basis of the risk calculations, the potential risks associated with the flowback water are generally limited. Potential risks to trespassers could occur with repeated exposures to flowback water. However, the cumulative risks are only slightly above the non-carcinogenic threshold discussed above where management and operational controls can be implemented to control potential exposures. There were no carcinogenic risks identified.

Limited to no risks to cattle and native mammals were identified in the risk assessment using the most conservative theoretical calculations (80 % chemical mass in the flowback water). Based on contractor experience and the empirical data collected as part of the SIMP, concentrations of constituents detected in flowback water are orders of magnitude lower than theoretical concentrations and no potential risks exist for livestock or native mammals.

Similarly, potential impacts could occur if releases of flowback water were to occur to aquatic environments. Based on the use of liners and operational controls that limit the potential for turkey's nest and dam overflows, the potential for these risks are also considered limited.

A combination of management and operational controls are being implemented to eliminate and control the potential for exposures. These include:

- Worker training and hazard identification
- Use of appropriate personal protective equipment (gloves etc.)
- Flowback storage pond fencing to prevent entry of livestock and minimize trespassing.
- Installation of clay dam liners and routine dam inspections to prevent releases from flowback storage ponds
- Routine operational and security patrols to prevent trespassing.

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C5.0 Conclusions

A weight-of-evidence evaluation of potential risks as described in **Section 5.0** was performed for the Schlumberger guar gum fluid system. Based on the qualitative and quantitative risk characterisations, the overall risk to human health and the environment is low. Existing operational control activities employed by Santos are in place that will limit the potential risks to human health and the environment. These measures include:

- Occupational health and safety procedures implemented during hydraulic fracturing operations to prevent workers from direct contact with chemicals during spills and when handling flowback water or sediments;
- Environmental authority conditions that preclude the construction of well pads within 100 m of a watercourse of water body.
- Implementation of spill containment procedures during operations to prevent migration of and exposure to chemicals;
- Disposal or capping of sediments contained within drained mud pits and turkey nests , to prevent exposure to contaminates in windborne dust;
- Fencing of drill pads to prevent trespassers and installation of signs to indicate that the water in the turkeys nest and mud pit is not potable and may contain contaminants;
- Installation and maintenance of fences around the well pad to prevent access to the drill pad by livestock and large native fauna;
- Santos operational procedures to ensure well integrity and design of fracture to stay within the target seam; and
- Mud pits and turkeys nests with clay liners, or similar material, to prevent seepage of flowback water into underlying aquifers.

Regular monitoring of water supply bores and surface water for a representative suite of chemicals within 2 kilometre of wells that are fractured is required to confirm the conclusion of incomplete exposure pathways and low risk.

No additional risks, other than those previously discussed, were identified with the chemicals or systems employed by Schlumberger in hydraulic fracturing. Evaluation of other potential risks associated with hydraulic fracturing (i.e., noise and vibration) was conducted. Refer to **Section 9.0** for methodology specifics and results of this evaluation.

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EHS Support Tables

Santos **Table 1 Oral Reference Doses and Drinking Water Guidelines Derived for Hydraulic Fracturing Chemicals**

Chemical	Study	Critical Effect/Target Organ(s)	NOAEL (mg/kg/day)	Uncertainty Factors	Oral Reference Dose (mg/kg/day)	Drinking Water Guideline (ppm)
Hemicellulase enzyme	13-wk rat dietary	General toxicity/liver	600	1,000	0.6	2
Lactose[a]	2-yr rat dietary	Effects not considered chemical-specific	1,580	1,000	1.0	3.5
Maltodextrin[b]	-	-	-	-	-	-
Sodium chloride[c]					-	180 for Na+ and 250 for Cl- (aesthetics)
Shellac, ammonium salt[e]	One –generation rat reproductive	None	500	1,000	0.5	1.8
Sodium carboxymethyl cellulose[f]	-	-	-	-	-	-
Sodium lauryl sulfate	2-yr rat dietary	Liver	113	100	1.1	4
Sorbitan, monododecanoate, poly(oxy-1,2-diethanediyl)	2-yr rat dietary	Marked diarrhea; distention of cecum	2,500[g]	100[g]	25[g]	88
Sulfuric acid					-	pH; 500 (health) and 250 (aesthetic) for $SO4^{2-}$
Talc[h]	-	-	-	-	-	-
Tributyl tetradecyl phosphonium chloride	No data	-	-	-	-	-
Potassium chloride[c]	2-yr rat dietary	Systemic effects	1820[d]	100	18.2	63.7

[a]Based on animal toxicity studies only.

[b]No toxicity data found. GRAS substance by FDA (no limitation in food).

[c]There is an Australian drinking water standard for chloride.

[d]the highest dose tested

[e]Food coating is a biopolymer and is insoluble in water. It is not expected to be bioavailable and therefore not hazardous to human health. There is an Australian drinking water standard for ammo

[f]ADI classified as “Not Specified” (formerly “Not Limited”) by Joint WHO/FAO Expert Committee on Food Additives (JECFA).

[g]ADI (Joint WHO/FAO Expert Committee on Food Additives or JECFA).

[h]Talc is a mineral that is insoluble in water. It is not expected to be bioavailable and therefore not hazardous to human health by oral ingestion.

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Table 2 Australian Drinking Water Screening Values for Hydraulic Fracturing Chemicals

Constituent	Drinking Water Screening Guideline	Drinking Water Screening Value (ppm)a
Diammonium peroxidisulfate	Sulfate	500 (health), 250 (aesthetic)
Hydrogen chloride	pH; Chloride	6.5 to 8.5; 250 (aesthetic)
Magnesium chloride	Chloride	250 (aesthetic)
Sodium acetate, anhydrous[b]	Sodium; pH	180 (aesthetic); 6.5 to 8.5
Sodium ethylenediaminetetraacetate	Sodium; EDTA	180 (aesthetic); 0.25
Sodium hydroxide	Sodium; pH	180 (aesthetic); 6.5 to 8.5

[a]Except for pH values.

[b]Joint FAO/WHO Expert Committee on Food Additives maintains an ADI of “not limited.”

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Table 3 Regulatory Screening Values for DERM Specified Analytes

Parameter	Drinking Water Guideline Values (mg/L)	Stock Watering (mg/L)	Aquatic Ecosystems (µg/L)
Wet Chemistry			
pH	6.5 to 8.5[a]	[d]	6.5 to 7.5 [f]
Electrical Conductivity	[b]	[d]	[h]
Turbidity	5[a]	[d]	1 to 50 NTU [f]
Total dissolved solids	500 (aesthetic)[a]	2,000 to 10,000 [f]	[h]
Temperature	[b]	[d]	[h]
Dissolved Oxygen	[b]	[d]	6.5 to 7.5 (% saturation) [f]
Dissolved Gases			
Methane	[b]	[d]	[h]
Chlorine	5 (health)[a]; 0.6 (aesthetic)[a]	[d]	3 [f]
Carbon Dioxide	[b]	[d]	[h]
Hydrogen Sulfide	0.05 (aesthetic)[a]	[d]	1 [f]
Alkalinity			
Bicarbonate as CaCO3	[b]	[d]	[h]
Carbonate as CaCO3	[b]	[d]	[h]
Hydroxide as CaCO3	[b]	[d]	[h]
Total as CaCO3	[b]	[d]	[h]
Residual Alkali	[b]	[d]	[h]
Sodium adsorption ratio (SAR)	[b]	[d]	
Anions			
Bicarbonate	[b]	[d]	[h]
Carbonate as CaCO3	[b]	[d]	[h]
Hydroxide as CaCO3	[b]	[d]	[h]
chloride	250 (aesthetic)[a]	[d]	230000 as chloride [i]
fluoride	1.5 (health)[a]	[d]	[h]
sulphate	500 (health)[a]; 250 (aesthetic)[a]	[d]	[h]
Cations			
Aluminium	0.2 (aesthetic)[a]	5 [f]	55[f]
Calcium	[b]	1,000 [f]	116,000 [j]
Magnesium	[b]	10 [g]	1,900[f]

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Table 3 Regulatory Screening Values for DERM Specified Analytes

Parameter	Drinking Water Guideline Values (mg/L)	Stock Watering (mg/L)	Aquatic Ecosystems (µg/L)
Potassium	[b]	[d]	53,000 [j]
Sodium	180 (aesthetic)[a]; 250 (aesthetic)[a]	2,000 as sodium [g]	680,000 [j]
Dissolved Metals			
Aluminium	[b]	[d]	[i]
Arsenic III	[b]	[d]	[i]
Barium	[b]	[d]	[i]
Boron	[b]	[d]	[i]
cadmium	[b]	[d]	[i]
Chromium III	[b]	[d]	[i]
Copper	[b]	[d]	[i]
Iron	[b]	[d]	[i]
Lead	[b]	[d]	[i]
Manganese	[b]	[d]	[i]
Mercury	[b]	[d]	[i]
Nickel	[b]	[d]	[i]
Selenium	[b]	[d]	[i]
Silver	[b]	[d]	[i]
Zinc	[b]	[d]	[i]
Total Metals			
Aluminium	0.2[a]	5 [f]	55 [f]
Arsenic III	0.007 as arsenic, not specified (health)[a]	0.5 to 5 as arsenic, not specified [f]	24 [f]
Barium	0.7 (health)[a]	[d]	4 [j]
Boron	4 (health)[a]	5 [f]	370 [f]
Cadmium	0.002 (health)[a]	1 [f]	0.2 [f]
Chromium III	0.05 as chromium VI (health)[a]; 0.1 as total chromium (health)[k]	1 as chromium, not specified [f]	1.0 as chromium VI [f]
Copper	2 (health)[a]; 1 (aesthetic)[a]	0.4 to 5 [f]	1.4 [f]
Iron	0.3 (aesthetic)[a]	10 [g]	
Lead	0.01 (health)[a]	0.1 [f]	3.4 [f]
Manganese	0.5 (health)[a]; 0.1 (aesthetic)[a]	10 [g]	1,400 [f]
Mercury	0.001 (health)[a]	0.002 [f]	0.6 [f]

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Table 3 Regulatory Screening Values for DERM Specified Analytes

Parameter	Drinking Water Guideline Values (mg/L)	Stock Watering (mg/L)	Aquatic Ecosystems (µg/L)
Nickel	0.02 (health)[a]	1 [f]	11 [f]
Selenium	0.01 (health)a	0.02 [f]	11 [f]
Silver	0.1 (health)[a]	[d]	0.05 [f]
Zinc	3 (aesthetic)[a]	20 [f]	8 [f]
Total Petroleum Hydrocarbons	[b]	[d]	[h]
BTEX			
Benzene	0.001 (health)a	14.3 to 74.3 [e]	950 [f]
Ethylbenzene	0.3 (health)a; 0.003 (aesthetic)a	11.7 to 60.6 [e]	90 [j]
toluene	0.8 (health)[a] and 0.025 (aesthetics)[a].	89.5 to 464 e	2 [j]
ortho-xylene	[b]	[d]	350 [f]
para-xylene	[b]	[d]	200 [f]
meta-xylene	[b]	[d]	1.8 [j]
total xylene	0.6 (health)[a]; 0.02 (aesthetic)[a]	71.7 to 371 [e]	13 [j]
Polycyclic Aromatic Hydrocarbons			
Naphthalene	[b]	2.01 to 10.4 as LMW PAH [e]	16 [f]
Phenanthrene	[b]	2.01 to 10.4 as LMW PAH [e]	0.4 [j]
Benzo (a)pyrene	0.00001[a]	0.402 to 2.08 as HMW PAH [e]	0.015 [j]
Sodium Hypochlorite	[b]	[d]	[h]
Sodium Hydroxide	[b]	[d]	[h]
Formaldehyde	0.5 (health)[a]	[d]	[h]
Ethanol	[b]	[d]	1,400 [f]
Gross alpha Radiation	0.5[a]	0.5 Bq/L [f]	[h]

Notes

[a] Australia Drinking Water Guidelines

[b] No existing guideline based on Drinking Water hierarchy

[c] May contain bromate from naturally occurring sodium bromide (WHO Guidelines for Drinking-water Quality, pp. 187-188). Australian drinking water guideline for bromate is 0.02 mg/L.

[d] No existing guideline based on Stock Watering hierarchy

[e] API Risk-Based Screening Levels for the Protection of Livestock Exposed to Petroleum Hydrocarbons (cattle/calves, sheep, goat, horse)

[f] Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ, 2000)

Table 3 Regulatory Screening Values for DERM Specified Analytes

Parameter	Drinking Water Guideline Values (mg/L)	Stock Watering (mg/L)	Aquatic Ecosystems (µg/L)

[g] Other (Department of Water Affairs and Forestry, 1996. South African Water Quality Guidelines (second edition). Volume 5: Agricultural Use: Livestock Watering.)

[h] No existing guideline based on Aquatic Ecosystem hierarchy

[i] EPA Ambient Water Quality Criteria

[j] Other (EPA Region 3 Biological Technical Assistance Group Freshwater Screening Benchmarks)

[k] U.S. EPA Maximum Contaminant Levels (MCLs)

[l] Section 8.3.5.15 Incorporating effects of water hardness of ANZECC & ARMCANZ (2000) notes to compare total to guideline, if exceeds, then compare dissolved

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Table 4 Exposure Assumptions - Trespasser

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/hr	0.05
	ET	Exposure time	hr/day	0.5
	EF	Exposure frequency	day/yr	20
	ED	Exposure duration	yr	10
	BW	Body weight	kg	47
	AT-NC	Averaging time - noncancer	days	3,650
	AT-C	Averaging time - cancer	days	25,550
Dermal	SA	Surface area for contact	cm^2/day	13,000
	DP	Dermal permeability factor	cm/h	chemical-specific
	ET	Exposure time	hr/day	1
	EF	Exposure frequency	day/yr	20
	ED	Exposure duration	yr	10
	BW	Body weight	kg	47
	AT-NC	Averaging time - noncancer	days	3,650
	AT-C	Averaging time - cancer	days	25,550
	CF	Conversion factor	l/cm^3	1.0E-03

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Table 5 Risk Estimates for Trespasser Schlumberger Theoretical Exposure for 20% Mass Returned

		20% Mass Returned			Toxicity	Specific Frac Stimulation Event				Maximum Frac Stimulation Event			
								Hazard Quotient				Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**C_{max} (mg/l)**	**PC (cm/hr)**	**RfDo**	**$CADD_{oral}$**	**$CADD_{derm}$**	**Incidental Ingestion**	**Dermal**	**$CADD_{oral}$**	**$CADD_{derm}$**	**Incidental Ingestion**	**Dermal**
Magnesium chloride	7786-30-3	1.3E-01	4.0E-01	5.0E-04	NA	7.8E-06	5.1E-07			2.3E-05	1.5E-06		
Diatomaceous earth, calcined	91053-39-3	2.9E+00	4.0E+00		NA	1.7E-04				2.3E-04			
Crystalline silica (cristobalite)	14464-46-1				NA								
Crystalline silica (quartz)	14808-60-7				NA								
Diammonium peroxidisulphate (ammonium persulphate)	7727-54-0	9.5E+01	9.5E+01		14.29	5.5E-03		3.9E-04		5.5E-03		3.9E-04	
Carbohydrate polymer (guar gum[1])	9000-30-0	3.8E+02	4.7E+02		1.3	2.2E-02		1.7E-02		2.8E-02		2.1E-02	
Non-crystalline silica (amorphous silica surrogate)	7631-86-9	1.1E+00	1.3E+00		2.5	6.2E-05		2.5E-05		7.8E-05		3.1E-05	
Polypropylene glycol	25322-69-4		4.0E+00	4.3E-04	0.5					2.3E-04	1.3E-05	4.7E-04	2.6E-05
Ammonium C6-C10 alcohol ethoxysulfate	68187-17-7		1.4E+02	2.7E-03	0.75					8.1E-03	2.8E-03	1.1E-02	3.7E-03
Alcohols C6-C10 ethoxylated	68439-45-2		2.4E+00	1.5E-04	0.5					1.4E-04	2.8E-06	2.8E-04	5.5E-06
Hydrochloric acid	7647-01-0	8.5E+01	8.5E+01	2.3E-03	NA	4.9E-03	1.4E-03			4.9E-03	1.4E-03		
Vinylidene chloride/methylacrylate	25038-72-6	2.4E+00	2.4E+00	1.1E-02	NA	1.4E-04	2.1E-04			1.4E-04	2.1E-04		
Tetrasodium ethylenediaminetetraacetate (EDTA)	64-02-8	1.1E+00	1.1E+00	2.4E-14	0.007	6.2E-05	1.9E-16	8.9E-03	2.8E-14	6.2E-05	1.9E-16	8.9E-03	2.8E-14
magnesium silicate hydrate (talc)	14807-96-6	1.3E-01	1.3E-01	5.9E-05	NA	7.8E-06	6.0E-08			7.8E-06	6.0E-08		
Sodium hydroxide	1310-73-2	1.3E-01	1.3E-01	2.6E-06	5.14	7.8E-06	2.6E-09	1.5E-06	5.1E-10	7.8E-06	2.6E-09	1.5E-06	5.1E-10
								Hazard Index	2.7E-02			**Hazard Index**	4.6E-02

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Table 6 Risk Estimates for Trespasser Schlumberger Theoretical Exposure for 80% Mass Returned

		80% Mass Returned			Toxicity	Specific Frac Stimulation Event				Maximum				
								Hazard Quotient					Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**C_{max} (mg/l)**	**PC (cm/hr)**	**RfDo**	**$CADD_{oral}$**	**$CADD_{derm}$**	**Incidental Ingestion**	**Dermal**	**$CADD_{oral}$**	**$LADD_{oral}$**	**$CADD_{derm}$**	**Incidental Ingestion**	**Dermal**
Magnesium chloride	7786-30-3	5.3E-01	1.6E+00	5.0E-04	NA	3.1E-05	2.0E-06			9.3E-05	1.3E-05	6.1E-06		
Diatomaceous earth, calcined	91053-39-3	1.2E+01	1.6E+01		NA	6.8E-04				9.3E-04	1.3E-04			
Crystalline silica (cristobalite)	14464-46-1				NA									
Crystalline silica (quartz)	14808-60-7				NA									
Diammonium peroxidisulphate (ammonium persulphate)	7727-54-0	3.8E+02	3.8E+02		14.29	2.2E-02		1.5E-03		2.2E-02	3.2E-03		1.5E-03	
Carbohydrate polymer (guar gum[1])	9000-30-0	1.0E+03	1.0E+03		1.3	5.8E-02		4.5E-02		5.8E-02	8.3E-03		4.5E-02	
Non-crystalline silica (amorphous silica surrogate)	7631-86-9	4.3E+00	5.3E+00		2.5	2.5E-04		9.9E-05		3.1E-04	4.4E-05		1.2E-04	
Polypropylene glycol	25322-69-4	-	1.6E+01	4.3E-04	0.5					9.3E-04	1.3E-04	5.2E-05	1.9E-03	1.0E-04
Ammonium C6-C10 alcohol ethoxysulfate	68187-17-7	-	5.6E+02	2.7E-03	0.75					3.3E-02	4.7E-03	1.1E-02	4.3E-02	1.5E-02
Alcohols C6-C10 ethoxylated	68439-45-2	-	9.6E+00	1.5E-04	0.5					5.6E-04	8.0E-05	1.1E-05	1.1E-03	2.2E-05
Hydrochloric acid	7647-01-0	3.4E+02	3.4E+02	2.3E-03	NA	2.0E-02	5.8E-03			2.0E-02	2.8E-03	5.8E-03		
Vinylidene chloride/methylacrylate	25038-72-6	9.6E+00	9.6E+00	1.1E-02	NA	5.6E-04	8.3E-04			5.6E-04	8.0E-05	8.3E-04		
Tetrasodium ethylenediaminetetraacetate (EDTA)	64-02-8	4.3E+00	4.3E+00	2.4E-14	0.007	2.5E-04	7.7E-16	3.6E-02	1.1E-13	2.5E-04	3.6E-05	7.7E-16	3.6E-02	1.1E-13
magnesium silicate hydrate (talc)	14807-96-6	5.3E-01	5.3E-01	5.9E-05	NA	3.1E-05	2.4E-07			3.1E-05	4.4E-06	2.4E-07		
Sodium hydroxide	1310-73-2	5.3E-01	5.3E-01	2.6E-06	5.14	3.1E-05	1.1E-08	6.0E-06	2.0E-09	3.1E-05	4.4E-06	1.1E-08	6.0E-06	2.0E-09
								Hazard Index	8.2E-02				**Hazard Index**	1.4E-01

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Table 7 Risk Estimates for Trespasser Empirical Exposure - Flowback Storage Ponds

	Turkey Nest			Toxicity		Turkey Nest Maximum Concentrations								Turkey Nest Mean Concentrations							
										Excess Cancer Lifetime Risk		Hazard Quotient						Excess Cancer Lifetime Risk		Hazard Quotient	
Constituent Name	**C_{max} (mg/l)**	**C_{mean} (mg/l)**	**PC (cm/hr)**	**CSFo**	**RfDo**	**$CADD_{oral}$**	**$LADD_{oral}$**	**$CADD_{derm}$**	**$LADD_{derm}$**	**Incidental Ingestion**	**Dermal**	**Incidental Ingestion**	**Dermal**	**$CADD_{oral}$**	**$LADD_{oral}$**	**$CADD_{derm}$**	**$LADD_{derm}$**	**Incidental Ingestion**	**Dermal**	**Incidental Ingestion**	**Dermal**
Aluminium	19.8	4.2E+00	1.0E-03		1	1.2E-03	1.6E-04	1.5E-04	2.1E-05	0.0E+00	0.0E+00	1.2E-03	1.5E-04	2.4E-04	3.5E-05	3.1E-05	4.5E-06	0.0E+00	0.0E+00	2.4E-04	3.1E-05
Arsenic	0.135	1.0E-02	1.0E-03		0.002	7.9E-06	1.1E-06	1.0E-06	1.5E-07	0.0E+00	0.0E+00	3.9E-03	5.1E-04	5.8E-07	8.3E-08	7.6E-08	1.1E-08	0.0E+00	0.0E+00	2.9E-04	3.8E-05
Barium	1.87	3.8E-01	1.0E-03		0.2	1.1E-04	1.6E-05	1.4E-05	2.0E-06	0.0E+00	0.0E+00	5.5E-04	7.1E-05	2.2E-05	3.1E-06	2.8E-06	4.1E-07	0.0E+00	0.0E+00	1.1E-04	1.4E-05
Benzene	0	0.0E+00	2.1E-02	0.055	0.004	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Beryllium	0	0.0E+00	1.0E-03		0.002	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Boron And Borates Only	1.47	6.5E-01	1.0E-03		0.2	8.6E-05	1.2E-05	1.1E-05	1.6E-06	0.0E+00	0.0E+00	4.3E-04	5.6E-05	3.8E-05	5.4E-06	4.9E-06	7.1E-07	0.0E+00	0.0E+00	1.9E-04	2.5E-05
Cadmium	0	0.0E+00	1.0E-03		0.0005	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Chromium (total)	0.031	7.9E-03	1.3E-03		1.5	1.8E-06	2.6E-07	3.1E-07	4.4E-08	0.0E+00	0.0E+00	1.2E-06	2.0E-07	4.6E-07	6.6E-08	7.8E-08	1.1E-08	0.0E+00	0.0E+00	3.1E-07	5.2E-08
Cobalt	0.005	2.1E-03	1.2E-03		0.000006	2.9E-07	4.2E-08	4.6E-08	6.5E-09	0.0E+00	0.0E+00	4.9E-02	7.6E-03	1.2E-07	1.7E-08	1.9E-08	2.8E-09	0.0E+00	0.0E+00	2.0E-02	3.2E-03
Copper	0.14	1.0E-02	1.0E-03		0.04	8.2E-06	1.2E-06	1.1E-06	1.5E-07	0.0E+00	0.0E+00	2.0E-04	2.7E-05	5.9E-07	8.4E-08	7.6E-08	1.1E-08	0.0E+00	0.0E+00	1.5E-05	1.9E-06
Ethylbenzene	0	0.0E+00	7.4E-02	0.011	0.1	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Lead	0.009	4.9E-03	1.0E-04		0.0036	5.2E-07	7.5E-08	6.8E-09	9.7E-10	0.0E+00	0.0E+00	1.5E-04	1.9E-06	2.9E-07	4.1E-08	3.7E-09	5.3E-10	0.0E+00	0.0E+00	7.9E-05	1.0E-06
Lithium	0.46	9.8E-02	1.0E-03		2.00E-03	2.7E-05	3.8E-06	3.5E-06	5.0E-07	0.0E+00	0.0E+00	1.3E-02	1.7E-03	5.7E-06	8.2E-07	7.4E-07	1.1E-07	0.0E+00	0.0E+00	2.9E-03	3.7E-04
Manganese	0.255	4.2E-02	1.7E-03		0.024	1.5E-05	2.1E-06	3.2E-06	4.6E-07	0.0E+00	0.0E+00	6.2E-04	1.3E-04	2.5E-06	3.5E-07	5.3E-07	7.6E-08	0.0E+00	0.0E+00	1.0E-04	2.2E-05
Molybdenum	0.628	4.7E-02	1.0E-03		5.00E-03	3.7E-05	5.2E-06	4.8E-06	6.8E-07	0.0E+00	0.0E+00	7.3E-03	9.5E-04	2.7E-06	3.9E-07	3.6E-07	5.1E-08	0.0E+00	0.0E+00	5.5E-04	7.1E-05
Naphthalene	0.0054	5.4E-03	6.9E-02		0.02	3.1E-07	4.5E-08	2.8E-06	4.0E-07	0.0E+00	0.0E+00	1.6E-05	1.4E-04	3.1E-07	4.5E-08	2.8E-06	4.0E-07	0.0E+00	0.0E+00	1.6E-05	1.4E-04
Nickel (soluble salts)	0.12	8.8E-03	1.0E-03		0.02	7.0E-06	1.0E-06	9.1E-07	1.3E-07	0.0E+00	0.0E+00	3.5E-04	4.5E-05	5.1E-07	7.3E-08	6.7E-08	9.5E-09	0.0E+00	0.0E+00	2.6E-05	3.3E-06
Selenium	0	0.0E+00	1.0E-03		5.00E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Silver	0	0.0E+00	6.0E-04		5.00E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Strontium, Stable	2.7	6.5E-01	1.0E-03		6.00E-01	1.6E-04	2.2E-05	2.0E-05	2.9E-06	0.0E+00	0.0E+00	2.6E-04	3.4E-05	3.8E-05	5.4E-06	4.9E-06	7.1E-07	0.0E+00	0.0E+00	6.3E-05	8.2E-06
Tin	0.004	3.0E-03	1.0E-03		6.00E-01	2.3E-07	3.3E-08	3.0E-08	4.3E-09	0.0E+00	0.0E+00	3.9E-07	5.1E-08	1.7E-07	2.5E-08	2.3E-08	3.2E-09	0.0E+00	0.0E+00	2.9E-07	3.8E-08
Toluene	0.004	3.0E-03	4.5E-02		0.08	2.3E-07	3.3E-08	1.4E-06	1.9E-07	0.0E+00	0.0E+00	2.9E-06	1.7E-05	1.7E-07	2.5E-08	1.0E-06	1.5E-07	0.0E+00	0.0E+00	2.2E-06	1.3E-05
TPH Aliphatic C6-9	1.08	2.8E-01	3.0E-01		5	6.3E-05	9.0E-06	2.4E-03	3.5E-04	0.0E+00	0.0E+00	1.3E-05	4.9E-04	1.6E-05	2.3E-06	6.3E-04	9.1E-05	0.0E+00	0.0E+00	3.3E-06	1.3E-04
TPH Aliphatic C10-14	0.68	3.9E-01	1.9E+00		0.1	4.0E-05	5.7E-06	9.8E-03	1.4E-03	0.0E+00	0.0E+00	4.0E-04	9.8E-02	2.3E-05	3.2E-06	5.6E-03	8.1E-04	0.0E+00	0.0E+00	2.3E-04	5.6E-02
TPH Aliphatic C15-28	1.11	5.0E-01	9.2E+01		2	6.5E-05	9.2E-06	7.7E-01	1.1E-01	0.0E+00	0.0E+00	3.2E-05	3.9E-01	2.9E-05	4.2E-06	3.5E-01	5.0E-02	0.0E+00	0.0E+00	1.5E-05	1.7E-01
TPH Aliphatic C29-36	0.92	2.5E-01	9.2E+01		12	5.4E-05	7.7E-06	6.4E-01	9.1E-02	0.0E+00	0.0E+00	4.5E-06	5.3E-02	1.5E-05	2.1E-06	1.8E-01	2.5E-02	0.0E+00	0.0E+00	1.2E-06	1.5E-02
Uranium	0.002	1.8E-03	1.0E-03		0.003	1.2E-07	1.7E-08	1.5E-08	2.2E-09	0.0E+00	0.0E+00	3.9E-05	5.1E-06	1.0E-07	1.5E-08	1.4E-08	1.9E-09	0.0E+00	0.0E+00	3.5E-05	4.5E-06
Vanadium	0.14	5.0E-02	1.0E-03		0.00007	8.2E-06	1.2E-06	1.1E-06	1.5E-07	0.0E+00	0.0E+00	1.2E-01	1.5E-02	2.9E-06	4.2E-07	3.8E-07	5.4E-08	0.0E+00	0.0E+00	4.2E-02	5.4E-03
Xylenes (total)	0.014	5.8E-03	8.0E-02		0.2	8.2E-07	1.2E-07	8.5E-06	1.2E-06	0.0E+00	0.0E+00	4.1E-06	4.2E-05	3.4E-07	4.8E-08	3.5E-06	5.0E-07	0.0E+00	0.0E+00	1.7E-06	1.8E-05
Zinc	0.046	1.9E-02	6.0E-04		0.3	2.7E-06	3.8E-07	2.1E-07	3.0E-08	0.0E+00	0.0E+00	8.9E-06	7.0E-07	1.1E-06	1.6E-07	8.6E-08	1.2E-08	0.0E+00	0.0E+00	3.7E-06	2.9E-07
										Total Risk	0.0E+00	**Hazard Index**	7.6E-01					**Total Risk**	0.0E+00	**Hazard Index**	3.2E-01

EHS Support consider it done

Santos

Table 8 Risk Estimates for Trespasser Empirical Exposure - Pump Flowback

	Pump Flowback			Toxicity		Pump Flowback Maximum Concentrations								Pump Flowback Mean Treated Concentrations							
										Excess Cancer Lifetime Risk		Hazard Quotient						Excess Cancer Lifetime Risk		Hazard Quotient	
Constituent Name	**C_{max} (mg/l)**	**C_{mean} (mg/l)**	**PC (cm/hr)**	**CSFo**	**RfDo**	**$CADD_{oral}$**	**$LADD_{oral}$**	**$CADD_{derm}$**	**$LADD_{derm}$**	**Incidental Ingestion**	**Dermal**	**Incidental Ingestion**	**Dermal**	**$CADD_{oral}$**	**$LADD_{oral}$**	**$CADD_{derm}$**	**$LADD_{derm}$**	**Incidental Ingestion**	**Dermal**	**Incidental Ingestion**	**Dermal**
Aluminium	2.65	1.1E-01	1.0E-03		1	1.5E-04	2.2E-05	2.0E-05	2.9E-06	0.0E+00	0.0E+00	1.5E-04	2.0E-05	6.2E-06	8.9E-07	8.1E-07	1.2E-07	0.0E+00	0.0E+00	6.2E-06	8.1E-07
Arsenic	0.015	3.5E-03	1.0E-03		0.002	8.7E-07	1.2E-07	1.1E-07	1.6E-08	0.0E+00	0.0E+00	4.4E-04	5.7E-05	2.0E-07	2.9E-08	2.7E-08	3.8E-09	0.0E+00	0.0E+00	1.0E-04	1.3E-05
Barium	37.9	4.6E+00	1.0E-03		0.2	2.2E-03	3.2E-04	2.9E-04	4.1E-05	0.0E+00	0.0E+00	1.1E-02	1.4E-03	2.7E-04	3.9E-05	3.5E-05	5.0E-06	0.0E+00	0.0E+00	1.3E-03	1.8E-04
Benzene	0.041	1.5E-02	2.1E-02	0.055	0.004	2.4E-06	3.4E-07	6.5E-06	9.3E-07	1.3E-07	3.6E-07	6.0E-04	1.6E-03	8.8E-07	1.3E-07	2.4E-06	3.4E-07	4.8E-08	1.3E-07	2.2E-04	6.0E-04
Beryllium	0	0.0E+00	1.0E-03		0.002	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Boron And Borates Only	55.3	1.4E+01	1.0E-03		0.2	3.2E-03	4.6E-04	4.2E-04	6.0E-05	0.0E+00	0.0E+00	1.6E-02	2.1E-03	7.9E-04	1.1E-04	1.0E-04	1.5E-05	0.0E+00	0.0E+00	4.0E-03	5.1E-04
Cadmium	0.0004	1.0E-04	1.0E-03		0.0005	2.3E-08	3.3E-09	3.0E-09	4.3E-10	0.0E+00	0.0E+00	4.7E-05	6.1E-06	5.8E-09	8.3E-10	7.6E-10	1.1E-10	0.0E+00	0.0E+00	1.2E-05	1.5E-06
Chromium (total)	0.147	1.5E-02	1.3E-03		1.5	8.6E-06	1.2E-06	1.4E-06	2.1E-07	0.0E+00	0.0E+00	5.7E-06	9.7E-07	8.9E-07	1.3E-07	1.5E-07	2.1E-08	0.0E+00	0.0E+00	5.9E-07	1.0E-07
Cobalt	0.01	1.3E-03	1.2E-03		0.000006	5.8E-07	8.3E-08	9.2E-08	1.3E-08	0.0E+00	0.0E+00	9.7E-02	1.5E-02	7.6E-08	1.1E-08	1.2E-08	1.7E-09	0.0E+00	0.0E+00	1.3E-02	2.0E-03
Copper	0.156	2.2E-02	1.0E-03		0.04	9.1E-06	1.3E-06	1.2E-06	1.7E-07	0.0E+00	0.0E+00	2.3E-04	3.0E-05	1.3E-06	1.8E-07	1.7E-07	2.4E-08	0.0E+00	0.0E+00	3.2E-05	4.2E-06
Ethylbenzene	0.003	2.4E-03	7.4E-02	0.011	0.1	1.7E-07	2.5E-08	1.7E-06	2.4E-07	1.9E-09	1.9E-08	1.7E-06	1.7E-05	1.4E-07	2.0E-08	1.3E-06	1.9E-07	1.5E-09	1.5E-08	1.4E-06	1.3E-05
Lead	0.035	2.0E-03	1.0E-04		0.0036	2.0E-06	2.9E-07	2.7E-08	3.8E-09	0.0E+00	0.0E+00	5.7E-04	7.4E-06	1.2E-07	1.7E-08	1.5E-09	2.2E-10	0.0E+00	0.0E+00	3.2E-05	4.2E-07
Lithium	2.84	1.5E+00	1.0E-03		2.00E-03	1.7E-04	2.4E-05	2.2E-05	3.1E-06	0.0E+00	0.0E+00	8.3E-02	1.1E-02	8.6E-05	1.2E-05	1.1E-05	1.6E-06	0.0E+00	0.0E+00	4.3E-02	5.6E-03
Manganese	1.66	4.0E-01	1.7E-03		0.024	9.7E-05	1.4E-05	2.1E-05	3.0E-06	0.0E+00	0.0E+00	4.0E-03	8.8E-04	2.3E-05	3.3E-06	5.1E-06	7.2E-07	0.0E+00	0.0E+00	9.7E-04	2.1E-04
Molybdenum	0.231	1.6E-02	1.0E-03		5.00E-03	1.3E-05	1.9E-06	1.8E-06	2.5E-07	0.0E+00	0.0E+00	2.7E-03	3.5E-04	9.1E-07	1.3E-07	1.2E-07	1.7E-08	0.0E+00	0.0E+00	1.8E-04	2.4E-05
Naphthalene	0.231	1.6E-02	6.9E-02		0.02	1.3E-05	1.9E-06	1.2E-04	1.7E-05	0.0E+00	0.0E+00	6.7E-04	6.0E-03	9.1E-07	1.3E-07	8.2E-06	1.2E-06	0.0E+00	0.0E+00	4.5E-05	4.1E-04
Nickel (soluble salts)	0.051	1.2E-02	1.0E-03		0.02	3.0E-06	4.2E-07	3.9E-07	5.5E-08	0.0E+00	0.0E+00	1.5E-04	1.9E-05	7.2E-07	1.0E-07	9.3E-08	1.3E-08	0.0E+00	0.0E+00	3.6E-05	4.7E-06
Selenium	0.01	1.0E-02	1.0E-03		5.00E-03	5.8E-07	8.3E-08	7.6E-08	1.1E-08	0.0E+00	0.0E+00	1.2E-04	1.5E-05	5.8E-07	8.3E-08	7.6E-08	1.1E-08	0.0E+00	0.0E+00	1.2E-04	1.5E-05
Silver	0	0.0E+00	6.0E-04		5.00E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Strontium, Stable	32.4	1.2E+01	1.0E-03		6.00E-01	1.9E-03	2.7E-04	2.5E-04	3.5E-05	0.0E+00	0.0E+00	3.1E-03	4.1E-04	7.2E-04	1.0E-04	9.3E-05	1.3E-05	0.0E+00	0.0E+00	1.2E-03	1.6E-04
Tin	0.161	3.5E-03	1.0E-03		6.00E-01	9.4E-06	1.3E-06	1.2E-06	1.7E-07	0.0E+00	0.0E+00	1.6E-05	2.0E-06	2.0E-07	2.9E-08	2.7E-08	3.8E-09	0.0E+00	0.0E+00	3.4E-07	4.4E-08
Toluene	0.094	2.1E-02	4.5E-02		0.08	5.5E-06	7.8E-07	3.2E-05	4.6E-06	0.0E+00	0.0E+00	6.8E-05	4.0E-04	1.2E-06	1.8E-07	7.2E-06	1.0E-06	0.0E+00	0.0E+00	1.5E-05	9.0E-05
TPH Aliphatic C6-9	0.25	7.9E-02	3.0E-01		5	1.5E-05	2.1E-06	5.7E-04	8.1E-05	0.0E+00	0.0E+00	2.9E-06	1.1E-04	4.6E-06	6.6E-07	1.8E-04	2.5E-05	0.0E+00	0.0E+00	9.2E-07	3.6E-05
TPH Aliphatic C10-14	0.5	2.4E-01	1.9E+00		0.1	2.9E-05	4.2E-06	7.2E-03	1.0E-03	0.0E+00	0.0E+00	2.9E-04	7.2E-02	1.4E-05	2.0E-06	3.5E-03	5.1E-04	0.0E+00	0.0E+00	1.4E-04	3.5E-02
TPH Aliphatic C15-28	5.16	7.3E-01	9.2E+01		2	3.0E-04	4.3E-05	3.6E+00	5.1E-01	0.0E+00	0.0E+00	1.5E-04	1.8E+00	4.2E-05	6.0E-06	5.0E-01	7.2E-02	0.0E+00	0.0E+00	2.1E-05	2.5E-01
TPH Aliphatic C29-36	3.28	4.5E-01	9.2E+01		12	1.9E-04	2.7E-05	2.3E+00	3.3E-01	0.0E+00	0.0E+00	1.6E-05	1.9E-01	2.6E-05	3.7E-06	3.1E-01	4.4E-02	0.0E+00	0.0E+00	2.2E-06	2.6E-02
Uranium	0	0.0E+00	1.0E-03		0.003	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Vanadium	0.02	1.5E-02	1.0E-03		0.00007	1.2E-06	1.7E-07	1.5E-07	2.2E-08	0.0E+00	0.0E+00	1.7E-02	2.2E-03	8.7E-07	1.2E-07	1.1E-07	1.6E-08	0.0E+00	0.0E+00	1.2E-02	1.6E-03
Xylenes (total)	0.031	1.4E-02	8.0E-02		0.2	1.8E-06	2.6E-07	1.9E-05	2.7E-06	0.0E+00	0.0E+00	9.0E-06	9.4E-05	8.4E-07	1.2E-07	8.7E-06	1.2E-06	0.0E+00	0.0E+00	4.2E-06	4.4E-05
Zinc	0.251	2.2E-02	6.0E-04		0.3	1.5E-05	2.1E-06	1.1E-06	1.6E-07	0.0E+00	0.0E+00	4.9E-05	3.8E-06	1.3E-06	1.8E-07	9.9E-08	1.4E-08	0.0E+00	0.0E+00	4.2E-06	3.3E-07
										Total Risk	5.1E-07	**Hazard Index**	2.3E+00					**Total Risk**	2.0E-07	**Hazard Index**	4.0E-01

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Table 9 Aquatic Toxicity Values (PNECs)

Chemical	Endpoint	NOEC (mg/L)	Assessment Factor	$PNEC_{aquatic}$ (mg/L)	$PNEC_{sediment}$ (mg/kg dry wt)	$PNEC_{soil}$ (mg/kg)
Guar gum	48-hr EC50 (Daphnia)	42	1,000	0.042	-	-
Tetrasodium ethylenediamine tetraacetate	Chronic Daphnia	22	10	2.2[a]	-[a]	-[a]
Sodium acetate	96-hr LC50 (fish)	100 mg/L	1,000	0.1	-	-
C6-C10 alcohol ethoxylates	Chronic Daphnia QSAR	[b]	10	2.63 Range: 0.118-11.9	243 Range: 2.76 - 1250	138 Range: 1.03 - 1012
C6-C10 alcohol ethoxysulfates	Chronic Cerioaphnia QSAR	[e]	10	0.27	-	0.0083
Diammonium peroxidisulfate	96-hr LC50 (fish)	76	1,000	0.076	-	-
Hydrochloric acid	-	-	-	-	-	-
Sodium hydroxide	-	-	-	-	-	-
Magnesium chloride	72-hr EC50 (algae)	100	1,000	0.1	-	-
Polypropylene glycol	96-hr LC50 (fish) 48-hr EC50 (Daphnia)	100	1,000	0.1	0.08	0.0133
Sodium hypochlorite	48-hr EC50 (Daphnia)	0.04	1,000	4×10^{-5} (0.04 µg/L)	-	-
TPH Fractions C15-C36 Aliphatics	72-hr NOEL (algae)	100	50	2	-	-
Vinylidene/methylacrylate copolymer	NA	NA	NA	NA	NA	NA
Noncrystalline silica/Silica gel	NA	NA	NA	NA	NA	NA
Talc	NA	NA	NA	NA	NA	NA
Crystalline silica, quartz	NA	NA	NA	NA	NA	NA
Crystalline silica, cristobalite	NA	NA	NA	NA	NA	NA
Diatomaceous earth, calcined	NA	NA	NA	NA	NA	NA

[a]EU Risk Assessment Report for Tetrasodium ethylenediaminetetraacetate.

[b]See HERA Report on Alcohol Ethoxylates.

[d]Interim Canadian Water Quality Guideline for the Protection of Aquatic Life for Didecyldimethyl ammonium chloride (DDAC).

[e]See HERA Report on Alcohol Ethoxysulfates.

[f]Canadian Water Quality Guidelines for the Protection of Aquatic Life: Long-term Exposure to Boron (2009)

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Table 10 Environmental Fate Information

C6-C10 Alcohol Ethoxylates	Readily biodegradable and also anaerobically biodegradable. Proposed half-lives in river water at 12^{o}C: 4 to 24 hours (based on experimental data). BCF (see HERA report)
C6-C12 Alcohol Ethoxysulfate	AES are readily biodegradable under aerobic conditions; they are expected to be easily biodegradable under anaerobic conditions. Degradation rate in surface water: 0.48 d^{-1} (measured)
Guar gum	Expected to be readily biodegradable as a polysaccharide; not expected to bioaccumulate. [No data]
Vinylene chloride / methylacrylate polymer	Biologically inert. Persistent in the environment.
Polypropylene glycol	Readily biodegradable. 65% degradation after 20 days (OECD 301F). Bioconcentration potential is low (BCF less than 100 or log Pow less than 3).
Tetrasodium ethylenediamine tetraacetate	Not biodegraded. Biodegradation rate constant: 0 d^{-1}. Unlikely to bioaccumulate.

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Table 14 Risk Estimates for Cattle Schlumberger Theoretical Exposure for 20% Mass Returned

		20% Mass Returned		Toxicity		Specific Frac Stimulation Event		Maximum	
							Hazard Quotient		Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**C_{max} (mg/l)**	**Sreening Level**	**TRVs**	**$CADD_{oral}$**	**Incidental Ingestion**	**$CADD_{oral}$**	**Incidental Ingestion**
Magnesium chloride	7786-30-3	1.3E-01	4.0E-01	2000		6.6E-04		2.0E-03	
Diatomaceous earth, calcined	91053-39-3	2.9E+00	4.0E+00			1.5E-02		2.0E-02	
Crystalline silica (cristobalite)	14464-46-1								
Crystalline silica (quartz)	14808-60-7								
Diammonium peroxidisulphate (ammonium persulphate)	7727-54-0	9.5E+01	9.5E+01	1000		4.7E-01		4.7E-01	
Carbohydrate polymer (guar gum[1])	9000-30-0	3.8E+02	4.7E+02		2.1E+02	1.9E+00	9.2E-03	2.3E+00	1.1E-02
Non-crystalline silica (amorphous silica surrogate)	7631-86-9	1.1E+00	1.3E+00		4.2E+02	5.3E-03	1.3E-05	6.6E-03	1.6E-05
Polypropylene glycol	25322-69-4	-	9.9E-02		8.3E+01			4.9E-04	5.9E-06
Ammonium C6-C10 alcohol ethoxysulfate	68187-17-7	-	3.5E+00		1.2E+01			1.7E-02	1.4E-03
Alcohols C6-C10 ethoxylated	68439-45-2	-	6.0E-02		8.3E+00			3.0E-04	3.6E-05
Hydrochloric acid	7647-01-0	8.5E+01	8.5E+01	2000		4.2E-01		4.2E-01	
Vinylidene chloride/methylacrylate	25038-72-6	2.4E+00	2.4E+00			1.2E-02		1.2E-02	
Tetrasodium ethylenediaminetetraacetate (EDTA)	64-02-8	1.1E+00	1.1E+00	2000		5.3E-03		5.3E-03	
magnesium silicate hydrate (talc)	14807-96-6	1.3E-01	1.3E-01			6.6E-04		6.6E-04	
Sodium hydroxide	1310-73-2	1.3E-01	1.3E-01	2000		6.6E-04		6.6E-04	
							Hazard Index		**Hazard Index**
							9.2E-03		1.3E-02

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Table 15 Risk Estimates for Cattle Schlumberger Theoretical Exposure for 80% Mass Returned

		80% Mass Returned		Toxicity		Specific Frac Stimulation Event		Maximum	
							Hazard Quotient		Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**C_{max} (mg/l)**	**Sreening Level**	**TRVs**	**$CADD_{oral}$**	**Incidental Ingestion**	**$CADD_{oral}$**	**Incidental Ingestion**
Magnesium chloride	7786-30-3	5.3E-01	1.6E+00	2000		2.7E-03		8.0E-03	
Diatomaceous earth, calcined	91053-39-3	1.2E+01	1.6E+01			5.8E-02		8.0E-02	
Crystalline silica (cristobalite)	14464-46-1								
Crystalline silica (quartz)	14808-60-7								
Diammonium peroxidisulphate (ammonium persulphate)	7727-54-0	3.8E+02	3.8E+02	1000		1.9E+00		1.9E+00	
Carbohydrate polymer (guar gum[1])	9000-30-0	1.5E+03	1.9E+03		2.1E+02	7.7E+00	3.7E-02	9.4E+00	4.5E-02
Non-crystalline silica (amorphous silica surrogate)	7631-86-9	4.3E+00	5.3E+00		4.2E+02	2.1E-02	5.1E-05	2.7E-02	6.4E-05
Polypropylene glycol	25322-69-4	-	4.0E-01		8.3E+01			2.0E-03	2.4E-05
Ammonium C6-C10 alcohol ethoxysulfate	68187-17-7	-	1.4E+01		1.2E+01			6.9E-02	5.5E-03
Alcohols C6-C10 ethoxylated	68439-45-2	-	2.4E-01		8.3E+00			1.2E-03	1.4E-04
Hydrochloric acid	7647-01-0	3.4E+02	3.4E+02	2000		1.7E+00		1.7E+00	
Vinylidene chloride/methylacrylate	25038-72-6	9.6E+00	9.6E+00			4.8E-02		4.8E-02	
Tetrasodium ethylenediaminetetraacetate (EDTA)	64-02-8	4.3E+00	4.3E+00	2000		2.1E-02		2.1E-02	
magnesium silicate hydrate (talc)	14807-96-6	5.3E-01	5.3E-01			2.7E-03		2.7E-03	
Sodium hydroxide	1310-73-2	5.3E-01	5.3E-01	2000		2.7E-03		2.7E-03	
							Hazard Index		**Hazard Index**
							3.7E-02		5.1E-02

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Table 16 Risk Estimates for Kangaroo Schlumberger Theoretical Exposure for 20% Mass Returned

		20% Mass Returned		Toxicity		Specific Frac Stimulation Event		Maximum	
							Hazard Quotient		Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**C_{max} (mg/l)**	**Sreening Level**	**TRVs**	**$CADD_{oral}$**	**Incidental Ingestion**	**$CADD_{oral}$**	**Incidental Ingestion**
Magnesium chloride	7786-30-3	1.3E-01	4.0E-01	2000		4.4E-04		1.3E-03	
Diatomaceous earth, calcined	91053-39-3	2.9E+00	4.0E+00			9.6E-03		1.3E-02	
Crystalline silica (cristobalite)	14464-46-1								
Crystalline silica (quartz)	14808-60-7								
Diammonium peroxidisulphate (ammonium persulphate)	7727-54-0	9.5E+01	9.5E+01	1000		3.1E-01		3.1E-01	
Carbohydrate polymer (guar gum[1])	9000-30-0	3.8E+02	4.7E+02		2.1E+02	1.3E+00	6.1E-03	1.6E+00	7.5E-03
Non-crystalline silica (amorphous silica surrogate)	7631-86-9	1.1E+00	1.3E+00		4.2E+02	3.5E-03	8.4E-06	4.4E-03	1.1E-05
Polypropylene glycol	25322-69-4	-	9.9E-02		8.3E+01			3.3E-04	3.9E-06
Ammonium C6-C10 alcohol ethoxysulfate	68187-17-7	-	3.5E+00		1.2E+01			1.1E-02	9.1E-04
Alcohols C6-C10 ethoxylated	68439-45-2	-	6.0E-02		8.3E+00			2.0E-04	2.3E-05
Hydrochloric acid	7647-01-0	8.5E+01	8.5E+01	2000		2.8E-01		2.8E-01	
Vinylidene chloride/methylacrylate	25038-72-6	2.4E+00	2.4E+00			7.9E-03		7.9E-03	
Tetrasodium ethylenediaminetetraacetate (EDTA)	64-02-8	1.1E+00	1.1E+00	2000		3.5E-03		3.5E-03	
magnesium silicate hydrate (talc)	14807-96-6	1.3E-01	1.3E-01			4.4E-04		4.4E-04	
Sodium hydroxide	1310-73-2	1.3E-01	1.3E-01	2000		4.4E-04		4.4E-04	
							Hazard Index		**Hazard Index**
							6.1E-03		8.4E-03

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Table 17 Risk Estimates for Kangaroo Schlumberger Theoretical Exposure for 80% Mass Returned

		80% Mass Returned		Toxicity		Specific Frac Stimulation Event		Maximum	
							Hazard Quotient		Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**C_{max} (mg/l)**	**Sreening Level**	**TRVs**	**$CADD_{oral}$**	**Incidental Ingestion**	**$CADD_{oral}$**	**Incidental Ingestion**
Magnesium chloride	7786-30-3	5.3E-01	1.6E+00	2000		1.8E-03		5.3E-03	
Diatomaceous earth, calcined	91053-39-3	1.2E+01	1.6E+01			3.9E-02		5.3E-02	
Crystalline silica (cristobalite)	14464-46-1								
Crystalline silica (quartz)	14808-60-7								
Diammonium peroxidisulphate (ammonium persulphate)	7727-54-0	3.8E+02	3.8E+02	1000		1.2E+00		1.2E+00	
Carbohydrate polymer (guar gum[1])	9000-30-0	1.5E+03	1.9E+03		2.1E+02	5.1E+00	2.4E-02	6.2E+00	3.0E-02
Non-crystalline silica (amorphous silica surrogate)	7631-86-9	4.3E+00	5.3E+00		4.2E+02	1.4E-02	3.4E-05	1.8E-02	4.2E-05
Polypropylene glycol	25322-69-4	-	4.0E-01		8.3E+01			1.3E-03	1.6E-05
Ammonium C6-C10 alcohol ethoxysulfate	68187-17-7	-	1.4E+01		1.2E+01			4.6E-02	3.6E-03
Alcohols C6-C10 ethoxylated	68439-45-2	-	2.4E-01		8.3E+00			7.8E-04	9.4E-05
Hydrochloric acid	7647-01-0	3.4E+02	3.4E+02	2000		1.1E+00		1.1E+00	
Vinylidene chloride/methylacrylate	25038-72-6	9.6E+00	9.6E+00			3.2E-02		3.2E-02	
Tetrasodium ethylenediaminetetraacetate (EDTA)	64-02-8	4.3E+00	4.3E+00	2000		1.4E-02		1.4E-02	
magnesium silicate hydrate (talc)	14807-96-6	5.3E-01	5.3E-01			1.8E-03		1.8E-03	
Sodium hydroxide	1310-73-2	5.3E-01	5.3E-01	2000		1.8E-03		1.8E-03	
							Hazard Index		**Hazard Index**
							2.4E-02		3.4E-02

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Table 18 Risk Estimates for Dingo Schlumberger Theoretical Exposure for 20% Mass Returned

		20% Mass Returned		Toxicity		Specific Frac Stimulation Event		Maximum	
							Hazard Quotient		Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**C_{max} (mg/l)**	**Sreening Level**	**TRVs**	**$CADD_{oral}$**	**Incidental Ingestion**	**$CADD_{oral}$**	**Incidental Ingestion**
Magnesium chloride	7786-30-3	1.3E-01	4.0E-01	2000		2.1E-04		6.3E-04	
Diatomaceous earth, calcined	91053-39-3	2.9E+00	4.0E+00			4.6E-03		6.3E-03	
Crystalline silica (cristobalite)	14464-46-1								
Crystalline silica (quartz)	14808-60-7								
Diammonium peroxidisulphate (ammonium persulphate	7727-54-0	9.5E+01	9.5E+01	1000		1.5E-01		1.5E-01	
Carbohydrate polymer (guar gum[1])	9000-30-0	3.8E+02	4.7E+02		2.1E+02	6.1E-01	2.9E-03	7.5E-01	3.6E-03
Non-crystalline silica (amorphous silica surrogate)	7631-86-9	1.1E+00	1.3E+00		4.2E+02	1.7E-03	4.0E-06	2.1E-03	5.1E-06
Polypropylene glycol	25322-69-4	-	9.9E-02		8.3E+01			1.6E-04	1.9E-06
Ammonium C6-C10 alcohol ethoxysulfate	68187-17-7	-	3.5E+00		1.2E+01			5.5E-03	4.4E-04
Alcohols C6-C10 ethoxylated	68439-45-2	-	6.0E-02		8.3E+00			9.4E-05	1.1E-05
Hydrochloric acid	7647-01-0	8.5E+01	8.5E+01	2000		1.3E-01		1.3E-01	
Vinylidene chloride/methylacrylate	25038-72-6	2.4E+00	2.4E+00			3.8E-03		3.8E-03	
Tetrasodium ethylenediaminetetraacetate (EDTA)	64-02-8	1.1E+00	1.1E+00	2000		1.7E-03		1.7E-03	
magnesium silicate hydrate (talc)	14807-96-6	1.3E-01	1.3E-01			2.1E-04		2.1E-04	
Sodium hydroxide	1310-73-2	1.3E-01	1.3E-01	2000		2.1E-04		2.1E-04	
							Hazard Index		**Hazard Index**
							2.9E-03		4.0E-03

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Table 19 Risk Estimates for Dingo Schlumberger Theoretical Exposure for 80% Mass Returned

		80% Mass Returned		Toxicity		Specific Frac Stimulation Event		Maximum	
							Hazard Quotient		Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**C_{max} (mg/l)**	**Sreening Level**	**TRVs**	**$CADD_{oral}$**	**Incidental Ingestion**	**$CADD_{oral}$**	**Incidental Ingestion**
Magnesium chloride	7786-30-3	5.3E-01	1.6E+00	2000		8.4E-04		2.5E-03	
Diatomaceous earth, calcined	91053-39-3	1.2E+01	1.6E+01			1.9E-02		2.5E-02	
Crystalline silica (cristobalite)	14464-46-1								
Crystalline silica (quartz)	14808-60-7								
Diammonium peroxidisulphate (ammonium persulphate)	7727-54-0	3.8E+02	3.8E+02	1000		6.0E-01		6.0E-01	
Carbohydrate polymer (guar gum[1])	9000-30-0	1.5E+03	1.9E+03		2.1E+02	2.4E+00	1.2E-02	3.0E+00	1.4E-02
Non-crystalline silica (amorphous silica surrogate)	7631-86-9	4.3E+00	5.3E+00		4.2E+02	6.7E-03	1.6E-05	8.4E-03	2.0E-05
Polypropylene glycol	25322-69-4	-	4.0E-01		8.3E+01			6.3E-04	7.5E-06
Ammonium C6-C10 alcohol ethoxysulfate	68187-17-7	-	1.4E+01		1.2E+01			2.2E-02	1.8E-03
Alcohols C6-C10 ethoxylated	68439-45-2	-	2.4E-01		8.3E+00			3.8E-04	4.5E-05
Hydrochloric acid	7647-01-0	3.4E+02	3.4E+02	2000		5.4E-01		5.4E-01	
Vinylidene chloride/methylacrylate	25038-72-6	9.6E+00	9.6E+00			1.5E-02		1.5E-02	
Tetrasodium ethylenediaminetetraacetate (EDTA)	64-02-8	4.3E+00	4.3E+00	2000		6.7E-03		6.7E-03	
magnesium silicate hydrate (talc)	14807-96-6	5.3E-01	5.3E-01			8.4E-04		8.4E-04	
Sodium hydroxide	1310-73-2	5.3E-01	5.3E-01	2000		8.4E-04		8.4E-04	
							Hazard Index		**Hazard Index**
							1.2E-02		1.6E-02

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Table 20 Risk Estimates for Cattle Empirical Exposure - Flowback Storage Ponds

	Turkey Nest		Toxicity		Turkey Nest Maximum Concentrations		Turkey Nest Mean Concentrations	
						Hazard Quotient		Hazard Quotient
Constituent Name	**C_{max} (mg/l)**	**C_{mean} (mg/l)**	**Sreening Level**	**TRVs**	**$CADD_{oral}$**	**Incidental Ingestion**	**$CADD_{oral}$**	**Incidental Ingestion**
Aluminium	19.8	4.2E+00		1.7E+01	9.9E-02	5.9E-03	2.1E-02	1.2E-03
Arsenic	0.135	1.0E-02		5.0E-03	6.7E-04	1.3E-01	5.0E-05	1.0E-02
Barium	1.87	3.8E-01		3.3E+00	9.3E-03	2.8E-03	1.9E-03	5.6E-04
Benzene	0	0.0E+00		6.7E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Beryllium	0	0.0E+00		3.3E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Boron And Borates Only	1.47	6.5E-01		3.3E+00	7.3E-03	2.2E-03	3.3E-03	9.8E-04
Cadmium	0	0.0E+00		8.3E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Chromium (total)	0.031	7.9E-03		2.5E+01	1.5E-04	6.2E-06	3.9E-05	1.6E-06
Cobalt	0.005	2.1E-03		1.0E-04	2.5E-05	2.5E-01	1.0E-05	1.0E-01
Copper	0.14	1.0E-02		6.7E-01	7.0E-04	1.0E-03	5.0E-05	7.5E-05
Ethylbenzene	0	0.0E+00		1.7E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Lead	0.009	4.9E-03		6.0E-02	4.5E-05	7.5E-04	2.4E-05	4.1E-04
Lithium	0.46	9.8E-02		3.3E-02	2.3E-03	6.9E-02	4.9E-04	1.5E-02
Manganese	0.255	4.2E-02		4.0E-01	1.3E-03	3.2E-03	2.1E-04	5.2E-04
Molybdenum	0.628	4.7E-02		8.3E-02	3.1E-03	3.8E-02	2.3E-04	2.8E-03
Naphthalene	0.0054	5.4E-03		3.3E-01	2.7E-05	8.1E-05	2.7E-05	8.1E-05
Nickel (soluble salts)	0.12	8.8E-03		3.3E-01	6.0E-04	1.8E-03	4.4E-05	1.3E-04
Selenium	0	0.0E+00		8.3E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Silver	0	0.0E+00		8.3E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Strontium, Stable	2.7	6.5E-01		1.0E+01	1.3E-02	1.3E-03	3.2E-03	3.2E-04
Tin	0.004	3.0E-03		1.0E+01	2.0E-05	2.0E-06	1.5E-05	1.5E-06
Toluene	0.004	3.0E-03		1.3E+00	2.0E-05	1.5E-05	1.5E-05	1.1E-05
TPH Aliphatic C6-9	1.08	2.8E-01		8.3E+01	5.4E-03	6.5E-05	1.4E-03	1.7E-05
TPH Aliphatic C10-14	0.68	3.9E-01		1.7E+00	3.4E-03	2.0E-03	1.9E-03	1.2E-03
TPH Aliphatic C15-28	1.11	5.0E-01		3.3E+01	5.5E-03	1.7E-04	2.5E-03	7.5E-05
TPH Aliphatic C29-36	0.92	2.5E-01		2.0E+02	4.6E-03	2.3E-05	1.3E-03	6.3E-06
Uranium	0.002	1.8E-03		5.0E-02	1.0E-05	2.0E-04	9.0E-06	1.8E-04
Vanadium	0.14	5.0E-02		1.2E-03	7.0E-04	6.0E-01	2.5E-04	2.1E-01
Xylenes (total)	0.014	5.8E-03		3.3E+00	7.0E-05	2.1E-05	2.9E-05	8.7E-06
Zinc	0.046	1.9E-02		5.0E+00	2.3E-04	4.6E-05	9.5E-05	1.9E-05
						Hazard Index		Hazard Index
						1.1E+00		1.4E-01

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Table 21 Risk Estimates for Cattle Empirical Exposure - Pump Flowback

	Pump Flowback		Toxicity		Pump Flowback Maximum Concentrations		Pump Flowback Mean Treated Concentrations	
						Hazard Quotient		Hazard Quotient
Constituent Name	**C_{max} (mg/l)**	**C_{mean} (mg/l)**	**Sreening Level**	**TRVs**	**$CADD_{oral}$**	**Incidental Ingestion**	**$CADD_{oral}$**	**Incidental Ingestion**
Aluminium	2.65	1.1E-01		1.7E+01	1.3E-02	7.9E-04	5.3E-04	3.2E-05
Arsenic	0.015	3.5E-03		5.0E-03	7.5E-05	1.5E-02	1.7E-05	3.5E-03
Barium	37.9	4.6E+00		3.3E+00	1.9E-01	5.7E-02	2.3E-02	6.9E-03
Benzene	0.041	1.5E-02		6.7E-02	2.0E-04	3.1E-03	7.5E-05	1.1E-03
Beryllium	0	0.0E+00		3.3E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Boron And Borates Only	55.3	1.4E+01		3.3E+00	2.8E-01	8.3E-02	6.8E-02	2.0E-02
Cadmium	0.0004	1.0E-04		8.3E-03	2.0E-06	2.4E-04	5.0E-07	6.0E-05
Chromium (total)	0.147	1.5E-02		2.5E+01	7.3E-04	2.9E-05	7.6E-05	3.0E-06
Cobalt	0.01	1.3E-03		1.0E-04	5.0E-05	5.0E-01	6.5E-06	6.5E-02
Copper	0.156	2.2E-02		6.7E-01	7.8E-04	1.2E-03	1.1E-04	1.6E-04
Ethylbenzene	0.003	2.4E-03		1.7E+00	1.5E-05	9.0E-06	1.2E-05	7.2E-06
Lead	0.035	2.0E-03		6.0E-02	1.7E-04	2.9E-03	1.0E-05	1.7E-04
Lithium	2.84	1.5E+00		3.3E-02	1.4E-02	4.2E-01	7.3E-03	2.2E-01
Manganese	1.66	4.0E-01		4.0E-01	8.3E-03	2.1E-02	2.0E-03	5.0E-03
Molybdenum	0.231	1.6E-02		8.3E-02	1.2E-03	1.4E-02	7.8E-05	9.3E-04
Naphthalene	0.231	1.6E-02		3.3E-01	1.2E-03	3.5E-03	7.8E-05	2.3E-04
Nickel (soluble salts)	0.051	1.2E-02		3.3E-01	2.5E-04	7.6E-04	6.1E-05	1.8E-04
Selenium	0.01	1.0E-02		8.3E-02	5.0E-05	6.0E-04	5.0E-05	6.0E-04
Silver	0	0.0E+00		8.3E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Strontium, Stable	32.4	1.2E+01		1.0E+01	1.6E-01	1.6E-02	6.1E-02	6.1E-03
Tin	0.161	3.5E-03		1.0E+01	8.0E-04	8.0E-05	1.7E-05	1.7E-06
Toluene	0.094	2.1E-02		1.3E+00	4.7E-04	3.5E-04	1.0E-04	7.9E-05
TPH Aliphatic C6-9	0.25	7.9E-02		8.3E+01	1.2E-03	1.5E-05	3.9E-04	4.7E-06
TPH Aliphatic C10-14	0.5	2.4E-01		1.7E+00	2.5E-03	1.5E-03	1.2E-03	7.3E-04
TPH Aliphatic C15-28	5.16	7.3E-01		3.3E+01	2.6E-02	7.7E-04	3.6E-03	1.1E-04
TPH Aliphatic C29-36	3.28	4.5E-01		2.0E+02	1.6E-02	8.2E-05	2.2E-03	1.1E-05
Uranium	0	0.0E+00		5.0E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Vanadium	0.02	1.5E-02		1.2E-03	1.0E-04	8.5E-02	7.5E-05	6.4E-02
Xylenes (total)	0.031	1.4E-02		3.3E+00	1.5E-04	4.6E-05	7.2E-05	2.2E-05
Zinc	0.251	2.2E-02		5.0E+00	1.2E-03	2.5E-04	1.1E-04	2.2E-05
						Hazard Index		Hazard Index
						1.2E+00		3.3E-01

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Table 22 Risk Estimates for Kangaroo Empirical Exposure Flowback Storage Pond

	Turkey Nest		Toxicity		Turkey Nest Maximum Concentrations		Turkey Nest Mean Concentrations	
						Hazard Quotient		Hazard Quotient
Constituent Name	**C_{max} (mg/l)**	**C_{mean} (mg/l)**	**Sreening Level**	**TRVs**	**$CADD_{oral}$**	**Incidental Ingestion**	**$CADD_{oral}$**	**Incidental Ingestion**
Aluminium	19.8	4.2E+00		1.7E+01	6.5E-02	3.9E-03	1.4E-02	8.2E-04
Arsenic	0.135	1.0E-02		5.0E-03	4.4E-04	8.9E-02	3.3E-05	6.6E-03
Barium	1.87	3.8E-01		3.3E+00	6.1E-03	1.8E-03	1.2E-03	3.7E-04
Benzene	0	0.0E+00		6.7E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Beryllium	0	0.0E+00		3.3E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Boron And Borates Only	1.47	6.5E-01		3.3E+00	4.8E-03	1.5E-03	2.1E-03	6.4E-04
Cadmium	0	0.0E+00		8.3E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Chromium (total)	0.031	7.9E-03		2.5E+01	1.0E-04	4.1E-06	2.6E-05	1.0E-06
Cobalt	0.005	2.1E-03		1.0E-04	1.6E-05	1.6E-01	6.9E-06	6.9E-02
Copper	0.14	1.0E-02		6.7E-01	4.6E-04	6.9E-04	3.3E-05	5.0E-05
Ethylbenzene	0	0.0E+00		1.7E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Lead	0.009	4.9E-03		6.0E-02	3.0E-05	4.9E-04	1.6E-05	2.7E-04
Lithium	0.46	9.8E-02		3.3E-02	1.5E-03	4.5E-02	3.2E-04	9.7E-03
Manganese	0.255	4.2E-02		4.0E-01	8.4E-04	2.1E-03	1.4E-04	3.5E-04
Molybdenum	0.628	4.7E-02		8.3E-02	2.1E-03	2.5E-02	1.5E-04	1.9E-03
Naphthalene	0.0054	5.4E-03		3.3E-01	1.8E-05	5.3E-05	1.8E-05	5.3E-05
Nickel (soluble salts)	0.12	8.8E-03		3.3E-01	3.9E-04	1.2E-03	2.9E-05	8.7E-05
Selenium	0	0.0E+00		8.3E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Silver	0	0.0E+00		8.3E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Strontium, Stable	2.7	6.5E-01		1.0E+01	8.9E-03	8.9E-04	2.1E-03	2.1E-04
Tin	0.004	3.0E-03		1.0E+01	1.3E-05	1.3E-06	9.9E-06	9.9E-07
Toluene	0.004	3.0E-03		1.3E+00	1.3E-05	9.9E-06	9.9E-06	7.4E-06
TPH Aliphatic C6-9	1.08	2.8E-01		8.3E+01	3.6E-03	4.3E-05	9.2E-04	1.1E-05
TPH Aliphatic C10-14	0.68	3.9E-01		1.7E+00	2.2E-03	1.3E-03	1.3E-03	7.7E-04
TPH Aliphatic C15-28	1.11	5.0E-01		3.3E+01	3.6E-03	1.1E-04	1.6E-03	4.9E-05
TPH Aliphatic C29-36	0.92	2.5E-01		2.0E+02	3.0E-03	1.5E-05	8.3E-04	4.1E-06
Uranium	0.002	1.8E-03		5.0E-02	6.6E-06	1.3E-04	5.9E-06	1.2E-04
Vanadium	0.14	5.0E-02		1.2E-03	4.6E-04	3.9E-01	1.6E-04	1.4E-01
Xylenes (total)	0.014	5.8E-03		3.3E+00	4.6E-05	1.4E-05	1.9E-05	5.7E-06
Zinc	0.046	1.9E-02		5.0E+00	1.5E-04	3.0E-05	6.2E-05	1.2E-05
						Hazard Index		Hazard Index
						7.3E-01		9.1E-02

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Table 23 Risk Estimates for Kangaroo Empirical Exposure - Pump Flowback

	Pump Flowback		Toxicity		Pump Flowback Maximum Concentrations		Pump Flowback Mean Treated Concentrations	
						Hazard Quotient		Hazard Quotient
Constituent Name	**C_{max} (mg/l)**	**C_{mean} (mg/l)**	**Sreening Level**	**TRVs**	**$CADD_{oral}$**	**Incidental Ingestion**	**$CADD_{oral}$**	**Incidental Ingestion**
Aluminium	2.65	1.1E-01		1.7E+01	8.7E-03	5.2E-04	3.5E-04	2.1E-05
Arsenic	0.015	3.5E-03		5.0E-03	4.9E-05	9.9E-03	1.2E-05	2.3E-03
Barium	37.9	4.6E+00		3.3E+00	1.2E-01	3.7E-02	1.5E-02	4.6E-03
Benzene	0.041	1.5E-02		6.7E-02	1.3E-04	2.0E-03	5.0E-05	7.4E-04
Beryllium	0	0.0E+00		3.3E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Boron And Borates Only	55.3	1.4E+01		3.3E+00	1.8E-01	5.5E-02	4.5E-02	1.3E-02
Cadmium	0.0004	1.0E-04		8.3E-03	1.3E-06	1.6E-04	3.3E-07	3.9E-05
Chromium (total)	0.147	1.5E-02		2.5E+01	4.8E-04	1.9E-05	5.0E-05	2.0E-06
Cobalt	0.01	1.3E-03		1.0E-04	3.3E-05	3.3E-01	4.3E-06	4.3E-02
Copper	0.156	2.2E-02		6.7E-01	5.1E-04	7.7E-04	7.2E-05	1.1E-04
Ethylbenzene	0.003	2.4E-03		1.7E+00	9.9E-06	5.9E-06	7.9E-06	4.7E-06
Lead	0.035	2.0E-03		6.0E-02	1.2E-04	1.9E-03	6.6E-06	1.1E-04
Lithium	2.84	1.5E+00		3.3E-02	9.3E-03	2.8E-01	4.8E-03	1.5E-01
Manganese	1.66	4.0E-01		4.0E-01	5.5E-03	1.4E-02	1.3E-03	3.3E-03
Molybdenum	0.231	1.6E-02		8.3E-02	7.6E-04	9.1E-03	5.1E-05	6.2E-04
Naphthalene	0.231	1.6E-02		3.3E-01	7.6E-04	2.3E-03	5.1E-05	1.5E-04
Nickel (soluble salts)	0.051	1.2E-02		3.3E-01	1.7E-04	5.0E-04	4.0E-05	1.2E-04
Selenium	0.01	1.0E-02		8.3E-02	3.3E-05	3.9E-04	3.3E-05	3.9E-04
Silver	0	0.0E+00		8.3E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Strontium, Stable	32.4	1.2E+01		1.0E+01	1.1E-01	1.1E-02	4.0E-02	4.0E-03
Tin	0.161	3.5E-03		1.0E+01	5.3E-04	5.3E-05	1.2E-05	1.2E-06
Toluene	0.094	2.1E-02		1.3E+00	3.1E-04	2.3E-04	6.9E-05	5.2E-05
TPH Aliphatic C6-9	0.25	7.9E-02		8.3E+01	8.2E-04	9.9E-06	2.6E-04	3.1E-06
TPH Aliphatic C10-14	0.5	2.4E-01		1.7E+00	1.6E-03	9.9E-04	8.0E-04	4.8E-04
TPH Aliphatic C15-28	5.16	7.3E-01		3.3E+01	1.7E-02	5.1E-04	2.4E-03	7.2E-05
TPH Aliphatic C29-36	3.28	4.5E-01		2.0E+02	1.1E-02	5.4E-05	1.5E-03	7.3E-06
Uranium	0	0.0E+00		5.0E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Vanadium	0.02	1.5E-02		1.2E-03	6.6E-05	5.6E-02	4.9E-05	4.2E-02
Xylenes (total)	0.031	1.4E-02		3.3E+00	1.0E-04	3.1E-05	4.7E-05	1.4E-05
Zinc	0.251	2.2E-02		5.0E+00	8.3E-04	1.7E-04	7.2E-05	1.4E-05
						Hazard Index		Hazard Index
						8.1E-01		2.2E-01

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Table 24 Risk Estimates for Dingo Empirical Exposure - Flowback Storage Ponds

	Turkey Nest		Toxicity		Turkey Nest Maximum Concentrations		Turkey Nest Mean Concentrations	
						Hazard Quotient		Hazard Quotient
Constituent Name	**C_{max} (mg/l)**	**C_{mean} (mg/l)**	**Sreening Level**	**TRVs**	**$CADD_{oral}$**	**Incidental Ingestion**	**$CADD_{oral}$**	**Incidental Ingestion**
Aluminium	19.8	4.2E+00		1.7E+01	3.1E-02	1.9E-03	6.6E-03	3.9E-04
Arsenic	0.135	1.0E-02		5.0E-03	2.1E-04	4.3E-02	1.6E-05	3.2E-03
Barium	1.87	3.8E-01		3.3E+00	3.0E-03	8.9E-04	5.9E-04	1.8E-04
Benzene	0	0.0E+00		6.7E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Beryllium	0	0.0E+00		3.3E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Boron And Borates Only	1.47	6.5E-01		3.3E+00	2.3E-03	7.0E-04	1.0E-03	3.1E-04
Cadmium	0	0.0E+00		8.3E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Chromium (total)	0.031	7.9E-03		2.5E+01	4.9E-05	2.0E-06	1.2E-05	5.0E-07
Cobalt	0.005	2.1E-03		1.0E-04	7.9E-06	7.9E-02	3.3E-06	3.3E-02
Copper	0.14	1.0E-02		6.7E-01	2.2E-04	3.3E-04	1.6E-05	2.4E-05
Ethylbenzene	0	0.0E+00		1.7E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Lead	0.009	4.9E-03		6.0E-02	1.4E-05	2.4E-04	7.7E-06	1.3E-04
Lithium	0.46	9.8E-02		3.3E-02	7.3E-04	2.2E-02	1.5E-04	4.6E-03
Manganese	0.255	4.2E-02		4.0E-01	4.0E-04	1.0E-03	6.7E-05	1.7E-04
Molybdenum	0.628	4.7E-02		8.3E-02	9.9E-04	1.2E-02	7.4E-05	8.9E-04
Naphthalene	0.0054	5.4E-03		3.3E-01	8.5E-06	2.6E-05	8.5E-06	2.6E-05
Nickel (soluble salts)	0.12	8.8E-03		3.3E-01	1.9E-04	5.7E-04	1.4E-05	4.2E-05
Selenium	0	0.0E+00		8.3E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Silver	0	0.0E+00		8.3E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Strontium, Stable	2.7	6.5E-01		1.0E+01	4.3E-03	4.3E-04	1.0E-03	1.0E-04
Tin	0.004	3.0E-03		1.0E+01	6.3E-06	6.3E-07	4.7E-06	4.7E-07
Toluene	0.004	3.0E-03		1.3E+00	6.3E-06	4.7E-06	4.7E-06	3.6E-06
TPH Aliphatic C6-9	1.08	2.8E-01		8.3E+01	1.7E-03	2.0E-05	4.4E-04	5.3E-06
TPH Aliphatic C10-14	0.68	3.9E-01		1.7E+00	1.1E-03	6.5E-04	6.2E-04	3.7E-04
TPH Aliphatic C15-28	1.11	5.0E-01		3.3E+01	1.8E-03	5.3E-05	7.9E-04	2.4E-05
TPH Aliphatic C29-36	0.92	2.5E-01		2.0E+02	1.5E-03	7.3E-06	4.0E-04	2.0E-06
Uranium	0.002	1.8E-03		5.0E-02	3.2E-06	6.3E-05	2.8E-06	5.7E-05
Vanadium	0.14	5.0E-02		1.2E-03	2.2E-04	1.9E-01	7.9E-05	6.8E-02
Xylenes (total)	0.014	5.8E-03		3.3E+00	2.2E-05	6.6E-06	9.2E-06	2.8E-06
Zinc	0.046	1.9E-02		5.0E+00	7.3E-05	1.5E-05	3.0E-05	6.0E-06
						Hazard Index		Hazard Index
						3.5E-01		4.4E-02

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Table 25 Risk Estimates for Dingo Empirical Exposure - Pump Flowback

	Pump Flowback		Toxicity		Pump Flowback Maximum Concentrations		Pump Flowback Mean Treated Concentrations	
						Hazard Quotient		Hazard Quotient
Constituent Name	**C_{max} (mg/l)**	**C_{mean} (mg/l)**	**Sreening Level**	**TRVs**	**$CADD_{oral}$**	**Incidental Ingestion**	**$CADD_{oral}$**	**Incidental Ingestion**
Aluminium	2.65	1.1E-01		1.7E+01	4.2E-03	2.5E-04	1.7E-04	1.0E-05
Arsenic	0.015	3.5E-03		5.0E-03	2.4E-05	4.7E-03	5.5E-06	1.1E-03
Barium	37.9	4.6E+00		3.3E+00	6.0E-02	1.8E-02	7.3E-03	2.2E-03
Benzene	0.041	1.5E-02		6.7E-02	6.5E-05	9.7E-04	2.4E-05	3.6E-04
Beryllium	0	0.0E+00		3.3E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Boron And Borates Only	55.3	1.4E+01		3.3E+00	8.7E-02	2.6E-02	2.1E-02	6.4E-03
Cadmium	0.0004	1.0E-04		8.3E-03	6.3E-07	7.6E-05	1.6E-07	1.9E-05
Chromium (total)	0.147	1.5E-02		2.5E+01	2.3E-04	9.3E-06	2.4E-05	9.6E-07
Cobalt	0.01	1.3E-03		1.0E-04	1.6E-05	1.6E-01	2.1E-06	2.1E-02
Copper	0.156	2.2E-02		6.7E-01	2.5E-04	3.7E-04	3.5E-05	5.2E-05
Ethylbenzene	0.003	2.4E-03		1.7E+00	4.7E-06	2.8E-06	3.8E-06	2.3E-06
Lead	0.035	2.0E-03		6.0E-02	5.5E-05	9.2E-04	3.2E-06	5.3E-05
Lithium	2.84	1.5E+00		3.3E-02	4.5E-03	1.3E-01	2.3E-03	7.0E-02
Manganese	1.66	4.0E-01		4.0E-01	2.6E-03	6.6E-03	6.3E-04	1.6E-03
Molybdenum	0.231	1.6E-02		8.3E-02	3.7E-04	4.4E-03	2.5E-05	3.0E-04
Naphthalene	0.231	1.6E-02		3.3E-01	3.7E-04	1.1E-03	2.5E-05	7.4E-05
Nickel (soluble salts)	0.051	1.2E-02		3.3E-01	8.1E-05	2.4E-04	1.9E-05	5.8E-05
Selenium	0.01	1.0E-02		8.3E-02	1.6E-05	1.9E-04	1.6E-05	1.9E-04
Silver	0	0.0E+00		8.3E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Strontium, Stable	32.4	1.2E+01		1.0E+01	5.1E-02	5.1E-03	1.9E-02	1.9E-03
Tin	0.161	3.5E-03		1.0E+01	2.5E-04	2.5E-05	5.5E-06	5.5E-07
Toluene	0.094	2.1E-02		1.3E+00	1.5E-04	1.1E-04	3.3E-05	2.5E-05
TPH Aliphatic C6-9	0.25	7.9E-02		8.3E+01	4.0E-04	4.7E-06	1.2E-04	1.5E-06
TPH Aliphatic C10-14	0.5	2.4E-01		1.7E+00	7.9E-04	4.7E-04	3.9E-04	2.3E-04
TPH Aliphatic C15-28	5.16	7.3E-01		3.3E+01	8.2E-03	2.4E-04	1.1E-03	3.4E-05
TPH Aliphatic C29-36	3.28	4.5E-01		2.0E+02	5.2E-03	2.6E-05	7.0E-04	3.5E-06
Uranium	0	0.0E+00		5.0E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Vanadium	0.02	1.5E-02		1.2E-03	3.2E-05	2.7E-02	2.4E-05	2.0E-02
Xylenes (total)	0.031	1.4E-02		3.3E+00	4.9E-05	1.5E-05	2.3E-05	6.8E-06
Zinc	0.251	2.2E-02		5.0E+00	4.0E-04	7.9E-05	3.4E-05	6.9E-06
						Hazard Index		Hazard Index
						3.9E-01		1.1E-01

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Golder Tables

Table 50: On site exposure assessment summary

Source	Exposure Scenario	Receptors	Exposure Pathways	Likelihood of exposure scenario	Comments
Mud pit and turkeys nest sediments	Entry to pit or excavation/stockpiling of pit sediments	Workers, trespassers	Ingestion, dermal	Unlikely	OH&S procedures limit workers exposure to sediment.
	Pit dries and pit sediments become windblown dusts	Workers, trespassers	Inhalation of dusts	Possible	Pathway is limited by disposal or capping of sediments contained in the mud pit and turkeys nest at the end of operations
	Pit dries and pit sediments become windblown dusts, contaminating surrounding soil	Native terrestrial fauna (mammals, reptiles, birds), terrestrial flora	Ingestion, uptake	Unlikely	Volume of pit sediments considered insufficient to cause significant contamination of drill pad.
	Entry to pit or exposure to excavated pit sediments	Native terrestrial fauna (mammals, reptiles, birds)	Ingestion	Unlikely	Mud pit and turkeys nest does not contain food or habitat for terrestrial species.
Flow back water in Turkey nest and mud pit	Working with turkey nest inlet/liner, or drainage of turkey nest or mud pit	Workers	Ingestion, dermal	Possible	OH&S procedures limit workers exposure to flow back water.
	Entry (accidental or deliberate) to Turkeys nest or mud pit	Trespassers	Ingestion, dermal	Possible	Trespassers entry is limited via fencing and signage around drill pad areas. Trespassers can be entirely precluded from areas.
	Entry (accidental or deliberate) to Turkeys nest or mud pit	Native terrestrial fauna (mammals, reptiles, birds)	Ingestion	Observed	Native fauna has been observed in and around the turkey nests, despite areas being fenced.
	Entry (accidental or deliberate) to Turkeys nest or mud pit	Stock animals	Ingestion	Observed	Maintained fences and grids with routine maintenance can be effective at precluding livestock however, some stock animals have been observed in well pad areas.
Hydraulic fracturing Chemicals	Spill, leak of well delivery system failure during surface handling. Supply or disposal vehicle accident on-site	Workers, terrestrial fauna (mammals, reptiles, birds), terrestrial flora	Ingestion, dermal	Unlikely	OH&S and spill containment, procedures adequately address this exposure.
Flow back water	Spill, leak, mud pit, turkey nest delivery system failure or overflow	Workers, terrestrial fauna (mammals, reptiles, birds), terrestrial flora	Ingestion, dermal, inhal	Possible	

Table 51: Off site exposure assessment summary

Source	Exposure Scenario	Receptors	Exposure Pathways	Likelihood of exposure scenario	Comment/Management/control measures
Hydraulic fracturing fluids	Fracture fluid escapes into aquifer via a well casing failure, or a fault/fracture/unconformity in seam/strata, and fluids enter aquifer used downgradient for domestic water supply	Residents: adults and children	Ingestion, dermal, inhalation	Unlikely	Exposure scenario unlikely however; dependant on Santos operational procedures i.e. well integrity testing and design of fracture to stay with the target seam. No recorded instances in peer-reviewed literature of fracturing chemicals in downgradient water supplies (Osborn et al 2011).
	Fracture fluid escapes into aquifer via a well casing failure, or a fault/fracture/unconformity in seam/strata, and fluids enter aquifer used downgradient for stock water supply	Stock animals	Ingestion	Unlikely	
	Fracture fluid escapes into aquifer via a well casing failure, or a fault/fracture/unconformity in seam/strata, and fluids enter aquifer that discharges to surface water	Aquatic ecosystems	Direct exposure	Unlikely	
	Residual fracturing fluid in the coal seam migrates down gradient and enters a spring or water supply bore	Residents, aquatic ecosystems, stock animals	Ingestion, dermal, inhalation	Unlikely	Fate and transport modelling used to estimate the likely extent of migration of residual fluids in coal seam (section 7.4)
Turkeys nest or mud pit sediments	Nest/Pit dries and sediments become windblown dusts, contaminating surrounding soil	Native terrestrial flora and fauna, stock, Residents adults and children	Direct exposure/ inhalation of dusts	Unlikely	Volume of pit sediments considered insufficient to result in concentrations of concern in the surrounding land.
Flow back water	Seepage of chemicals from mud pit or turkeys nest to a shallow aquifer used downgradient for domestic water supply	Residents: adults and children	Ingestion, dermal, inhalation	Unlikely	Considered unlikely that the concentrations of chemicals would be of a concern however regular maintenance of liners required to remove exposure pathway. Monitoring of down gradient bores also recommended to confirm no exposure.
	Seepage of chemicals from mud pit or turkeys nest to a shallow aquifer used downgradient for stock water supply	Stock animals	Ingestion	Unlikely	
	Seepage of chemicals from mud pit or turkeys nest to a shallow aquifer that discharges to surface water	Aquatic ecosystems	Direct exposure	Unlikely	
	Spill, leak, turkey nest overflow	Residents, terrestrial fauna (mammals, reptiles, birds), terrestrial flora	Ingestion, dermal, inhalation	Possible	Possible overflows during prolonged periods of high rainfall (>500 mm of rainfall required) based on freeboard control requirements. Likelihood of occurrence can be reduced through minimising duration of storage in pit and turkeys nest, and toxicity of fluid is likely to decrease rapidly due to short biotransformation half-lives of most chemicals.

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Appendix C1-1

APPENDIX D
Hydraulic Fracturing Risk Assessment - Table D3

Table D3: Chemical mass balance and estimated concentrations in typical hydraulic fracturing fluids

Constituent Name	CAS No.	Estimated mass per coal seam (kg)				Estimated concentration in pre-injection fluid systems (mg/L)			
		Waterfrac / Slickwater	WF130 Linear Gel	WF130 Linear Base Gel for Foam Fluid	YF125LG Crosslinked Gel	Waterfrac / Slickwater	WF130 Linear Gel	WF130 Linear Base Gel for Foam Fluid	YF125LG Crosslinked Gel
Magnesium chloride	7786-30-3	6.82	1.15	0.34	0.47	3	3	3	1
Diatomaceous earth, calcined	91053-39-3	68.18	11.45	3.43	8.18	30	30	30	22
Crystalline silica (cristobalite)	14464-46-1	Assumed to be sand, not included in chemical mass balance				Assumed to be sand, not included in chemical mass balance			
Crystalline silica (quartz)	14808-60-7								
Diammonium peroxidisulphate (ammonium persulphate)	7727-54-0	-	155.26	-	269.44	-	410	-	712
Carbohydrate polymer (guar gum[1])	9000-30-0	-	1340.04	377.38	1091.83	-	3540	3323	2884
Non-crystalline silica (amorphous silica surrogate)	7631-86-9	-	3.66	1.03	2.90	-	10	9	8
Polypropylene glycol	25322-69-4	-	11.53	-	-	-	30		-
Ammonium C6-C10 alcohol ethoxysulfate	68187-17-7	-	-	119.04	-	-	-	1048	-
Alcohols C6-C10 ethoxylated	68439-45-2	-	-	1.99	-	-	-	18	-
Hydrochloric acid	7647-01-0	-	-	-	240.41	-	-	-	635
Vinylidene chloride/methylacrylate	25038-72-6	-	-	-	6.91	-	-	-	18
Tetrasodium ethylenediaminetetraacetate (EDTA)	64-02-8	-	-	-	2.98	-	-	-	8
magnesium silicate hydrate (talc)	14807-96-6	-	-	-	0.30	-	-	-	1
Sodium hydroxide	1310-73-2	-	-	-	0.26	-	-	-	1
Total chemical mass injected per coal seam (kg):		***216***	***1720***	***683***	***2812***				
Residual chemical mass assuming 60% recovery (kg):		***86***	***688***	***273***	***1125***				

Notes:

1. Estimated concentration in pre-injection fracturing fluid may exceed the effective solubility of the compound.

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Appendix C1-2

Table C-1 Surface Water Quality Data for Theoretical Scenario in Initial Flowback for Schlumberger

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)					Estimated Initial Mud Pit Concentration in flowback (150% of injected fluid volume) per coal seam per percent of mass returned calculated using equation: Mud Pitcon = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L)							
							YF125LG Crosslinked Gel				Maximum of All Stimulation Events			
		Waterfrac / Slickwater	WF130 Linear Gel	WF130 Linear Base Gel for Foam Fluid	YF125LG Crosslinked Gel	Maximum of All Stimulation Events	20%	40%	60%	80%	20%	40%	60%	80%
Magnesium chloride	7786-30-3	3	3	3	1	3	0.1	0.3	0.4	0.5	0.4	0.8	1.2	1.6
Diatomaceous earth, calcined	91053-39-3	30	30	30	22	30	2.9	5.9	8.8	11.7	4.0	8.0	12.0	16.0
Crystalline silica (cristobalite)	14464-46-1													
Crystalline silica (quartz)	14808-60-7													
Diammonium peroxodisulphate (ammonium persulphate)	7727-54-0	-	410	-	712	712	94.9	189.9	284.8	379.7	94.9	189.9	284.8	379.7
Carbohydrate polymer (guar gum[1])	9000-30-0	-	3,540	3,323	2,884	3,540	384.5	769.1	1153.6	1538.1	472.0	944.0	1416.0	1888.0
Non-crystalline silica (amorphous silica surrogate)	7631-86-9	-	10	9	8	10	1.1	2.1	3.2	4.3	1.3	2.7	4.0	5.3
Polypropylene glycol	25322-69-4	-	30		-	30	-	-	-	-	4.0	8.0	12.0	16.0
Ammonium C6-C10 alcohol ethoxysulfate	68187-17-7	-	-	1,048	-	1,048	-	-	-	-	139.7	279.5	419.2	558.9
Alcohols C6-C10 ethoxylated	68439-45-2	-	-	18	-	18	-	-	-	-	2.4	4.8	7.2	9.6
Hydrochloric acid	7647-01-0	-	-	-	635	635	84.7	169.3	254.0	338.7	84.7	169.3	254.0	338.7
Vinylidene chloride/methylacrylate	25038-72-6	-	-	-	18	18	2.4	4.8	7.2	9.6	2.4	4.8	7.2	9.6
Tetrasodium ethylenediaminetetraacetate (EDTA)	64-02-8	-	-	-	8	8	1.1	2.1	3.2	4.3	1.1	2.1	3.2	4.3
magnesium silicate hydrate (talc)	14807-96-6	-	-	-	1	1	0.1	0.3	0.4	0.5	0.1	0.3	0.4	0.5
Sodium hydroxide	1310-73-2	-	-	-	1	1	0.1	0.3	0.4	0.5	0.1	0.3	0.4	0.5

Table C-2 Surface Water Quality Data for Stimulation Monitoring in Flowback Storage Pond

Parameter	Number of Detections	Detection Ratio	Minimum	Maximum	Mean
Polychlorinated Biphenyls (mg/L)					
Aroclor 1016	0	0/27	NA	NA	NA
Aroclor 1221	0	0/27	NA	NA	NA
Aroclor 1232	0	0/27	NA	NA	NA
Aroclor 1242	0	0/27	NA	NA	NA
Aroclor 1248	0	0/27	NA	NA	NA
Aroclor 1254	0	0/27	NA	NA	NA
Aroclor 1260	0	0/27	NA	NA	NA
Aroclor 1262	0	0/27	NA	NA	NA
Total Polychlorinated Biphenyls	0	0/27	NA	NA	NA
BTEX (mg/L)					
Benzene	0	0/54	NA	NA	NA
Ethylbenzene	0	0/54	NA	NA	NA
meta- & para-Xylene	4	4/54	0.002	0.009	0.0045
ortho-Xylene	1	1/54	0.005	0.005	0.005
Sum of BTEX	4	4/53	0.003	0.018	0.00725
Toluene	2	2/54	0.002	0.004	0.003
Total Xylenes	4	4/53	0.002	0.014	0.00575
Polycyclic Aromatic Hydrocarbons (mg/L)					
2-Methylnaphthalene	0	0/23	NA	NA	NA
Acenaphthene	0	0/53	NA	NA	NA
Acenaphthylene	0	0/54	NA	NA	NA
Anthracene	0	0/54	NA	NA	NA
Benz(a)anthracene	0	0/54	NA	NA	NA
Benzo(a)pyrene	0	0/54	NA	NA	NA
Benzo(b)fluoranthene	0	0/54	NA	NA	NA
Benzo(g.h.i)perylene	0	0/54	NA	NA	NA
Benzo(k)fluoranthene	0	0/54	NA	NA	NA
Chrysene	0	0/54	NA	NA	NA
Dibenz(a,h)anthracene	0	0/54	NA	NA	NA
Fluoranthene	0	0/54	NA	NA	NA
Fluorene	0	0/54	NA	NA	NA
Indeno(1.2.3.cd)pyrene	0	0/54	NA	NA	NA
Naphthalene	1	1/53	0.0054	0.0054	0.0054
Phenanthrene	0	0/54	NA	NA	NA
Pyrene	0	0/54	NA	NA	NA
Sum of Polycyclic Aromatic Hydrocarbons	1	1/47	0.0054	0.0054	0.0054
Total Petroleum Hydrocarbons (mg/L)					
C10-C14 Fraction	3	3/54	0.18	0.68	0.39
C10-C36 Fraction (sum)	11	11/54	0.06	2.71	0.651818182
C15-C28 Fraction	7	7/54	0.12	1.11	0.497142857
C29-C36 Fraction	10	10/54	0.05	0.92	0.252
C6-C9 Fraction	7	7/54	0.02	1.08	0.278571429
Total Recoverable Hydrocarbons (mg/L)					
>C10-C16 Fraction	3	3/53	0.23	0.5	0.36
>C10-C40 Fraction (sum)	13	13/53	0.11	2.48	0.576923077
>C16-C34 Fraction	13	13/53	0.11	1.72	0.448461538
>C34-C40 Fraction	3	3/53	0.1	0.26	0.196666667
C6-C10 Fraction	6	6/53	0.03	0.56	0.251666667
C6-C10 Fraction minus BTEX (F1)	6	6/53	0.03	0.56	0.248333333
SG>C10 - C16 Fraction	0	0/21	NA	NA	NA
SG>C10 - C40 Fraction (sum)	0	0/21	NA	NA	NA
SG>C16 - C34 Fraction	0	0/21	NA	NA	NA
SG>C34 - C40 Fraction	0	0/21	NA	NA	NA
SGC10 - C14 Fraction	0	0/21	NA	NA	NA
SGC10 - C36 Fraction (sum)	0	0/21	NA	NA	NA

Table C-2 Surface Water Quality Data for Stimulation Monitoring in Flowback Storage Pond

Parameter	Number of Detections	Detection Ratio	Minimum	Maximum	Mean
SGC15 - C28 Fraction	0	0/21	NA	NA	NA
SGC29 - C36 Fraction	0	0/21	NA	NA	NA
Alkalinity (mg/L)					
Bicarbonate Alkalinity as CaCO3	32	32/54	59	636	374.46875
Carbonate Alkalinity as CaCO3	22	22/54	3	1740	203.3181818
Hydroxide Alkalinity as CaCO3	0	0/54	NA	NA	NA
Residual Alkali (meq/L)	26	26/47	-1.42	36.9	9.020384615
Total Alkalinity as CaCO3	32	32/54	59	1850	514.25
Anions (mg/L)					
Chloride	33	33/54	25	4530	627.1818182
Fluoride	33	33/54	0.4	4.6	1.766666667
Sulfate as SO4 2-	33	33/54	1	19400	628.9090909
Sulfide as S2-	0	0/24	NA	NA	NA
Total Anions (meq/L)	31	31/52	3.74	569	41.59612903
Cations (mg/L)					
Calcium	33	33/54	1	44	11.33333333
Magnesium	26	26/54	1	12	4.5
Potassium	33	33/54	3	13200	503.4545455
Sodium	33	33/54	49	5160	611.6060606
Total Cations (meq/L)	31	31/52	3.81	562	41.12322581
Other Inorganics (mg/L)					
Ammonia as N	29	29/53	0.01	2.6	0.253793103
Dissolved Oxygen (Lab Test)	6	6/27	7.5	10.1	9.05
Sodium Absorption Ratio	6	6/27	5.26	40.2	21.36
Total Cyanide	0	0/27	NA	NA	NA
Total Dissolved Solids @180°C					
Dissolved Metals (mg/L)					
Aluminium (Dissolved)	24	24/47	0.02	2.54	0.32125
Arsenic (Dissolved)	26	26/54	0.001	0.128	0.007115385
Barium (Dissolved)	32	32/54	0.056	1.86	0.37271875
Beryllium (Dissolved)	1	1/54	0.096	0.096	0.096
Boron (Dissolved)	25	25/48	0.12	1.52	0.5872
Cadmium (Dissolved)	0	0/54	NA	NA	NA
Caesium (Dissolved)	1	1/22	-5.7	-5.7	-5.7
Chromium (Dissolved)	9	9/54	0.001	0.028	0.004555556
Cobalt (Dissolved)	1	1/54	0.001	0.001	0.001
Copper (Dissolved)	22	22/54	0.001	0.119	0.008318182
Dysprosium (Dissolved)	1	1/22	-5.6	-5.6	-5.6
Iron (Dissolved)	16	16/48	0.07	0.54	0.24375
Lead (Dissolved)	1	1/54	0.002	0.002	0.002
Lithium (Dissolved)	20	20/41	0.006	0.501	0.09825
Manganese (Dissolved)	26	26/54	0.001	0.236	0.032153846
Mercury (Dissolved)	0	0/54	NA	NA	NA
Molybdenum (Dissolved)	18	18/47	0.001	0.532	0.033333333
Nickel (Dissolved)	9	9/54	0.001	0.106	0.014555556
Selenium (Dissolved)	0	0/48	NA	NA	NA
Silver (Dissolved)	0	0/43	NA	NA	NA
Strontium (Dissolved)	29	29/50	0.112	2.72	0.587310345
Tin (Dissolved)	3	3/41	0.002	0.003	0.002333333
Uranium (Dissolved)	3	3/43	0.001	0.002	0.001333333
Vanadium (Dissolved)	4	4/54	0.01	0.14	0.0425
Zinc (Dissolved)					
Total Metals (mg/L)					
Aluminium (Total)	19	19/41	0.02	19.8	4.147894737
Arsenic (Total)	18	18/48	0.001	0.135	0.009888889
Barium (Total)	27	27/48	0.076	1.87	0.374777778

Table C-2 Surface Water Quality Data for Stimulation Monitoring in Flowback Storage Pond

Parameter	Number of Detections	Detection Ratio	Minimum	Maximum	Mean
Beryllium (Total)	0	0/48	NA	NA	NA
Boron (Total)	19	19/42	0.07	1.47	0.652631579
Cadmium (Total)	0	0/48	NA	NA	NA
Chromium (Total)	13	13/48	0.002	0.031	0.007923077
Cobalt (Total)	7	7/48	0.001	0.005	0.002142857
Copper (Total)	22	22/48	0.001	0.14	0.010045455
Iron (Total)	18	18/42	0.06	11.8	3.167222222
Lead (Total)	8	8/48	0.001	0.009	0.004875
Lithium (Total)	20	20/41	0.005	0.46	0.09815
Manganese (Total)	27	27/48	0.005	0.255	0.042148148
Mercury (Total)	0	0/48	NA	NA	NA
Molybdenum (Total)	14	14/41	0.001	0.628	0.047357143
Nickel (Total)	20	20/48	0.001	0.12	0.00875
Selenium (Total)	0	0/42	NA	NA	NA
Silver (Total)	0	0/43	NA	NA	NA
Strontium (Total)	23	23/44	0.13	2.7	0.651565217
Tin (Total)	3	3/41	0.002	0.004	0.002666667
Uranium (Total)	4	4/43	0.001	0.002	0.00175
Vanadium (Total)	5	5/48	0.02	0.14	0.05
Zinc (Total)					
Radioactivity (Bq/L)					
Gross Alpha	0	0/22	NA	NA	NA
Gross Beta Activity - 40k	1	1/22	1.43	1.43	1.43

Table C-3 Surface Water Quality Data for Stimulation Monitoring in Initial Flowback

Parameter	Number of Detections	Detection Ratio	Minimum	Maximum	Mean
Polychorindated Biphenyls (mg/L)					
Aroclor 1016	0	0/25	NA	NA	NA
Aroclor 1221	0	0/25	NA	NA	NA
Aroclor 1232	0	0/25	NA	NA	NA
Aroclor 1242	0	0/25	NA	NA	NA
Aroclor 1248	0	0/25	NA	NA	NA
Aroclor 1254	0	0/25	NA	NA	NA
Aroclor 1260	0	0/25	NA	NA	NA
Aroclor 1262	0	0/25	NA	NA	NA
Total Polychlorinated Biphenyls	0	0/25	NA	NA	NA
BTEX (mg/L)					
Benzene	0	0/44	NA	NA	NA
Ethylbenzene	0	0/44	NA	NA	NA
meta- & para-Xylene	0	0/44	NA	NA	NA
ortho-Xylene	0	0/44	NA	NA	NA
Sum of BTEX	2	2/44	0.002	0.004	0.003
Toluene	2	2/44	0.002	0.004	0.003
Total Xylenes	0	0/44	NA	NA	NA
Polycyclic Aromatic Hydrocarbons (mg/L)					
2-Methylnaphthalene	0	0/22	NA	NA	NA
Acenaphthene	0	0/44	NA	NA	NA
Acenaphthylene	0	0/44	NA	NA	NA
Anthracene	0	0/44	NA	NA	NA
Benz(a)anthracene	0	0/44	NA	NA	NA
Benzo(a)pyrene	0	0/44	NA	NA	NA
Benzo(b)fluoranthene	0	0/44	NA	NA	NA
Benzo(g.h.i)perylene	0	0/44	NA	NA	NA
Benzo(k)fluoranthene	0	0/44	NA	NA	NA
Chrysene	0	0/44	NA	NA	NA
Dibenz(a,h)anthracene	0	0/44	NA	NA	NA
Fluoranthene	0	0/44	NA	NA	NA
Fluorene	0	0/44	NA	NA	NA
Indeno(1.2.3.cd)pyrene	0	0/44	NA	NA	NA
Naphthalene	6	6/44	0.0017	0.0111	0.0053
Phenanthrene	0	0/44	NA	NA	NA
Pyrene	0	0/44	NA	NA	NA
Sum of Polycyclic Aromatic Hydrocarbons	6	6/40	0.0017	0.0111	0.0053
Total Petroleum Hydrocarbons (mg/L)					
C10-C14 Fraction	14	14/44	0.05	1.15	0.338461538
C10-C36 Fraction (sum)	22	22/44	0.16	5.74	1.515238095
C15-C28 Fraction	22	22/44	0.1	2.94	0.746666667
C29-C36 Fraction	19	19/44	0.12	2.62	0.652222222
C6-C9 Fraction	5	5/44	0.19	2.64	1.0875
Total Recoverable Hydrocarbons (mg/L)					
>C10-C16 Fraction	11	11/44	0.17	1.22	0.375454545
>C10-C40 Fraction (sum)	21	21/44	0.11	5.92	1.6265
>C16-C34 Fraction	21	21/44	0.11	4.52	1.192
>C34-C40 Fraction	15	15/44	0.1	1.22	0.325714286
C6-C10 Fraction	7	7/44	0.02	2.66	0.745
C6-C10 Fraction minus BTEX (F1)	7	7/44	0.02	2.66	0.745
SG>C10 - C16 Fraction	0	0/21	NA	NA	NA
SG>C10 - C40 Fraction (sum)	0	0/21	NA	NA	NA
SG>C16 - C34 Fraction	0	0/21	NA	NA	NA
SG>C34 - C40 Fraction	0	0/21	NA	NA	NA
SGC10 - C14 Fraction	0	0/21	NA	NA	NA
SGC10 - C36 Fraction (sum)	0	0/21	NA	NA	NA
SGC15 - C28 Fraction	0	0/21	NA	NA	NA
SGC29 - C36 Fraction	0	0/21	NA	NA	NA

Table C-3 Surface Water Quality Data for Stimulation Monitoring in Initial Flowback

Parameter	Number of Detections	Detection Ratio	Minimum	Maximum	Mean
Alkalinity (mg/L)					
Bicarbonate Alkalinity as CaCO3	21	21/44	37	1190	387.45
Carbonate Alkalinity as CaCO3	6	6/44	19	162	24
Hydroxide Alkalinity as CaCO3	0	0/44	NA	NA	NA
Residual Alkali (meq/L)	19	19/40	-67.8	22.4	1.405
Total Alkalinity as CaCO3	21	21/44	37	1210	393.3
Anions (mg/L)					
Chloride	23	23/44	34	24200	2318.909091
Fluoride	23	23/44	0.2	4.3	1.1
Sulfate as SO4 2-	23	23/44	4	1400	145.9090909
Sulfide as S2-	0	0/27	NA	NA	NA
Total Anions (meq/L)	21	21/42	4.18	729	80.079
Cations (mg/L)					
Calcium	23	23/44	6	1590	96
Magnesium	23	23/44	1	72	9.590909091
Potassium	23	23/44	6	18200	1513.545455
Sodium	23	23/44	59	3890	585.9090909
Total Cations (meq/L)	21	21/42	4.18	720	74.1395
Other Inorganics (mg/L)					
Ammonia as N	23	23/44	0.02	17.3	2.909090909
Dissolved Oxygen (Lab Test)	4	4/25	3.2	9.5	7.35
Sodium Absorption Ratio	3	3/24	24.8	38.6	29.76666667
Total Cyanide	0	0/25	NA	NA	NA
Total Dissolved Solids @180°C	23	23/44	310	64400	6641.818182
Dissolved Metals (mg/L)					
Aluminium (Dissolved)	20	20/42	0.08	1.45	0.365263158
Arsenic (Dissolved)	21	21/44	0.001	0.066	0.0095
Barium (Dissolved)	23	23/44	0.019	6.55	0.888863636
Beryllium (Dissolved)	0	0/44	NA	NA	NA
Boron (Dissolved)	20	20/42	0.05	6.96	2.044736842
Cadmium (Dissolved)	4	4/44	0.0001	0.0002	0.00015
Caesium (Dissolved)	0	0/21	NA	NA	NA
Chromium (Dissolved)	17	17/44	0.002	0.09	0.014375
Cobalt (Dissolved)	14	14/44	0.001	0.005	0.002615385
Copper (Dissolved)	21	21/44	0.001	0.093	0.01115
Dysprosium (Dissolved)	0	0/21	NA	NA	NA
Iron (Dissolved)	20	20/42	0.1	38.9	7.421578947
Lead (Dissolved)	9	9/44	0.001	0.004	0.001555556
Lithium (Dissolved)	17	17/38	0.006	0.461	0.0759375
Manganese (Dissolved)	23	23/44	0.004	0.889	0.357409091
Mercury (Dissolved)	0	0/44	NA	NA	NA
Molybdenum (Dissolved)	21	21/42	0.001	0.352	0.0408
Nickel (Dissolved)	22	22/44	0.004	0.064	0.023333333
Selenium (Dissolved)	0	0/42	NA	NA	NA
Silver (Dissolved)	0	0/39	NA	NA	NA
Strontium (Dissolved)	22	22/43	0.074	74.5	4.354761905
Tin (Dissolved)	3	3/38	0.002	0.066	0.025333333
Uranium (Dissolved)	3	3/39	0.001	0.002	0.001333333
Vanadium (Dissolved)	1	1/44	0.01	0.01	0.01
Zinc (Dissolved)	20	20/44	0.005	0.704	0.121894737

Table C-3 Surface Water Quality Data for Stimulation Monitoring in Initial Flowback

Parameter	Number of Detections	Detection Ratio	Minimum	Maximum	Mean
Total Metals (mg/L)					
Aluminium (Total)	17	17/38	0.15	9.43	1.865
Arsenic (Total)	17	17/40	0.002	0.019	0.004875
Barium (Total)	19	19/40	0.08	7.12	0.603055556
Beryllium (Total)	0	0/40	NA	NA	NA
Boron (Total)	16	16/38	0.06	8.14	2.642666667
Cadmium (Total)	5	5/40	0.0002	0.0003	0.000225
Chromium (Total)	17	17/40	0.002	0.123	0.0418125
Cobalt (Total)	16	16/40	0.001	0.019	0.0042
Copper (Total)	19	19/40	0.004	0.144	0.041333333
Iron (Total)	17	17/38	0.27	45.4	20.45875
Lead (Total)	16	16/40	0.001	0.012	0.003
Lithium (Total)	17	17/38	0.008	0.429	0.0785625
Manganese (Total)	19	19/40	0.036	0.921	0.485777778
Mercury (Total)	0	0/40	NA	NA	NA
Molybdenum (Total)	15	15/38	0.001	0.396	0.048428571
Nickel (Total)	19	19/40	0.004	0.122	0.040833333
Selenium (Total)	0	0/38	NA	NA	NA
Silver (Total)	0	0/40	NA	NA	NA
Strontium (Total)	19	19/40	0.103	82.4	4.986055556
Tin (Total)	3	3/38	0.001	0.005	0.003
Uranium (Total)	6	6/40	0.001	0.002	0.0016
Vanadium (Total)	2	2/40	0.01	0.03	0.01
Zinc (Total)	18	18/40	0.014	0.694	0.215411765
Radioactivity (Bq/L)					
Gross Alpha	0	0/22	NA	NA	NA
Gross Beta Activity - 40k	1	1/22	18.4	18.4	18.4

Table C-4 Water Quality Data for Stimulation Monitoring in Pumped Flowback

Parameter	Number of Detections	Detection Ratio	Minimum	Maximum	Mean
Polychorindated Biphenyls (mg/L)					
Aroclor 1016	0	0/16	NA	NA	NA
Aroclor 1221	0	0/16	NA	NA	NA
Aroclor 1232	0	0/16	NA	NA	NA
Aroclor 1242	0	0/16	NA	NA	NA
Aroclor 1248	0	0/16	NA	NA	NA
Aroclor 1254	0	0/16	NA	NA	NA
Aroclor 1260	0	0/16	NA	NA	NA
Aroclor 1262	0	0/16	NA	NA	NA
Total Polychlorinated Biphenyls	0	0/16	NA	NA	NA
BTEX (mg/L)					
Benzene	56	56/74	<0.001	1.92	0.4584
Ethylbenzene	54	54/74	<0.002	0.053	0.0095
meta- & para-Xylene	55	55/74	<0.002	0.522	0.0946
ortho-Xylene	52	52/74	<0.002	0.153	0.0276
Sum of BTEX	61	61/74	<0.001	3.24	0.9944
Toluene	61	61/74	<0.002	1.77	0.4058
Total Xylenes	65	55/74	<0.002	0.61	0.1215
Polycyclic Aromatic Hydrocarbons (mg/L)					
2-Methylnaphthalene	0	0/0	NA	NA	NA
Acenaphthene	0	0/74	NA	NA	NA
Acenaphthylene	0	0/74	NA	NA	NA
Anthracene	0	0/74	NA	NA	NA
Benz(a)anthracene	0	0/74	NA	NA	NA
Benzo(a)pyrene	0	0/74	NA	NA	NA
Benzo(b)fluoranthene	0	0/74	NA	NA	NA
Benzo(g.h.i)perylene	0	0/74	NA	NA	NA
Benzo(k)fluoranthene	0	0/74	NA	NA	NA
Chrysene	0	0/74	NA	NA	NA
Dibenz(a,h)anthracene	0	0/74	NA	NA	NA
Fluoranthene	0	0/74	NA	NA	NA
Fluorene	0	0/74	NA	NA	NA
Indeno(1.2.3.cd)pyrene	0	0/74	NA	NA	NA
Naphthalene	52	52/74	<0.001	0.0218	0.0065
Phenanthrene	0	0/74	NA	NA	NA
Pyrene	0	0/74	NA	NA	NA
Sum of Polycyclic Aromatic Hydrocarbons	52	52/74	<0.001	0.0218	0.008
Total Petroleum Hydrocarbons (mg/L)					
C10-C14 Fraction	73	73/74	<0.05	3.56	0.4019
C10-C36 Fraction (sum)	73	73/74	<0.05	9.53	1.4193
C15-C28 Fraction	51	51/74	<0.1	4.8	0.6515
C29-C36 Fraction	55	55/74	<0.05	3.13	0.3895
C6-C9 Fraction	57	57/74	<0.02	4.4	1.2585
Total Recoverable Hydrocarbons (mg/L)					
>C10-C16 Fraction	67	67/74	<0.1	2.57	0.3455
>C10-C40 Fraction (sum)	68	68/74	<0.1	9.89	1.4424
>C16-C34 Fraction	55	55/74	<0.1	7.34	0.925
>C34-C40 Fraction	36	36/74	<0.1	1.56	0.2145
C6-C10 Fraction	59	59/74	<0.02	4.7	1.4018
C6-C10 Fraction minus BTEX (F1)	37	37/54	<0.02	1.98	0.3553
SG>C10 - C16 Fraction	0	0/2	<0.1	<0.1	<0.1
SG>C10 - C40 Fraction (sum)	1	1/2	<0.1	0.7	0.375
SG>C16 - C34 Fraction	1	1/2	<0.1	0.59	0.32
SG>C34 - C40 Fraction	1	1/2	<0.1	0.11	<0.1
SGC10 - C14 Fraction	0	0/2	<0.05	<0.05	<0.05
SGC10 - C36 Fraction (sum)	2	2/2	0.05	0.65	0.35
SGC15 - C28 Fraction	1	1/2	<0.1	0.38	0.215
[illegible] - C36 Fraction	2	2/2	0.05	0.27	0.16

Table C-4 Water Quality Data for Stimulation Monitoring in Pumped Flowback

Parameter	Number of Detections	Detection Ratio	Minimum	Maximum	Mean
Alkalinity (mg/L)					
Bicarbonate Alkalinity as CaCO3	74	74/74	166	3680	1238.9459
Carbonate Alkalinity as CaCO3	24	24/74	<1	1420	50.1892
Hydroxide Alkalinity as CaCO3	0	0/74	<1	<1	<1
Residual Alkali (meq/L)	59	59/59	0.67	71.9	24.6868
Total Alkalinity as CaCO3	74	74/74	262	3680	1288.8514
Anions (mg/L)					
Chloride	74	74	210	73200	3794.6081
Fluoride	74	74	0.2	3.3	1.7203
Sulfate as SO4 2-	68	68/74	<1	280	33.4324
Sulfide as S2-					
Total Anions (meq/L)	74	74/74	19.8	2080	133.477
Cations (mg/L)					
Calcium	74	74/74	1	215	54.5946
Magnesium	60	60/74	<1	40	8.027
Potassium	74	74/74	9	22200	452.5946
Sodium	74	74/74	426	31200	2537.8378
Total Cations (meq/L)	74	74/74	19.8	1930	126.7622
Other Inorganics (mg/L)					
Ammonia as N	74	74/74	0.8	44.2	9.4418
Dissolved Oxygen (Lab Test)	15	15/15	4.1	10.4	6.6133
Sodium Absorption Ratio	56	56/56	58.3	911	109.2821
Total Cyanide	0	0/15	<0.004	<0.004	<0.004
Total Dissolved Solids @180°C	74	74/74	1110	119000	8783.9189
Dissolved Metals (mg/L)					
Aluminium (Dissolved)	30	30/74	NA	NA	NA
Arsenic (Dissolved)	48	48/74	<0.001	0.14	0.0026
Barium (Dissolved)	74	74/74	0.008	36.3	3.485
Beryllium (Dissolved)	0	0/74	NA	NA	NA
Boron (Dissolved)	74	74/74	0.43	26.1	10.0908
Cadmium (Dissolved)	12	12/74	NA	NA	NA
Caesium (Dissolved)	0	0/0	NA	NA	NA
Chromium (Dissolved)	59	59/74	<0.001	0.016	0.0042
Cobalt (Dissolved)	5	5/74	<0.001	0.002	0.0014
Copper (Dissolved)	38	38/74	<0.001	0.005	0.0016
Dysprosium (Dissolved)	0	0/0	NA	NA	NA
Iron (Dissolved)	72	72/74	<0.05	120	10.8368
Lead (Dissolved)	0	0/74	NA	NA	NA
Lithium (Dissolved)	59	59/59	0.176	2.64	1.4019
Manganese (Dissolved)	74	74/74	0.004	1.18	0.2461
Mercury (Dissolved)	0	0/74	NA	NA	NA
Molybdenum (Dissolved)	56	56/74	<0.001	0.257	0.0233
Nickel (Dissolved)	65	65/74	<0.001	0.05	0.0066
Selenium (Dissolved)	0	0/74	NA	NA	NA
Silver (Dissolved)	0	0/59	NA	NA	NA
Strontium (Dissolved)	74	74/74	0.032	31.1	9.6296
Tin (Dissolved)	4	4/59	<0.001	0.037	0.0012
Uranium (Dissolved)	0	0/59	NA	NA	NA
Vanadium (Dissolved)	20	20/74	<0.01	0.03	0.0205
Zinc (Dissolved)	34	30/74	<0.005	0.047	0.0079

Table C-4 Water Quality Data for Stimulation Monitoring in Pumped Flowback

Parameter	Number of Detections	Detection Ratio	Minimum	Maximum	Mean
Total Metals (mg/L)					
Aluminium (Total)	50	50/59	<0.01	2.65	0.1069
Arsenic (Total)	41	41/59	<0.001	0.015	0.0035
Barium (Total)	59	59/59	0.098	37.9	4.6268
Beryllium (Total)	0	0/59	NA	NA	NA
Boron (Total)	59	59/59	0.55	55.3	13.5805
Cadmium (Total)	12	12/59	<0.0001	0.0004	0.0001
Chromium (Total)	58	58/59	<0.001	0.147	0.0152
Cobalt (Total)	22	22/59	<0.001	0.01	0.0013
Copper (Total)	59	59/59	0.002	0.156	0.022
Iron (Total)	59	59/59	0.79	150	25.8159
Lead (Total)	13	13/59	<0.001	0.035	0.002
Lithium (Total)	59	59/59	0.199	2.84	1.4732
Manganese (Total)	59	59/59	0.054	1.66	0.4
Mercury (Total)	0	0/59	NA	NA	NA
Molybdenum (Total)	48	48/59	<0.001	0.231	0.0156
Nickel (Total)	54	54/59	<0.001	0.051	0.0123
Selenium (Total)	2	2/59	<0.01	0.01	0.01
Silver (Total)	0	0/59	NA	NA	NA
Strontium (Total)	59	59/59	0.159	32.4	12.3153
Tin (Total)	45	45/59	<0.001	0.161	0.0035
Uranium (Total)	0	0/59	NA	NA	NA
Vanadium (Total)	2	2/59	<0.01	0.02	0.015
Zinc (Total)	37	37/59	<0.005	0.251	0.0218
Radioactivity (Bq/L)					
Gross Alpha	0	0/24	NA	NA	NA
Gross Beta Activity - 40k	13	13/24	<0.1	1.02	0.2504

Santos

Appendix C1-3

Table E1. Comparison of Estimated Schlumberger Theoretical Concentrations to Human Health Drinking Water Guidelines

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)					Estimated Initial Concentration in flowback (150% of injected fluid volume) per coal seam per percent of mass returned calculated using equation: Initial Flowback Concentration = FBconcentration (mg/L)/ FB dilution 150% x percent mass								Drinking Water Guideline (mg/L)	Rapidly Biodegradable	Ratio of COPC Concentrations and Screening Criteria (Ratio greater than one = unacceptable potential risk)							
							YF125LG Crosslinked Gel				Maximum of All Stimulation Events						YF125LG Crosslinked Gel				Maximum of All Stimulation Events			
		Waterfrac / Slickwater	WF130 Linear Gel	WF130 Linear Base Gel for Foam Fluid	YF125LG Crosslinked Gel	Maximum of All Stimulation Events	20%	40%	60%	80%	20%	40%	60%	80%			20%	40%	60%	80%	20%	40%	60%	80%
Magnesium chloride	7786-30-3	3	3	3	1	3	0.1	0.3	0.4	0.5	0.4	0.8	1.2	1.6	250	No	0.001	0.001	0.002	0.002	0.002	0.003	0.005	0.006
Diatomaceous earth, calcined	91053-39-3	30	30	30	22	30	2.9	5.9	8.8	11.7	4.0	8.0	12.0	16.0	NA	No								
Crystalline silica (cristobalite)	14464-46-1	Assumed to be sand, not included in chemical mass balance													NA	No								
Crystalline silica (quartz)	14808-60-7														NA	No								
Diammonium peroxodisulphate (ammonium persulphate)	7727-54-0	-	410	-	712	712	94.9	189.9	284.8	379.7	94.9	189.9	284.8	379.7	250	No	0.380	1	1	2	0.380	1	1	2
Carbohydrate polymer (guar gum[1])	9000-30-0	-	3,540	3,323	2,884	3,540	384.5	769.1	1153.6	1538.1	472.0	944.0	1416.0	1888.0	44	No	9	17	26	35	11	21	32	43
Non-crystalline silica (amorphous silica surrogate)	7631-86-9	-	10	9	8	10	1.1	2.1	3.2	4.3	1.3	2.7	4.0	5.3	NA	No								
Polypropylene glycol	25322-69-4	-	30		-	30	-	-	-	-	4.0	8.0	12.0	16.0	2	Yes	-	-	-	-	2	4	6	8
Ammonium C6-C10 alcohol ethoxysulfate	68187-17-7	-	-	1,048	-	1,048	-	-	-	-	139.7	279.5	419.2	558.9	2.6	Yes	-	-	-	-	54	107	161	215
Alcohols C6-C10 ethoxylated	68439-45-2	-	-	18	-	18	-	-	-	-	2.4	4.8	7.2	9.6	2	Yes	-	-	-	-	1	2	4	5
Hydrochloric acid	7647-01-0	-	-	-	635	635	84.7	169.3	254.0	338.7	84.7	169.3	254.0	338.7	250	No	0.339	0.677	1	1	0.339	0.677	1	1
Vinylidene chloride/methylacrylate	25038-72-6	-	-	-	18	18	2.4	4.8	7.2	9.6	2.4	4.8	7.2	9.6	NA	No								
Tetrasodium ethylenediaminetetraacetate (EDTA)	64-02-8	-	-	-	8	8	1.1	2.1	3.2	4.3	1.1	2.1	3.2	4.3	0.25	No	4	9	13	17	4	9	13	17
magnesium silicate hydrate (talc)	14807-96-6	-	-	-	1	1	0.1	0.3	0.4	0.5	0.1	0.3	0.4	0.5	NA	No								
Sodium hydroxide	1310-73-2	-	-	-	1	1	0.1	0.3	0.4	0.5	0.1	0.3	0.4	0.5	180	No	0.001	0.001	0.002	0.003	0.001	0.001	0.002	0.003
Highlighted cells are ratios greater than one and indicate a potentially unacceptable risk																**Cumulative Ratio**	**14**	**27**	**41**	**55**	**73**	**145**	**218**	**291**

Table E-2 Comparison of Empirical Flowback Concentrations to Human Health Screening Guidelines

Human Health Screening Values	
Parameter	
BTEX (mg/L)	
Benzene	0.001
Ethylbenzene	0.3
meta-& para-Xyelenes	NA
ortho-Xylene	NA
Sum of BTEX	NA
Toluene	0.8
Total Xylenes	0.6
Polynuclear Aromatic Hydrocarbons (mg/L)	
Naphthalene	0.00014
Total Petroleum Hydrocarbons (mg/L)	
C10-C14 Fraction	NA
C10-C36 Fraction (sum)	18
C15-C28 Fraction	NA
C20-C36 Fraction	NA
C6-C9 Fraction	Na
Metals (mg/L)	
Aluminium	0.2
Arsenic	0.007
Barium	0.7
Boron	4
Cadmium	0.002
Chromium	0.1
Copper	2
Iron	0.3
Lead	0.01
Lithium	0.031
Manganese	0.5
Molybdenum	0.078
Nickel	0.02
Strontium	9.3
Tin	9.3
Vanadium	0.078
Zinc	3

Pump Flow Back Hazard Quotients		
Parameter	**Maximum**	**Mean**
BTEX (mg/L)		
Benzene	41.00	15.08
Ethylbenzene	0.01	0.01
meta- & para-Xylene	NA	NA
ortho-Xylene	NA	NA
Sum of BTEX	NA	NA
Toluene	0.1	0.0
Total Xylenes	0.1	0.0
Polycyclic Aromatic Hydrocarbons (mg/L)		
Naphthalene	27.1	15.0
Total Petroleum Hydrocarbons (mg/L)		
C10-C14 Fraction	NA	NA
C10-C36 Fraction (sum)	0.5	0.1
C15-C28 Fraction	NA	NA
C29-C36 Fraction	NA	NA
C6-C9 Fraction	NA	NA
Metals (mg/L)		
Aluminium	13.3	0.5
Arsenic	2.1	0.5
Barium	54.1	6.6
Boron	13.8	3.4
Cadmium	0.2	0.1
Chromium	1.5	0.2
Copper	0.1	0.0
Iron	500.0	86.1
Lead	3.5	0.2
Lithium	91.6	47.5
Manganese	3.3	0.8
Molybdenum	3.0	0.2
Nickel	2.6	0.6
Strontium	3.5	1.3
Tin	0.0	0.0
Vanadium	0.3	0.2
Zinc	0.1	0.0
Maximum Dilution Factor	**500**	**86**

Highlighted cells indicate exceedance of aquatic screening criteria

Table E-3. Comparison of Estimated Theoretical Schlumberger Concentrations to Aquatic Life Water Guidelines

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)					Estimated Initial Flowback Concentration in flowback (150% of injected fluid volume) per coal seam per percent of mass returned calculated using equation: Mud Pitcon = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L)								PNEC aquatic (mg/L)	Ratio of COPC Concentrations and Screening Criteria (Ratio greater than one = unacceptable potential risk)							
							YF125LG Crosslinked Gel				Maximum of All Stimulation Events					YF125LG Crosslinked Gel				Maximum of All Stimulation Events			
		Waterfrac / Slickwater	WF130 Linear Gel	WF130 Linear Base Gel for Foam Fluid	YF125LG Crosslinked Gel	Maximum of All Stimulation Events	20%	40%	60%	80%	20%	40%	60%	80%		20%	40%	60%	80%	20%	40%	60%	80%
Magnesium chloride	7786-30-3	3	3	3	1	3	0.1	0.3	0.4	0.5	0.4	0.8	1.2	1.6	0.1	1.3E+00	2.7E+00	4.0E+00	5.3E+00	4.0E+00	8.0E+00	1.2E+01	1.6E+01
Diatomaceous earth, calcined	91053-39-3	30	30	30	22	30									NA								
Crystalline silica (cristobalite)	14464-46-1	Assumed to be sand, not included in chemical mass balance													NA								
Crystalline silica (quartz)	14808-60-7														NA								
Diammonium peroxodisulphate (ammonium persulphate)	7727-54-0	-	410	-	712	712	94.9	189.9	284.8	379.7	94.9	189.9	284.8	379.7	0.076	1.2E+03	2.5E+03	3.7E+03	5.0E+03	1.2E+03	2.5E+03	3.7E+03	5.0E+03
Carbohydrate polymer (guar gum[1])	9000-30-0	-	3,540	3,323	2,884	3,540	384.5	769.1	1153.6	1538.1	472.0	944.0	1416.0	1888.0	0.042	9.2E+03	1.8E+04	2.7E+04	3.7E+04	1.1E+04	2.2E+04	3.4E+04	4.5E+04
Non-crystalline silica (amorphous silica surrogate)	7631-86-9	-	10	9	8	10									NA								
Polypropylene glycol	25322-69-4	-	30		-	30	-	-	-	-	4.0	8.0	12.0	16.0	0.1	-	-	-	-	4.0E+01	8.0E+01	1.2E+02	1.6E+02
Ammonium C6-C10 alcohol ethoxysulfate	68187-17-7	-	-	1,048	-	1,048	-	-	-	-	139.7	279.5	419.2	558.9	0.27	-	-	-	-	5.2E+02	1.0E+03	1.6E+03	2.1E+03
Alcohols C6-C10 ethoxylated	68439-45-2	-	-	18	-	18	-	-	-	-	2.4	4.8	7.2	9.6	2.63	-	-	-	-	9.1E-01	1.8E+00	2.7E+00	3.7E+00
Hydrochloric acid	7647-01-0	-	-	-	635	635									NA								
Vinylidene chloride/methylacrylate	25038-72-6	-	-	-	18	18									NA								
Tetrasodium ethylenediaminetetraacetate (EDTA)	64-02-8	-	-	-	8	8	1.1	2.1	3.2	4.3	1.1	2.1	3.2	4.3	2.2	4.8E-01	9.7E-01	1.5E+00	1.9E+00	4.8E-01	9.7E-01	1.5E+00	1.9E+00
magnesium silicate hydrate (talc)	14807-96-6	-	-	-	1	1									NA								
Sodium hydroxide	1310-73-2	-	-	-	1	1									NR								

Highlighted cells indicate exceedance of aquatic screening criteria

Cumulative Ratio 10,406 20,813 31,219 41,626 13,050 26,100 39,150 52,201

Table E-4 Comparison of Empirical Flowback Concentrations to Aquatic Life Water Guidelines

Aquatic Life Screening Values	
Parameter	
BTEX (mg/L)	
Benzene	0.95
Ethylbenzene	0.09
meta-& para-Xyelenes	NA
ortho-Xylene	NA
Sum of BTEX	NA
Toluene	0.002
Total Xylenes	0.013
Polynuclear Aromatic Hydrocarbons (mg/L)	
Naphthalene	0.016
Total Petroleum Hydrocarbons (mg/L)	
C10-C14 Fraction	NA
C10-C36 Fraction (sum)	2
C15-C28 Fraction	NA
C20-C36 Fraction	NA
C6-C9 Fraction	Na
Dissolved Metals (mg/L)	
Aluminium	0.055
Arsenic	0.024
Barium	0.004
Boron	0.37
Cadmium	0.0002
Chromium	0.001
Copper	0.0014
Iron	0.3
Lead	0.0034
Lithium (Dissolved)	0.014
Manganese	1.4
Molybdenum	0.073
Nickel	0.011
Strontium	1.5
Tin (Dissolved)	0.073
Vanadium	0.02
Zinc	0.008

Pump Flow Back Hazard Quotients		
Parameter	**Maximum**	**Mean**
BTEX (mg/L)		
Benzene	0.04	0.02
Ethylbenzene	0.03	0.03
meta- & para-Xylene	NA	NA
ortho-Xylene	NA	NA
Sum of BTEX	NA	NA
Toluene	47.0	10.5
Total Xylenes	2.4	1.1
Polycyclic Aromatic Hydrocarbons (mg/L)		
Naphthalene	0.2	0.1
Total Petroleum Hydrocarbons (mg/L)		
C10-C14 Fraction	NA	NA
C10-C36 Fraction (sum)	4.5	0.7
C15-C28 Fraction	NA	NA
C29-C36 Fraction	NA	NA
C6-C9 Fraction	NA	NA
Dissolved Metals (mg/L)		
Aluminium	48.2	1.9
Arsenic	0.6	0.1
Barium	9475.0	1156.7
Boron	149.5	36.7
Cadmium	2.0	0.5
Chromium	147.0	15.2
Copper	111.4	15.7
Iron	500.0	86.1
Lead	10.3	0.6
Lithium (Dissolved)	202.9	105.2
Manganese	1.2	0.3
Molybdenum	3.2	0.2
Nickel	4.6	1.1
Strontium	21.6	8.2
Tin (Dissolved)	2.2	0.0
Vanadium	1.0	0.8
Zinc	31.4	2.7
Cumulative Hazard Quotient	**10,766**	**1,445**

Highlighted cells indicate exceedance of aquatic screening criteria

Santos

Appendix C2
Halliburton Water and Guar Based Systems
(Original DeltaFoam 140 Formulation)

C1.0 Introduction

As presented in **Section 5.0** of the Hydraulic Fracturing Risk Assessment), a weight-of-evidence approach was used by Santos to evaluate the potential for human health and environmental (e.g., ecological) risks as a result of the hydraulic fracturing processes and the Halliburton water and guar-based fluid system (DeltaFoam 140 formulation).

Golder Associates (Golder), on behalf of Santos, completed a qualitative risk assessment (Golder, 2013d) that evaluated the nature of the geology in the areas undergoing stimulation, the potential for impacts on water resources, the process and chemicals used.

A Quantitative Risk Assessment (QRA), completed by EHS Support, LLC (EHS Support), supplemented the qualitative risk assessment (EHS Support, 2013b). The QRA was conducted to meet Conditions 49e and 49f of the 2 October 2011 approval under the Environmental Protection and Biodiversity Conservation Act 1999 (EPBC 2008/4059) and the EA conditions to assess the toxicity of the mixtures.

Key reports and studies previously submitted for these fluid systems comprise:

- Golder Associates. (2013d). Coal Seam Hydraulic Fracturing Risk Assessment. Combined Stage 1 and Stage 2 Risk Assessment for Halliburton. Revision 1. 3 May 2013.
- EHS Support. (2013b). Coal Seam Gas Hydraulic Fracturing Quantitative Risk Assessment Report for Halliburton Delta 140 Chemistry Report. 4 August 2013.

The QRA evaluated both the original DeltaFoam 140 and Delta 140 formulations; refer to Appendix C5 for discussion of the results of the QRA for the alternative fluid system (Delta 140).

The results and conclusions of the qualitative risk assessment components and the QRA are summarised below. Refer to the text of this report for detailed discussions on methodologies employed for each component; specific tables referred to in this summary are included for review with this document. Table numbers specific to the original reports were retained for consistency between documents.

C2.0 Qualitative Risk Assessment and Evaluation

C2.1 Chemicals Evaluated

Three 'fluid systems' were assessed, each having a foamed and non-foamed version, for a total of six hydraulic fracturing fluid mixtures. Chemical constituents identified in each hydraulic fracturing fluid system were evaluated in the hydraulic fracturing risk assessments. The list of individual chemicals is presented in Table 1. A mass balance of the chemicals within each of the hydraulic fracturing fluid systems is provided as **Appendix C2-1** (Table D-3; Golder, 2013d). The additive coffee extract was later added as a potential supplement to all fluid mixtures on an 'as-needed' basis to be used at an in-fluid concentration of 0.4 mg/L.

Information regarding the chemical and physical properties of the individual chemicals listed below can be found on the Safety Data Sheets in **Appendix E**.

It is noted, while none of the fracturing fluid chemicals identified contain benzene, toluene, ethylbenzene, xylenes (BTEX) or polycyclic aromatic hydrocarbons (PAHs), that PAHs occur naturally in coal and it is possible that certain PAHs may naturally be present in the coal seam groundwater used in the hydraulic fracturing process.

Table 1. Hydraulic fracturing chemicals

Chemical	Cas Number
Guar Gum	9000-30-0
Acetic Acid	64-19-7
Alkylated quaternary chloride (surrogate tetramethylammonium chloride)	75-57-0
Ethanol	67-17-5
Terpenes and terpenoids, sweet orange oil	68647-72-3
1,2 Benzisothiazolin -3-one	2634-33-5
Non-ionic surfactant mix™	-*
Surfactant mix™	-*
Coco dimethylaminopropyl betaine	61789-40-0
Fatty acid ester™	-*
Ethoxylated fatty acid ester™	-*
Tetrakis (hydroxymethyl) phosphonium sulphate (THPS)	55566-30-8
Enzyme™	-*
Terpene hydrocarbons by products™	68956-56-9
Sodium chloride	7647-14-5
Sodium hydroxide	1310-73-2
Sodium thiosulfate	7772-98-7
Bentonite	121888-68-4
Calcium chloride	10043-52-4
Silica gel	112926-00-8
Sodium sulfate	7757-82-6
Sodium sulfite	7757-83-7
Crystalline silica	14808-60-7

Chemical	Cas Number
Monoethanolamine borate	26038-87-9
Coffee Extract	68916-18-7

* The CAS numbers for fatty acid ester, ethoxylated fatty acid ester, non-ionic surfactant mix, surfactant mix, terpene hydrocarbon by products and enzyme have not been included in this table due to commercial confidentiality.

C2.2 Risk Assessment Framework and Findings

As discussed in **Section 5.0** of the systematic weight of evidence approach was utilised to complete the risk assessment for the Schlumberger Fluid Systems. The work has involved the following evaluations:

Qualitative Assessment Methodologies

- Environmental Hazard Assessment
- Exposure Assessment including Fate and Transport Assessment in Groundwater
- Mass Balance of the fluid systems
- Groundwater Fate and Transport Modelling.

Quantitative Risk Assessment Methodologies

- Quantitative Human Health Risk Assessment
- Quantitative Ecological Risk Assessment for Terrestrial and Aquatic Receptors.

C2.3 Environmental Hazard Assessment

The environmental hazard assessment approach outlined in **Section 6.1** was undertaken to rank the hydraulic fracturing chemicals based on persistence (P), bioaccumulation (B) and toxic (T) potential (hereafter referred to as PBT).

A combination of data sets were used in the PBT assessment including chemical information sheets (**Appendix E** and **Appendix G**), the Hazardous Substance Database, and modelled data from USEPA (2009) EPISUITE modelling software, when data not available from other sources.

Of the 24 chemicals listed above, three were not considered for PBT ranking. Physico-chemical and/or toxicological data were not available, and surrogates could not be identified for silica gel (surrogate amorphous silica, 112926-00-8), crystalline silica (14808-60-7), and terpene hydrocarbon by products in a non-specified formulation (CAS number withheld for proprietary reasons). Crystalline silica (14808-60-7) relate to the sand used as the proppant, and therefore is not considered to represent an environmental hazard.

C2.4 Exposure Assessment

As discussed in **Section 7.0**, the exposure assessment identified receptors potentially exposed to COPCs identified for the study and outlines the exposure pathways by which the receptors may come in to contact with the COPCs.

C2.4.1 Onsite Exposures

Of the pathways evaluated, the onsite assessment indicated that the majority of exposures were unlikely or incomplete; given the application of operational controls by Santos. These operational controls include:

- Occupational health and safety procedures implemented during hydraulic fracturing operations to prevent workers from direct contact with chemicals during spills and when handling flowback water or sediments
- Implementation of spill containment procedures during operations to prevent migration of and exposure to chemicals
- Disposal or capping of sediments contained within drained mud pits and turkey nests, to prevent exposure to contaminates in windborne dust
- Fencing of drill pads to prevent trespassers and installation of signs to indicate that the water in the turkey's nest and mud pit is not potable and may contain contaminants
- Installation and maintenance of fences around the well pad to prevent access to the drill pad by livestock and large native fauna
- Mud pits and turkey's nests lined with clay or similar material to prevent seepage of flowback water into underlying aquifer.

Details regarding onsite exposure scenarios, receptors, pathways evaluated are provided in Table 50 (Golder, 2013d) attached to this Appendix.

The following on-site pathways were determined to be potentially complete and were evaluated:

- Exposure to COPCs in mud pit and turkey's nest sediments:
  - Workers and trespassers via direct contact (inhalation of dusts).
- Exposure to COPCs in flowback water in turkey's nest and mud pit:
  - Workers while working with turkey's nest inlet/liner or drainage of turkey's nest or mud pit via direct contact
  - Trespassers after entry (accidental or deliberate) to turkey's nest or mud pit via direct contact
  - Native terrestrial fauna after entry (accidental or deliberate) to turkey's nest or mud pit via ingestion
  - Stock animals after entry (accidental or deliberate) to turkey's nest or mud pit via ingestion.
- Exposure to COPCs in flowback water released to environment (spill, leak, mud pit, turkey nest delivery system failure or overflow):
  - Workers, terrestrial fauna, terrestrial flora via ingestion, dermal contact and inhalation.

C2.4.2 Offsite Exposure Pathways

Potential off site exposure pathways were evaluated for residents, stock animals, native flora and fauna and aquatic ecosystems. Four possible sources were identified, hydraulic fracturing fluids, sediments from mud pit or turkey's nest, flowback water and coal seam gas (methane). The exposure assessment concluded that with the implementation of operational controls including use of clay liners in turkey nests, well integrity testing, operational monitoring and capping and/or removal of sludge all off-site exposures are considered unlikely and incomplete.

Of the pathways evaluated, the following off-site pathways were determined to be potentially complete and were evaluated:

- Exposure to COPCs in flowback water released to environment (spill, leak, mud pit, turkey nest delivery system failure or overflow):
  - Residents, terrestrial fauna, terrestrial flora via ingestion, dermal contact and inhalation.

Details regarding offsite exposure scenarios, receptors, pathways evaluated are provided in Table 51 (Golder, 2013d attached to this Appendix).

C2.5 Mass Balance of Fluid System

A quantitative mass balance calculation was undertaken to identify the amount of each chemical additive of the hydraulic fracturing fluid in the following fluid systems:

- Delta 140
- DeltaFoam 140
- Linear Gel
- Linear Gel Foamed
- Water
- Water Foamed.

The results of the mass balance calculations are presented in the referenced Table D-3 (Golder, 2013d) that is included in **Appendix C2-1**.

C2.6 Fate and Transport Modelling

For the sake of conservatism, the following chemicals were further assessed for mobility in the environment through fate and transport modelling:

- Fatty acid ester
- 1,2 Benzisothiazolin -3-one
- Alkylated quaternary chloride
- Sweet orange oil
- Surfactant mix.

Details on the fate and transport modelling methodology and results are provided in **Section 7.2** of the report. The modelling demonstrated that there is limited potential for chemicals to migrate within the coal seams.

C3.0 Quantitative Risk Assessment

In accordance with the methodologies presented in **Section 8.0**, a QRA was conducted on both theoretical and empirical datasets for those chemicals identified in the Combined Stage 1 and 2 Risk Assessments (EHS Support, 2013b). The QRA approach evaluates the toxicity of the individual substances and characterises the cumulative risks of the total effluent toxicity and ecotoxicity.

Generally, this methodology includes the identification of the hazards posed by constituents in the flowback water, compilation of the toxicity criteria for each constituent, development of exposure models to estimate the daily intake of the constituents, and calculations of individual constituent hazard quotients (daily intake divided by the toxicity criteria) and a cumulative constituent hazard index (HI) for each potentially complete exposure pathway for each human or terrestrial receptor.

Potential complete exposure pathways to the storage of flowback from hydraulically stimulated wells and potential risks to humans, terrestrial and aquatic receptors from the potential storage and accidental releases are evaluated in the QRA.

No further assessment of groundwater was determined to be necessary due to lack of potentially complete exposure pathways. Detailed operational procedures have been provided that are designed to contain the hydraulic fracturing fluids within the coal sequences, and no connection exists between groundwater in the coal seams and surface-water or springs (and therefore MNES). Further, the potential risks to workers involved with the hydraulic fracturing process were not considered as detailed Health and Safety (H&S) procedures are employed to manage exposures. The QRA considered the following specific exposure pathways:

1. Exposure of trespassers to flowback water contained within flowback storage ponds
2. Exposure of terrestrial receptors (e.g., livestock and wildlife) to flowback water contained within the flowback storage ponds
3. Exposure of aquatic receptors to flowback water in the situation of an accidental release, such as from piping or a release from the flowback storage pond. These potential releases could include a failure of containment systems, overtopping of the dam or in an extreme situation (considered highly unlikely) structural failure of the dam itself.

C3.1 Exposure Assessment

The purpose of the exposure assessment in the QRA was to predict the magnitude and frequency of potential human exposure to each COPC following the methodologies presented in **Section 8.1**. A conceptual site model (CSM) was developed which describes the potential receptors and exposure scenarios for the flowback water used in this exposure assessment. The potential exposures to receptors were evaluated based on the potential for a complete exposure pathway.

As discussed in **Section 8.3**, exposure point concentrations (EPCs) were derived for the theoretical assessment; empirical data were not available for evaluation. The EPCs for the theoretical assessment were calculated by estimating the mass and discharge flow of the COPCs from the flowback water monitoring data in **Appendix C2-2** (Appendix C, Table C-1; EHS Support, 2013b).

C3.2 Human Health QRA

A human health hazard assessment was conducted according to the methodologies presented in **Section 8.4**. The purpose of the hazard assessment process was to summarize the environmental data, and to address the toxicological assessment of the COPCs that will be evaluated further in the risk assessment process.

Exposure assumptions for the human trespasser scenario were developed based on default or site-specific assumptions (**Section 8.4**). This receptor exposure pathway includes a small child to teenager that may come in contact with the above grade water exposure scenario for approximately 20 days/year for a 10-year period with potential incidental ingestion (of 50 millitre [mL] water) and dermal contact (e.g., swimming where the whole body gets wet) for ½ hour (Table 3; EHS Support, 2013b).

Calculation of intake of COPCs was performed using the equations presented below:

Ingestion of water:

Intake (mg/kg-day) = (CW x IR X EF X ED) / (BW x AT)

Dermal contact with water:

Absorbed dose (mg/kg-day) = (CW x SA x DP x ET x EF x ED x CF) / (BW x AT)

Where:

CW = concentration in water (mg/l)
ET = exposure time (hr/day or hours/hours)
EF = exposure frequency (day/year)
ED = exposure duration (years)
CF = correction factor (1 x 10^{-3} l/cm^3)
AT = averaging time (days)
IR = ingestion rate (l/hr)
BW = body weight (kg)
SA = skin surface area available for contact (cm^2/d)
DP = dermal permeability factor (Kp – cm/hr)

C3.3 Toxicity Assessment

A toxicity assessment was conducted to determine the relationship between the dose of a COPC taken into the body, and the probability that an adverse effect will result from that dose. Quantitative estimates of the potency of COPCs include two sets of toxicity values, one for genotoxic carcinogens and one for other non-genotoxic carcinogens and non-carcinogenic effects. As discussed in **Section 8.4,** detailed toxicological profiles were developed for the chemicals. The toxicological profiles are included as **Appendix F**.

The assessment of toxicity of the COPCs was used to develop initial screening criteria for human health exposure scenarios as discussed in **Section 8.4**. Refer to Tables 1 and 2 of the QRA for details regarding the toxicity assessment of the COPCs (EHS Support, 2013b).

C3.4 Risk Estimation

Risk estimation was performed in accordance with the methodologies outlined in **Section 8.4**. The total target risk range for carcinogens was 1 x 10^{-4} to 1 x 10^{-6}; the target hazard index (HI) for non-threshold effects is less than or equal to 1.0.

No carcinogenic compounds are present in the stimulation fluids injected into the subsurface and as a result, only non-carcinogenic risks were calculated. The exposure scenarios include the specific fracturing fluids event from Golder (2013d) Table D-3, for the 20 and 80 percent (%) mass recovery from the fracturing fluid well flowback (**Appendix C2-1**). The modelled risks from injected chemicals in the flowback water at 20 % mass recovery were acceptable; the modelled risks to the trespasser for the maximum exposure to COPCs at the 80 % recovery predicted a HI of 2.5 (Tables 4 and 5; EHS Support, 2013b, attached). The primary risk drivers for this scenario were coco dimethylaminopropyl

betaine, alkylated quaternary chloride and tetrakis (hydroxylmethyl) phosphonium sulfate (THPS) via incidental ingestion, and alkylated quaternary chloride and terpenes via dermal contact.

Based on field observations, the risk assessment conducted on 80 per cent mass recovery in the flowback water diverted to the flowback storage ponds, is highly conservative. These conditions are not observed in the fields as the combination of biodegradation and sorption in the subsurface and biodegradation, complexation and settling of suspended solids in the flowback storage ponds results in lower concentrations. Based on stimulation flowback monitoring conducted by Santos and the QRA completed for the Schlumberger Fluid Systems (EHS Support, 2013b), 20 % of the total mass of constituents injected is assumed to be recovered in the flowback water. On this basis and using the theoretical concentrations, no adverse effects are predicted on trespassers.

C3.5 Ecological Risk Assessment

As discussed in **Section 8.5**, a screening level ecological risk assessment (ERA) was conducted to evaluate the potential for adverse ecological effects to terrestrial and aquatic ecological receptors that may be exposed to residual levels of hydraulic fracturing fluids in surface water used in the coal seam gas (CSG) fields.

Terrestrial receptors evaluated in the ERA include domesticated livestock, large mammalian wildlife and small mammalian wildlife. Beef cattle were used to evaluate domesticated livestock, kangaroos evaluated for large mammalian wildlife, and dingos for small mammalian wildlife. Aquatic receptors evaluated included invertebrates and fishes.

Ecological effects were characterised following the methodologies outlined in **Section 8.5.3** (Table 8; EHS Support, 2013b). Exposure scenarios were the same for ecological receptors as human receptors; EPCs were estimated in accordance with the methodology presented in **Section 8.5.4** (**Appendix C2-3**; Table A-1; EHS Support, 2013b). Environmental fate information is provided in Table 9 (EHS Support, 2013b).

Risks were characterised in accordance with the methodologies discussed in **Section 8.5.5**. The resulting ecological hazard quotient must be less than or equal to 1.0 for risks to be considered acceptable.

C3.5.1 Estimation of Risk

The HI calculated for flowback water for aquatic risk were elevated above the acceptable level for the majority of COPCs evaluated (**Appendix C2-2**, Table C-3; EHS Support, 2013b). Where large discharges of flowback water occur to surface water and/or flux dilution within the surface-water was insufficient, potential impacts on aquatic receptors could occur. As noted in the toxicity assessment section above, the lack of a robust aquatic toxicological database resulted in aquatic screening values for the theoretical exposure scenario COPCs to be conservatively very low.

The modelled risks from injected chemicals in the flowback water were all acceptable for each of the ecological receptors modelled, except livestock cattle for the maximum exposure to COPCs at the 80% recovery indicating a HI equal to 1.9 (Tables 13 and 14, 17 and 18, 21 and 22; EHS Support, 2013b, attached). Primary risk drivers were coco dimethylaminopropyl betaine, alkylated quaternary chloride and THPS via incidental ingestion; dermal contact was not evaluated for terrestrial ecological receptors. As discussed in the HHRA, 80 % recovery conditions are not observed in the fields. A recovery of 20 % is more realistic based on stimulation flow back monitoring conducted by Santos (EHS Support, 2013b).

C4.0 Summary of QRA Findings

The QRA was completed as discussed in **Section 8.0**. An assessment was conducted using highly conservative theoretical calculations based on the chemicals utilized by Halliburton in hydraulic fracturing. This assessment assumed that a range of theoretical percentages of injected chemicals would be present in the flow back water.

Consistent with the risk assessment and groundwater fate and transport modelling conducted by Golder, no potentially complete exposure pathways were identified for groundwater. Potential exposures are limited to the aboveground storage and handling of flowback water as part of the CSG Water Management Plan (WMP). Management of CSG water involves the temporary storage of flowback water in flowback storage ponds.

On the basis of the quantitative risk calculations, the potential risks associated with the flowback water are generally limited. Potential risks to trespassers could occur with repeated exposures to flowback water. However, the cumulative risks are only slightly above the non-carcinogenic threshold discussed above where management and operational controls can be implemented to control potential exposures. There were no carcinogenic risks identified.

Limited to no risks to cattle and native mammals were identified in the risk assessment; and only in the most conservative theoretical calculations (80 % chemical mass in the flowback water) were potentially unacceptable risks identified. Based on contractor experience and stimulation flowback monitoring, 20 % of the total mass constituents injected is assumed to be recovered in flowback water. Additionally, environmental fate information indicated primary risk drivers are readily biodegradable. Therefore, no potential risks exist for livestock or native mammals.

Similarly, potential impacts could occur if releases of flowback water were to occur to aquatic environments. Based on the use of clay liners and operational controls that limit the potential for turkey nest and dam overflows, the potential for these risks are also considered limited.

A combination of management and operational controls are being implemented to eliminate and control the potential for exposures. These include:

- Worker training and hazard identification
- Use of appropriate personal protective equipment (gloves etc.)
- Flowback storage pond fencing to prevent entry of livestock and minimize trespassing.
- Installation of clay dam liners and routine dam inspections to prevent releases from flowback storage ponds
- Routine operational and security patrols to prevent trespassing.

C5.0 Conclusions

A weight-of-evidence evaluation of potential risks as described in **Section 5.0** was performed for the Schlumberger ClearFRAC XT fluid system. Based on the qualitative and comparison to the Schlumberger water and guar based quantitative risk characterisations, the overall risk to human health and the environment is low. Existing operational control activities employed by Santos are in place that will limit the potential risks to human health and the environment. These measures include:

- Occupational health and safety procedures implemented during hydraulic fracturing operations to prevent workers from direct contact with chemicals during spills and when handling flowback water or sediments;
- Environmental authority conditions that preclude the construction of well pads within 100 metres of a watercourse of water body;
- Implementation of spill containment procedures during operations to prevent migration of and exposure to chemicals;
- Disposal or capping of sediments contained within drained mud pits and turkey's nests , to prevent exposure to contaminates in windborne dust;
- Fencing of drill pads to prevent trespassers and installation of signs to indicate that the water in the turkey's nest and mud pit is not potable and may contain contaminants;
- Installation and maintenance of fences around the well pad to prevent access to the drill pad by livestock and large native fauna;
- Santos operational procedures to ensure well integrity and design of fracture to stay within the target seam; and
- Mud pits and turkey's nests with clay liners, or similar material, to prevent seepage of flowback water into underlying aquifers.

Regular monitoring of water supply bores and surface water for a representative suite of chemicals within 2 kilometre of wells that are fractured is required to confirm the conclusion of incomplete exposure pathways and low risk.

No additional risks, other than those previously discussed, were identified with the chemicals or systems employed by Schlumberger in hydraulic fracturing. Evaluation of other potential risks associated with hydraulic fracturing (i.e., noise and vibration) was conducted. Refer to **Section 9.0** for methodology specifics and results of this evaluation.

Golder Associates Tables

Table 50: On site exposure assessment summary

Source	Exposure Scenario	Receptors	Exposure Pathways	Likelihood of exposure scenario	Comments
Mud pit and turkeys nest sediments	Entry to pit or excavation/stockpiling of pit sediments	Workers, trespassers	Ingestion, dermal	Unlikely	OH&S procedures limit workers exposure to sediment.
	Pit dries and pit sediments become windblown dusts	Workers, trespassers	Inhalation of dusts	Possible	Pathway is limited by disposal or capping of sediments contained in the mud pit and turkeys nest at the end of operations
	Pit dries and pit sediments become windblown dusts, contaminating surrounding soil	Native terrestrial fauna (mammals, reptiles, birds), terrestrial flora	Ingestion, uptake	Unlikely	Volume of pit sediments considered insufficient to cause significant contamination of drill pad.
	Entry to pit or exposure to excavated pit sediments	Native terrestrial fauna (mammals, reptiles, birds)	Ingestion	Unlikely	Mud pit and turkeys nest does not contain food or habitat for terrestrial species.
Flow back water in Turkey nest and mud pit	Working with turkey nest inlet/liner, or drainage of turkey nest or mud pit	Workers	Ingestion, dermal	Possible	OH&S procedures limit workers exposure to flow back water.
	Entry (accidental or deliberate) to Turkeys nest or mud pit	Trespassers	Ingestion, dermal	Possible	Trespassers entry is limited via fencing and signage around drill pad areas. Trespassers can be entirely precluded from areas.
	Entry (accidental or deliberate) to Turkeys nest or mud pit	Native terrestrial fauna (mammals, reptiles, birds)	Ingestion	Observed	Native fauna has been observed in and around the turkey nests, despite areas being fenced.
	Entry (accidental or deliberate) to Turkeys nest or mud pit	Stock animals	Ingestion	Observed	Maintained fences and grids with routine maintenance can be effective at precluding livestock however, some stock animals have been observed in well pad areas.
Hydraulic fracturing Chemicals	Spill, leak of well delivery system failure during surface handling. Supply or disposal vehicle accident on site	Workers, terrestrial fauna (mammals, reptiles, birds), terrestrial flora	Ingestion, dermal	Unlikely	OH&S and spill containment, procedures adequately address this exposure.
Flow back water	Spill, leak, mud pit, turkey nest delivery system failure or overflow	Workers, terrestrial fauna (mammals, reptiles, birds), terrestrial flora	Ingestion, dermal, inhal	Possible	

Table 51: Off site exposure assessment summary

Source	Exposure Scenario	Receptors	Exposure Pathways	Likelihood of exposure scenario	Comment/Management/control measures
Hydraulic fracturing fluids	Fracture fluid escapes into aquifer via a well casing failure, or a fault/fracture/unconformity in seam/strata, and fluids enter aquifer used downgradient for domestic water supply	Residents: adults and children	Ingestion, dermal, inhalation	Unlikely	Exposure scenario unlikely however; dependant on Santos operational procedures i.e. well integrity testing and design of fracture to stay with the target seam. No recorded instances in peer-reviewed literature of fracturing chemicals in downgradient water supplies (Osborn et al 2011).
	Fracture fluid escapes into aquifer via a well casing failure, or a fault/fracture/unconformity in seam/strata, and fluids enter aquifer used downgradient for stock water supply	Stock animals	Ingestion	Unlikely	
	Fracture fluid escapes into aquifer via a well casing failure, or a fault/fracture/unconformity in seam/strata, and fluids enter aquifer that discharges to surface water	Aquatic ecosystems	Direct exposure	Unlikely	

Table 51: Off site exposure assessment summary

Source	Exposure Scenario	Receptors	Exposure Pathways	Likelihood of exposure scenario	Comment/Management/control measures
	Residual fracturing fluid in the coal seam migrates down gradient and enters a spring or water supply bore	Residents, aquatic ecosystems, stock animals	Ingestion, dermal, inhalation	Unlikely	Fate and transport modelling used to estimate the likely extent of migration of residual fluids in coal seam (section 7.4)
Turkeys nest or mud pit sediments	Nest/Pit dries and sediments become windblown dusts, contaminating surrounding soil	Native terrestrial flora and fauna, stock, Residents adults and children	Direct exposure/ inhalation of dusts	Unlikely	Volume of pit sediments considered insufficient to result in concentrations of concern in the surrounding land.
Flow back water	Seepage of chemicals from mud pit or turkeys nest to a shallow aquifer used downgradient for domestic water supply	Residents: adults and children	Ingestion, dermal, inhalation	Unlikely	Considered unlikely that the concentrations of chemicals would be of a concern however regular maintenance of liners required to remove exposure pathway. Monitoring of down gradient bores also recommended to confirm no exposure.
	Seepage of chemicals from mud pit or turkeys nest to a shallow aquifer used downgradient for stock water supply	Stock animals	Ingestion	Unlikely	
	Seepage of chemicals from mud pit or turkeys nest to a shallow aquifer that discharges to surface water	Aquatic ecosystems	Direct exposure	Unlikely	

Table 51: Off site exposure assessment summary

Source	Exposure Scenario	Receptors	Exposure Pathways	Likelihood of exposure scenario	Comment/Management/control measures
	Spill, leak, turkey nest overflow	Residents, terrestrial fauna (mammals, reptiles, birds), terrestrial flora	Ingestion, dermal, inhalation	Possible	Possible overflows during prolonged periods of high rainfall (>500 mm of rainfall required) based on freeboard control requirements. Likelihood of occurrence can be reduced through minimising duration of storage in pit and turkeys nest, and toxicity of fluid is likely to decrease rapidly due to short biotransformation half-lives of most chemicals.

Santos

EHS Support Tables

Table 1 Oral Reference Doses and Drinking Water Guidlines Derived for Hydraulic Facturing Chemicals

Chemical	Study	Critical Effect/Target Organ(s)	NOAEL (mg/kg/day)	Uncertainty Factors	Oral Reference Dose (mg/kg/day)	Drinking Water Guideline (ppm)
DeltaFoam 140						
Cocoamidopropyl betaine	90-d rat oral gavage	Forestomach (irritation)	53.6	1,000	0.05	0.19
Guar gum	2-yr rat dietary	General toxicity	1250	100	1.3	44
Enzyme X	13-wk rat dietary	General toxicity	600	1,000	0.6	2
Ethanol	90-d rat dietary	Liver	2,400	1,000	2.4	8
Bentonite (Zeolite as surrogate)	104-wk rat dietary	-	1,000	100	10	35
C6-C10 Alcohol Ethoxylates	2-yr rat dietary	-	50	100	0.5	2
Monoethanolamine borate (Read-across from CASRN 68512-53-8)	28-day rat oral gavage	-	1,000	1,000	1	3.5
Noncrystalline Silica/Silica Gel	2-yr rat dietary	-	2,500	100	2.5	87.5
Terpene hydrocarbons, processing by-products / Terpenes & Terpenoids, sweet orange peel	2-yr rat and mouse oral gavage	Liver	107	100	1.1	3.8
Tetrakis(hydroxylmethyl) phosphonium sulfate (THPS)	2-yr rat and mouse	Liver	4a	1,000	0.004	0.01
Ethoxylated fatty acid ester	2-yr mouse dietary	forestomach	3,250a	1,000	3	11
Fatty acid ester	2-yr rat dietary	-	2,500	100	2.5	87.5
PEG oleate ester	2-yr rat dietary	Liver	1,000a	1,000	1	3.5
Alkylated quaternary chloride (DDAC as surrogate)	Rat 2-yr dietary	General toxicity	32	100	0.3	1
1,2-Benzothiazolin-3-one	Dog oral subchronic	Emesis/clinical chemistry	5	100	0.02	0.18
Crystalline silica, quartz	NA	NA	NA	NA	NA	NA
Delta 140						
Acetic acid	Australian drinking water standard for pH					
Alcohols, C6-C12, ethoxylated propoxylated	2-yr rat dietary	-	50	100	0.5	2
Alcohols, C10-C16, ethoxylated propoxylated	2-yr rat dietary	-	50	100	0.5	2
Choline chloride	Human study	Hypotension	142	2	71	248
Cocoamidopropyl betaine	90-d rat oral gavage	Forestomach (irritation)	53.6	1,000	0.05	0.19
Crystalline silica	-	-	-	-	-	-
Ethylene glycol	1-yr rat dietary	Kidney	150	100	1.5	5.3
Guar gum	2-yr rat dietary	General toxicity	1,250	100	12.5	44
Hemicellulase	13-wk rat dietary	General toxicity	600	1,000	0.6	2
Maltodextrin	No data	-	-	-	-	-
Monoethanolamine borate	28-day rat oral gavage	-	1,000	1,000	1	3.5
Polyethylene glycol	2-yr rat dietary	No toxicity at highest dose tested	1,880	100	19	66
Sodium hydroxide	Australian drinking water standard for pH					
Tetrakis(hydroxylmethyl) phosphonium sulfate	2-yr rat and mouse	Liver	4a	1,000	0.004	0.01
Acid						
Coffee Extract as Caffeine (based on 2.4% content in coffee beans)	-	-	-	-	-	100b

a LOAEL (lowest observed adverse effect level)

b Based on American College of Obstetricians and Gynecologists (2010) recommended 200 mg per day and 2 liters per day water intake level (see Appendix B)

DDAC = Didecyldimethylammonium chloride

mg/kg/day = milligrams per kilogram per day

NA = Not applicable

NOAEL = no observed adverse effect levelPEG = Polyethylene glycol

ppm = parts per million

Table 2 Australian Drinking Water Screening Values for Hydraulic Fracturing Chemicals

Constituent	Drinking Water Screening Guideline	Drinking Water Screening Value (ppm)
Acetic acid	pH	6.5 to 8.5
Calcium chloride	Chloride; Hardness as $CaCO_3$	250 (aesthetic); 200 (aesthetic)
Sodium chloride	Sodium; Chloride	180 (aesthetic); 250 (aesthetic)
Sodium hydroxide	Sodium; pH	180 (aesthetic); 6.5 to 8.5
Sodium sulfate	Sodium; Sulfate	180 (aesthetic); 500 (health), 250 (aesthetic)
Sodium sulfite	Sodium; Sulfate	180 (aesthetic); 500 (health), 250 (aesthetic)
Sodium thiosulfate	Sodium; Sulfate	180 (aesthetic); 500 (health), 250 (aesthetic)

Table 3 Exposure Assumptions - Trespasser

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/hr	0.05
	ET	Exposure time	hr/day	0.5
	EF	Exposure frequency	day/yr	20
	ED	Exposure duration	yr	10
	BW	Body weight	kg	47
	AT-NC	Averaging time - noncancer	days	3,650
	AT-C	Averaging time - cancer	days	25,550
Dermal	SA	Surface area for contact	cm_2/day	13,000
	DP	Dermal permeability factor	cm/h	chemical-specific
	ET	Exposure time	hr/day	1
	EF	Exposure frequency	day/yr	20
	ED	Exposure duration	yr	10
	BW	Body weight	kg	47
	AT-NC	Averaging time - noncancer	days	3,650
	AT-C	Averaging time - cancer	days	25,550
	CF	Conversion factor	l/cm_3	1.0E-03

Table 4 Risk Estimates for Trespasser DeltaFoam 140 Theoretical Exposure for 20% Mass Returned

		20% Mass Returned		Toxicity				DeltaFoam 140 Hazard Quotient	
Constituent Name	CAS No.	C_{frac} (mg/l)		PC (cm/hr)	RfDo	$CADD_{oral}$	$CADD_{derm}$	Incidental Ingestion	Dermal
1,2-Benzisothiazolin-3-one	2634-33-5	2.7E-01		6.0E-04	0.02	1.6E-05	1.2E-06	7.8E-04	6.0E-05
Acetic acid	64-19-7	2.8E+01		5.6E-04	NA				
Alcohols, C10-12, ethoxylated	67254-71-1	3.2E+00		1.5E-04	0.5	1.9E-04	3.7E-06	3.7E-04	7.4E-06
Alkylated quaternary chloride	75-57-0	2.8E+02		1.8E-02	0.3	1.6E-02	3.7E-02	5.4E-02	1.2E-01
Bentonite	121888-68-4	3.2E+01		NA	NA				
Calcium chloride	10043-52-4	2.7E-01		NA	NA				
Coffee extract	-	5.0E-02		NA	NA				
Crystalline silica, quartz	14808-60-7	1.6E+00		NA	NA				
Enzyme X	-	2.7E-01		NA	0.6	1.6E-05		2.6E-05	
Ethanol	64-17-5	1.5E+02		5.5E-04	2.4	8.7E-03	6.2E-04	3.6E-03	2.6E-04
Fatty acid ester 1,2	-	3.7E+01		5.1E-04	2.5	2.2E-03	1.5E-04	8.7E-04	5.8E-05
Ethoxylated fatty acid ester 1,2	-	3.7E+01		2.3E-03	3	2.2E-03	6.5E-04	7.3E-04	2.2E-04
Guar gum 1	9000-30-0	3.2E+02		NA	NA				
Monoethanolamine borate	26038-87-9	2.3E+02		1.8E-05	1	1.4E-02	3.1E-05	1.4E-02	3.1E-05
Polyethylene glycol oleate ester 1	56449-46-8	3.2E+00		NA	1	1.9E-04		1.9E-04	
Silica gel	112926-00-8	3.2E+00		NA	2.5	1.9E-04		7.5E-05	
Sodium chloride	7647-14-5	8.8E+00		NA	NA				
Sodium hydroxide	1310-73-2	6.1E+01		NA	NA				
THPS	55566-30-8	1.1E+01		2.9E-19	0.004	6.5E-04	2.5E-20	1.6E-01	6.1E-18
Sodium sulfate	7757-82-6	1.1E+00		NA	NA				
Sodium sulfite	7757-83-7	5.3E-01		NA	NA				
Sodium thiosulfate	7772-98-7	3.1E+01		NA	NA				
Terpene hydrocarbon by-products	68956-56-9	1.3E+01		4.2E-01	1.1	7.3E-04	4.0E-02	6.6E-04	3.6E-02
Terpene and Terpenoids, sweet orange oil 1	68647-72-3	1.3E+01		4.2E-01	1.1	7.3E-04	4.0E-02	6.6E-04	3.6E-02
Coco dimethylaminopropyl betaine	61789-40-0	1.7E+02		5.4E-05	0.05	9.7E-03	6.8E-05	1.9E-01	1.4E-03
								Hazard Index	6.3E-01

CADD = Chronic Average Daily Dose
CAS = Chemical Abstracts Service
cm/hr = centimetres per hour
mg/L = milligrams per litre
NA = not applicable
PC = Permeability Constant
RfDo = Reference Dose oral
THPS = Tetrakis(hydroxylmethyl) phosphonium sulfate

Table 5 Risk Estimates for Trespasser DeltaFoam 140 Theoretical Exposure for 80% Mass Returned

		80% Mass Returned		Toxicity			DeltaFoam 140		
								Hazard Quotient	
Constituent Name	CAS No.	C_{frac} (mg/l)		PC (cm/hr)	RfDo	$CADD_{oral}$	$CADD_{derm}$	Incidental Ingestion	Dermal
1,2-Benzisothiazolin-3-one	2634-33-5	1.1E+00		6.0E-04	0.02	6.2E-05	4.8E-06	3.1E-03	2.4E-04
Acetic acid	64-19-7	1.1E+02		5.6E-04	NA				
Polyethylene glycol oleate ester 1	67254-71-1	1.3E+01		1.5E-04	0.5	7.5E-04	1.5E-05	1.5E-03	2.9E-05
Alkylated quaternary chloride	75-57-0	1.1E+03		1.8E-02	0.3	6.4E-02	1.5E-01	2.1E-01	4.9E-01
Bentonite	121888-68-4	1.3E+02		NA	NA				
Calcium chloride	10043-52-4	1.1E+00		NA	NA				
Coffee extract	-	2.1E-01		NA	NA				
Crystalline silica, quartz	14808-60-7	6.4E+00		NA	NA				
Enzyme X	-	1.1E+00		NA	0.6	6.2E-05		1.0E-04	
Ethanol	64-17-5	6.0E+02		5.5E-04	2.4	3.5E-02	2.5E-03	1.5E-02	1.0E-03
Fatty acid ester 1,2	-	1.5E+02		5.1E-04	2.5	8.7E-03	5.8E-04	3.5E-03	2.3E-04
Ethoxylated fatty acid ester 1,2	-	1.5E+02		2.3E-03	3	8.7E-03	2.6E-03	2.9E-03	8.7E-04
Guar gum 1	9000-30-0	1.3E+03		NA	NA				
Monoethanolamine borate	26038-87-9	9.3E+02		1.8E-05	1	5.4E-02	1.2E-04	5.4E-02	1.2E-04
Polyethylene glycol oleate ester 1	56449-46-8	1.3E+01		NA	1	7.5E-04		7.5E-04	
Silica gel	112926-00-8	1.3E+01		NA	2.5	7.5E-04		3.0E-04	
Sodium chloride	7647-14-5	3.5E+01		NA	NA				
Sodium hydroxide	1310-73-2	2.4E+02		NA	NA				
THPS	55566-30-8	4.5E+01		2.9E-19	0.004	2.6E-03	9.8E-20	6.5E-01	2.5E-17
Sodium sulfate	7757-82-6	4.3E+00		NA	NA				
Sodium sulfite	7757-83-7	2.1E+00		NA	NA				
Sodium thiosulfate	7772-98-7	1.2E+02		NA	NA				
Terpene hydrocarbon by-products	68956-56-9	5.0E+01		4.2E-01	1.1	2.9E-03	1.6E-01	2.7E-03	1.5E-01
Terpene and Terpenoids, sweet orange oil 1	68647-72-3	5.0E+01		4.2E-01	1.1	2.9E-03	1.6E-01	2.7E-03	1.5E-01
Coco dimethylaminopropyl betaine	61789-40-0	6.7E+02		5.4E-05	0.05	3.9E-02	2.7E-04	7.8E-01	5.4E-03
								Hazard Index	2.5E+00

CADD = Chronic Average Daily Dose
CAS = Chemical Abstracts Service
cm/hr = centimetres per hour
mg/L = milligrams per litre
NA = not applicable
PC = Permeability Constant
RfDo = Reference Dose oral
THPS = Tetrakis(hydroxylmethyl) phosphonium sulfate

Table 8 Aquatic Toxicity Values (PNECs)

Chemical	Endpoint	NOEC (mg/L)	Assessment Factor	$PNEC_{aquatic}$ (mg/L)
DeltaFoam 140				
Cocoamidopropyl betaine	Chronic Daphnia	0.932	50	0.0186
Guar gum	48-hr EC50 (Daphnia)	42	1,000	0.042
Sodium sulfate	120-hr EC50 (algae)	1,900	1,000	1.9
1,2-Benzothiazolin-3-one	72-hr EC50 (algae)	0.084	1,000	8.4×10^{-5} (0.084 µg/L)
Acetic acid	Chronic Daphnia	23	50	0.46
C6-C10 alcohol ethoxylates	Chronic Daphnia QSAR	[a]	10	2.63 Range: 0.118-11.9
Alkylated quanternary chloride	-	-	-	0.0015[b]
Calcium chloride	Chronic Daphnia	160	50	3.2
Coffee extract	Acute fish, invertebrates, or algae	100 [WAF]	100	1 [WAF]
Ethanol	Chronic Ceriodaphnia sp.	9.6	10	0.96
Hydrochloric acid	-	-	-	-
Sodium hydroxide	-	-	-	-
Enzyme X/hemicellulase	96-hr LC50 (fish)	330	1,000	0.33
Fatty acid ester	-	-	-	0.0191[c]
Ethoxylated fatty acid	-	-	-	0.01914[c]
PEG Oleate ester	72-hr EC50 (algae)	93	1,000	0.093
Monoethanolamine borate	72-hr EC50 (algae)	13	1,000	0.013
Sodium sulfite	Chronic Daphnia	13	50	0.26
Sodium chloride	-	-	-	-
Sodium thiosulfate	96-hr EC50 (algae)	100	1,000	0.1
Terpene hydrocarbons, processing by-products / Terpenes & Terpenoids, sweet orange peel	96-hr EC50 (Daphnia)	0.421	1,000	4.21×10^{-4} (0.421 µg/L)
Tetrakis(hydroxymethyl) phosphonium sulfate (THPS)	72-hr EC50 (algae)	0.204	1,000	2.0×10^{-4} (0.20 µg/L)
Bentonite	NA	NA	NA	NA
Noncrystalline silica/Silica gel	NA	NA	NA	NA
Crystalline silica, quartz	NA	NA	NA	NA
Delta 140				
Acetic acid	Chronic Daphnia	23	50	0.5
Alcohols, C6-C12, ethyoxylated propoxylated	Chronic Daphnia QSAR	[a]	10	1.69 Range: 0.1 - 5.77
Alcohols, C10-C16, ethoxylated propoxylated	Chronic Daphnia QSAR	[a]	10	0.54 Range: 0.04 - 1.8
Choline chloride	Chronic Daphnia	30	50	0.6
Crystalline silica	-	-	-	-
Ethylene glycol	Chronic *Ceriodapnia dubia*	3,469	10	347
Guar gum	48-hr EC_{50} (Daphnia)	42	1,000	0.04
Hemicellulase	96-hr LC_{50} (fish)	330	1,000	0.33
Maltodextrin	No data	-	-	-
Monoethanolamine borate	72-hr EC_{50} (algae)	13	1,000	0.013
Polyethylene glycol	72-hr EC_{50} (algae)	100	50	2

Table 8 Aquatic Toxicity Values (PNECs)

Cocoamidopropyl betaine	Chronic Daphnia	0.932	50	0.0186
Sodium hydroxide	-	-	-	-
Tetrakis(hydroxymethyl)phosphonium sulfate	72-hr EC_{50} (algae)	0.204	1,000	0.0002

[a]See HERA Report on Alcohol Ethoxylates.

[b]Interim Canadian Water Quality Guideline for the Protection of Aquatic Life for Didecyldimethyl ammonium chloride (DDAC).

[c]PNEC is the water solubility limit because the calculated acute toxicity values are estimated to be higher than the water solubility limit.

PEG = polyethylene glycol

PNEC = predicted no effects concentration

µg/L = microgram per litre

mg/L = milligrams per litre

NOEC = no observed effect concentration

QSAR = quantitative strucuture activity relationship

WAF = water-accommodated fraction

Table 9 Environmental Fate Information

DeltaFoam 140	
Acetic acid	Dissociates to H^+ and $CH_3CO_2^-$ in aqueous media. Acetate anion is readily biodegradable under aerobic and anaerobic conditions. Biodegradation: 74% (BOD) after 14 days (MITI-I, OECD 301C); 99% after 7 days under anaerobic conditions.
Alkylated Quaternary chloride	Surrogate: Didecyldimethylammonium chloride (DDAC), a cationic surfactant. DDAC adsorbs strongly and rapidly to sediments, clay materials, and other negatively charged surfaces. In unacclimated river water, half-lifes of AQCs range from <1 to several days. Half-life of the 12 carbon alkyl chain reported as 2.1 d. Rate of degradation - with $^-$ alkyl chain. BCF (experimental) = 81 (whole body fish tissues).
C6-C10 Alcohol Ethoxylates	Readily biodegradable and also anaerobically biodegradable. Proposed half-lives in river water at 12°C: 4 to 24 hours (based on experimental data). BCF (see HERA report)
Benzothiazolin-3-one	Hydrolytically stable ($T_{1/2}$ >30 d); breaks down fairly quickly in aerobic soil ($T_{1/2}$ <24 hr in sandy loam). Moderate to strong binding to soils.
Cocoamidopropyl betaine	Readily biodegradable; easily biodegradable under anaerobic conditions. BCF between 3 and 71. Biodegradation: 86 – 100 % after 28 days (OECD 301A/B/D/E), 90 – 93 % after 35 days (OECD 301B) and 100 % after 20 days (Directive 84/449/EEC, C.5).
Ethanol	Readily biodegradable; unlikely to bioaccumulate; and is not persistent in the environment. Biodegradation: 74% after 5 days. Calculated log BCF = 0.5.
Ethoxylated fatty acid	Expected to be biodegradable, but not readily biodegradable based on ethoxylated castor oil. OECD 302B: 90-100% after 21 days.
PEG Oleate ester	Expected to be biodegradable, but not readily biodegradable based on ethoxylated castor oil. OECD 02B: 90-100% after 21 days.
Guar gum	Expected to be readily biodegradable as a polysaccharide; not expected to bioaccumulate. [No data]
Enzyme X	Readily biodegradable; unlikely to bioaccumulate. 84-92% DOC removal after 28 days (OECD 301E); 78% BOD/COD after 28 days (OECD 301C)
Monoethanolamine borate	Readily biodegradable. MEA Polyborate(1:1): 73% after 28 days (OECD 301B). MEA Polyborate (1:3): 75% after 28 days (OECD 301B). Does not adsorb to soil.
Terpene hydrocarbons	Readily biodegradable. Biodegradation of limonene: 41-98% degradation by BOD in 14 days (OECD 301C). Biodegradation of terpinolene: 80% biodegradation after 28 and 31 days (OECD 302C); 62.1% after 28 days (OECD 301B).
Tetrakis(hydroxymethyl) phosphonium sulfate	Rapidly biodegrades under aerobic and anaerobic conditions. Binds poorly to environmental particulates
Delta 140	
Acetic acid	Dissociates to H^+ and acetate ($CH_3CO_2^-$) in aqueous media. Acetate anion is readily biodegradable under aerobic and anaerobic conditions. Biodegradation: 96% after 20 days under aerobic conditions; 99% after 7 days under anaerobic conditions.
Alcohols, C6-C12, ethoxylated propoxylated	Read-across to C6-C12 alcohol ethoxylates. Readily biodegradable and also anaerobically biodegradable. Proposed half-lives in river water at 12°C: 4 to 24 hours (based on experimental data).
Alcohols, C10-C16 ethoxylated, propoxylated	Read-across to C10-C16 ethoxylates. Readily biodegradable and also anaerobically biodegradable. Proposed half-lives in river water at 12°C: 4 to 24 hours (based on experimental data).
Choline chloride	Readily biodegradable (93% within 14 days in a MITI-I test. In another MITI-I test, biodegradation was ≥60%.
Crystalline silica	Naturally occurring mineral that is insoluble in water. It is persistent in the environment.
Ethylene glycol	Readily biodegradable under both aerobic and anaerobic conditions. There was 97% degradation after 20 days in a BOD test, and 96% degradation after 28 days in an OECD 301D test.
Guar gum	Expected to be readily biodegradable, as it ia a naturally occurring polysaccharide.
Hemicellulase	Readily biodegradable. 84-92% DOC removal after 28 days (OECD 301E); 78% BOD/COD after 28 days (OECD 301C)
Maltodextrin	Expected to biodegrade, as it is a naturally occurring polysaccharide.
Monoethanolamine borate	Readily biodegradable. MEA Polyborate(1:1): 73% after 28 days (OECD 301B). MEA Polyborate (1:3): 75% after 28 days (OECD 301B).
Polyethylene glycol	Read-across to tetra- and penta- ethylene glycol, major constituents of low-molecular weight polyethylene glycol. Inherently biodegradable. TetraEG: 22% degradation after 20 days (BOD test); 40% degradation after 28 days (OECD 301D). PentaEF: 3% degradation after 20 days (BOD test).

Table 9 Environmental Fate Information

Sodium hydroxide	Disociates to Na^+ and OH^- in aqueous media.
Tetrakis(hydroxymethyl) phosphonium sulfate	Inherently biodegradable. >20% degradation within 28 days (OECD 302B).

Table 13 Risk Estimates for Cattle DeltaFoam 140 Theoretical Exposure for 20% Mass Returned

Constituent Name	CAS No.	20% Mass Returned C_{frac} (mg/l)		Toxicity TRVs	DeltaFoam 140 $CADD_{oral}$	Hazard Quotient Incidental Ingestion
1,2-Benzisothiazolin-3-one	2634-33-5	2.7E-01		8.3E-01	1.3E-03	1.6E-03
Acetic acid	64-19-7	2.8E+01				
Alcohols, C10-12, ethoxylated	67254-71-1	3.2E+00		8.3E+00	1.6E-02	1.9E-03
Alkylated quaternary chloride	75-57-0	2.8E+02		5.3E+00	1.4E+00	2.6E-01
Bentonite	121888-68-4	3.2E+01				
Calcium chloride	10043-52-4	2.7E-01				
Coffee extract	-	5.0E-02				
Crystalline silica, quartz	14808-60-7	1.6E+00				
Enzyme X	-	2.7E-01		1.0E+02	1.3E-03	1.3E-05
Ethanol	64-17-5	1.5E+02		4.0E+02	7.5E-01	1.9E-03
Fatty acid ester 1,2	-	3.7E+01		4.2E+02	1.9E-01	4.5E-04
Ethoxylated fatty acid ester 1,2	-	3.7E+01		5.4E+02	1.9E-01	3.4E-04
Guar gum 1	9000-30-0	3.2E+02				
Monoethanolamine borate	26038-87-9	2.3E+02		1.7E+02	1.2E+00	6.9E-03
Polyethylene glycol oleate ester 1	56449-46-8	3.2E+00		1.7E+01	1.6E-02	9.4E-04
Silica gel	112926-00-8	3.2E+00				
Sodium chloride	7647-14-5	8.8E+00				
Sodium hydroxide	1310-73-2	6.1E+01				
THPS	55566-30-8	1.1E+01		6.0E-01	5.6E-02	9.3E-02
Sodium sulfate	7757-82-6	1.1E+00				
Sodium sulfite	7757-83-7	5.3E-01				
Sodium thiosulfate	7772-98-7	3.1E+01				
Terpene hydrocarbon by-products	68956-56-9	1.3E+01		1.8E+01	6.2E-02	3.5E-03
Terpene and Terpenoids, sweet orange oil 1	68647-72-3	1.3E+01		1.8E+01	6.2E-02	3.5E-03
Coco dimethylaminopropyl betaine	61789-40-0	1.7E+02		8.9E+00	8.3E-01	9.3E-02
					Hazard Index	
					4.6E-01	

CADD = chronic average daily dose
CAS = Chemical Abstracts Service
Cfrac = concentration in fracturing fluid
mg/L = milligrams per litre
TRV = toxicity reference value

Table 14 Risk Estimates for Cattle DeltaFaom 140 Theoretical Exposure for 80% Mass Returned

Constituent Name	CAS No.	80% Mass Returned C_{frac} (mg/l)		Toxicity TRVs	DeltaFoam 140 $CADD_{oral}$	DeltaFoam 140 Hazard Quotient Incidental Ingestion
1,2-Benzisothiazolin-3-one	2634-33-5	1.1E+00		8.3E-01	5.3E-03	6.4E-03
Acetic acid	64-19-7	1.1E+02				
Alcohols, C10-12, ethoxylated	67254-71-1	1.3E+01		8.3E+00	6.4E-02	7.6E-03
Alkylated quaternary chloride	75-57-0	1.1E+03		5.3E+00	5.5E+00	1.0E+00
Bentonite	121888-68-4	1.3E+02				
Calcium chloride	10043-52-4	1.1E+00				
Coffee extract	-	2.1E-01				
Crystalline silica, quartz	14808-60-7	6.4E+00				
Enzyme X	-	1.1E+00		1.0E+02	5.3E-03	5.3E-05
Ethanol	64-17-5	6.0E+02		4.0E+02	3.0E+00	7.5E-03
Fatty acid ester 1,2	-	1.5E+02		4.2E+02	7.5E-01	1.8E-03
Ethoxylated fatty acid ester 1,2	-	1.5E+02		5.4E+02	7.5E-01	1.4E-03
Guar gum 1	9000-30-0	1.3E+03				
Monoethanolamine borate	26038-87-9	9.3E+02		1.7E+02	4.6E+00	2.8E-02
Polyethylene glycol oleate ester 1	56449-46-8	1.3E+01		1.7E+01	6.4E-02	3.7E-03
Silica gel	112926-00-8	1.3E+01				
Sodium chloride	7647-14-5	3.5E+01				
Sodium hydroxide	1310-73-2	2.4E+02				
THPS	55566-30-8	4.5E+01		6.0E-01	2.2E-01	3.7E-01
Sodium sulfate	7757-82-6	4.3E+00				
Sodium sulfite	7757-83-7	2.1E+00				
Sodium thiosulfate	7772-98-7	1.2E+02				
Terpene hydrocarbon by-products	68956-56-9	5.0E+01		1.8E+01	2.5E-01	1.4E-02
Terpene and Terpenoids, sweet orange oil 1	68647-72-3	5.0E+01		1.8E+01	2.5E-01	1.4E-02
Coco dimethylaminopropyl betaine	61789-40-0	6.7E+02		8.9E+00	3.3E+00	3.7E-01
					Hazard Index	
					1.9E+00	

CADD = chronic average daily dose
CAS = Chemical Abstracts Service
Cfrac = concentration in fracturing fluid
mg/L = milligrams per litre
TRV = toxicity reference value

Table 18 Risk Estimates for Kangaroo DeltaFoam 140 Theoretical Exposure for 80% Mass Returned

Constituent Name	CAS No.	80% Mass Returned C_{frac} (mg/l)		Toxicity TRVs	$CADD_{oral}$	DeltaFoam 140 Hazard Quotient Incidental Ingestion
1,2-Benzisothiazolin-3-one	2634-33-5	1.1E+00		1.7E+00	3.5E-03	2.0E-03
Acetic acid	64-19-7	1.1E+02				
Alcohols, C10-12, ethoxylated	67254-71-1	1.3E+01		1.7E+01	4.2E-02	2.4E-03
Alkylated quaternary chloride	75-57-0	1.1E+03		1.1E+01	3.6E+00	3.3E-01
Bentonite	121888-68-4	1.3E+02				
Calcium chloride	10043-52-4	1.1E+00				
Coffee extract	-	2.1E-01				
Crystalline silica, quartz	14808-60-7	6.4E+00				
Enzyme X	-	1.1E+00		2.1E+02	3.5E-03	1.7E-05
Ethanol	64-17-5	6.0E+02		8.3E+02	2.0E+00	2.4E-03
Fatty acid ester 1,2	-	1.5E+02		8.6E+02	4.9E-01	5.7E-04
Ethoxylated fatty acid ester 1,2	-	1.5E+02		1.1E+03	4.9E-01	4.4E-04
Guar gum 1	9000-30-0	1.3E+03				
Monoethanolamine borate	26038-87-9	9.3E+02		3.4E+02	3.0E+00	8.9E-03
Polyethylene glycol oleate ester 1	56449-46-8	1.3E+01		3.4E+01	4.2E-02	1.2E-03
Silica gel	112926-00-8	1.3E+01				
Sodium chloride	7647-14-5	3.5E+01				
Sodium hydroxide	1310-73-2	2.4E+02				
THPS	55566-30-8	4.5E+01		1.2E+00	1.5E-01	1.2E-01
Sodium sulfate	7757-82-6	4.3E+00				
Sodium sulfite	7757-83-7	2.1E+00				
Sodium thiosulfate	7772-98-7	1.2E+02				
Terpene hydrocarbon by-products	68956-56-9	5.0E+01		3.7E+01	1.6E-01	4.5E-03
Terpene and Terpenoids, sweet orange oil 1	68647-72-3	5.0E+01		3.7E+01	1.6E-01	4.5E-03
Coco dimethylaminopropyl betaine	61789-40-0	6.7E+02		1.8E+01	2.2E+00	1.2E-01
						Hazard Index
						5.9E-01

CADD = chronic average daily dose
CAS = Chemical Abstracts Service
Cfrac = concentration in fracturing fluid
mg/L = milligrams per litre
TRV = toxicity reference value

Table 17 Risk Estimates for Kangaroo DeltaFoam 140 Theoretical Exposure for 20% Mass Returned

Constituent Name	CAS No.	20% Mass Returned C_{frac} (mg/l)		Toxicity TRVs	DeltaFoam 140 $CADD_{oral}$	DeltaFoam 140 Hazard Quotient Incidental Ingestion
1,2-Benzisothiazolin-3-one	2634-33-5	2.7E-01		1.7E+00	8.8E-04	5.1E-04
Acetic acid	64-19-7	2.8E+01				
Alcohols, C10-12, ethoxylated	67254-71-1	3.2E+00		1.7E+01	1.1E-02	6.1E-04
Alkylated quaternary chloride	75-57-0	2.8E+02		1.1E+01	9.1E-01	8.2E-02
Bentonite	121888-68-4	3.2E+01				
Calcium chloride	10043-52-4	2.7E-01				
Coffee extract	-	5.0E-02				
Crystalline silica, quartz	14808-60-7	1.6E+00				
Enzyme X	-	2.7E-01		2.1E+02	8.8E-04	4.2E-06
Ethanol	64-17-5	1.5E+02		8.3E+02	4.9E-01	6.0E-04
Fatty acid ester 1,2	-	3.7E+01		8.6E+02	1.2E-01	1.4E-04
Ethoxylated fatty acid ester 1,2	-	3.7E+01		1.1E+03	1.2E-01	1.1E-04
Guar gum 1	9000-30-0	3.2E+02				
Monoethanolamine borate	26038-87-9	2.3E+02		3.4E+02	7.6E-01	2.2E-03
Polyethylene glycol oleate ester 1	56449-46-8	3.2E+00		3.4E+01	1.1E-02	3.1E-04
Silica gel	112926-00-8	3.2E+00				
Sodium chloride	7647-14-5	8.8E+00				
Sodium hydroxide	1310-73-2	6.1E+01				
THPS	55566-30-8	1.1E+01		1.2E+00	3.7E-02	3.0E-02
Sodium sulfate	7757-82-6	1.1E+00				
Sodium sulfite	7757-83-7	5.3E-01				
Sodium thiosulfate	7772-98-7	3.1E+01				
Terpene hydrocarbon by-products	68956-56-9	1.3E+01		3.7E+01	4.1E-02	1.1E-03
Terpene and Terpenoids, sweet orange oil 1	68647-72-3	1.3E+01		3.7E+01	4.1E-02	1.1E-03
Coco dimethylaminopropyl betaine	61789-40-0	1.7E+02		1.8E+01	5.5E-01	3.0E-02

CADD = chronic average daily dose
CAS = Chemical Abstracts Service
Cfrac = concentration in fracturing fluid
mg/L = milligrams per litre
TRV = toxicity reference value

Hazard Index
1.5E-01

Table 21 Risk Estimates for Dingo DeltaFoam 140 Theoretical Exposure for 20% Mass Returned

Constituent Name	CAS No.	20% Mass Returned C_{frac} (mg/l)		Toxicity TRVs	DeltaFoam 140 $CADD_{oral}$	DeltaFoam 140 Hazard Quotient Incidental Ingestion
1,2-Benzisothiazolin-3-one	2634-33-5	2.7E-01		2.0E+00	4.2E-04	2.1E-04
Acetic acid	64-19-7	2.8E+01				
Alcohols, C10-12, ethoxylated	67254-71-1	3.2E+00		2.0E+01	5.1E-03	2.5E-04
Alkylated quaternary chloride	75-57-0	2.8E+02		1.3E+01	4.4E-01	3.4E-02
Bentonite	121888-68-4	3.2E+01				
Calcium chloride	10043-52-4	2.7E-01				
Coffee extract	-	5.0E-02				
Crystalline silica, quartz	14808-60-7	1.6E+00				
Enzyme X	-	2.7E-01		2.4E+02	4.2E-04	1.7E-06
Ethanol	64-17-5	1.5E+02		9.7E+02	2.4E-01	2.4E-04
Fatty acid ester 1,2	-	3.7E+01		1.0E+03	5.9E-02	5.8E-05
Ethoxylated fatty acid ester 1,2	-	3.7E+01		1.3E+03	5.9E-02	4.5E-05
Guar gum 1	9000-30-0	3.2E+02				
Monoethanolamine borate	26038-87-9	2.3E+02		4.1E+02	3.7E-01	9.0E-04
Polyethylene glycol oleate ester 1	56449-46-8	3.2E+00		4.1E+02	5.1E-03	1.2E-05
Silica gel	112926-00-8	3.2E+00				
Sodium chloride	7647-14-5	8.8E+00				
Sodium hydroxide	1310-73-2	6.1E+01				
THPS	55566-30-8	1.1E+01		1.5E+00	1.8E-02	1.2E-02
Sodium sulfate	7757-82-6	1.1E+00				
Sodium sulfite	7757-83-7	5.3E-01				
Sodium thiosulfate	7772-98-7	3.1E+01				
Terpene hydrocarbon by-products	68956-56-9	1.3E+01		4.3E+01	2.0E-02	4.6E-04
Terpene and Terpenoids, sweet orange oil 1	68647-72-3	1.3E+01		4.3E+01	2.0E-02	4.6E-04
Coco dimethylaminopropyl betaine	61789-40-0	1.7E+02		2.2E+01	2.6E-01	1.2E-02
					Hazard Index	
					6.1E-02	

CADD = chronic average daily dose
CAS = Chemical Abstracts Service
Cfrac = concentration in fracturing fluid
mg/L = milligrams per litre
TRV = toxicity reference value

Table 22 Risk Estimates for Dingo DeltaFoam 140 Theoretical Exposure for 80% Mass Returned

Constituent Name	CAS No.	80% Mass Returned C_{frac} (mg/l)		Toxicity TRVs	DeltaFoam 140 $CADD_{oral}$	DeltaFoam 140 Hazard Quotient Incidental Ingestion
1,2-Benzisothiazolin-3-one	2634-33-5	1.1E+00		2.0E+00	1.7E-03	8.3E-04
Acetic acid	64-19-7	1.1E+02				
Alcohols, C10-12, ethoxylated	67254-71-1	1.3E+01		2.0E+01	2.0E-02	1.0E-03
Alkylated quaternary chloride	75-57-0	1.1E+03		1.3E+01	1.7E+00	1.3E-01
Bentonite	121888-68-4	1.3E+02				
Calcium chloride	10043-52-4	1.1E+00				
Coffee extract	-	2.1E-01				
Crystalline silica, quartz	14808-60-7	6.4E+00				
Enzyme X	-	1.1E+00		2.4E+02	1.7E-03	6.9E-06
Ethanol	64-17-5	6.0E+02		9.7E+02	9.5E-01	9.7E-04
Fatty acid ester 1,2	-	1.5E+02		1.0E+03	2.4E-01	2.3E-04
Ethoxylated fatty acid ester 1,2	-	1.5E+02		1.3E+03	2.4E-01	1.8E-04
Guar gum 1	9000-30-0	1.3E+03				
Monoethanolamine borate	26038-87-9	9.3E+02		4.1E+02	1.5E+00	3.6E-03
Polyethylene glycol oleate ester 1	56449-46-8	1.3E+01		4.1E+02	2.0E-02	4.9E-05
Silica gel	112926-00-8	1.3E+01				
Sodium chloride	7647-14-5	3.5E+01				
Sodium hydroxide	1310-73-2	2.4E+02				
THPS	55566-30-8	4.5E+01		1.5E+00	7.1E-02	4.9E-02
Sodium sulfate	7757-82-6	4.3E+00				
Sodium sulfite	7757-83-7	2.1E+00				
Sodium thiosulfate	7772-98-7	1.2E+02				
Terpene hydrocarbon by-products	68956-56-9	5.0E+01		4.3E+01	7.9E-02	1.8E-03
Terpene and Terpenoids, sweet orange oil 1	68647-72-3	5.0E+01		4.3E+01	7.9E-02	1.8E-03
Coco dimethylaminopropyl betaine	61789-40-0	6.7E+02		2.2E+01	1.1E+00	4.8E-02

Hazard Index
2.4E-01

CADD = chronic average daily dose
CAS = Chemical Abstracts Service
Cfrac = concentration in fracturing fluid
mg/L = milligrams per litre
TRV = toxicity reference value

Appendix C2-1

Table D3: Chemical mass balance and estimated concentrations in typical hydraulic fracturing fluids

Constituent Name	CASRN	Estimated mass per coal seam (kg)						Estimated concentration in fluid systems (mg/L)					
		Delta 140	DeltaFoam 140	Linear Gel	Linear Gel Foamed	Water	Water Foamed	Delta 140	DeltaFoam 140	Linear Gel	Linear Gel Foamed	Water	Water Foamed
1,2-Benzisothiazolin-3-one	2634-33-5	0.41	0.41	0.20	0.20	-	-	2	2	1	1	-	-
Acetic acid	64-19-7	39.69	39.69	39.69	39.69	-	-	210	210	210	210	-	-
Alcohols, C10-12, ethoxylated	67254-71-1	4.54	4.54	4.54	4.54	-	-	24	24	24	24	-	-
Alkylated quaternary chloride	75-57-0	391.45	391.59	391.59	391.59	391.59	391.59	2068	2069	2069	2069	2069	2069
Bentonite	121888-68-4	45.36	45.36	45.36	45.36	-	-	240	240	240	240	-	-
Calcium chloride	10043-52-4	0.41	0.41	0.20	0.20	-	-	2	2	1	1	-	-
Crystalline silica, quartz	14808-60-7	2.27	2.27	2.27	2.27	-	-	12	12	12	12	-	-
Endo-1,4-beta-mannanase enzyme	37288-54-3	0.41	0.41	0.41	0.23	-	-	2	2	2	1	-	-
Ethanol	64-17-5	212.62	212.62	212.62	212.62	-	-	1123	1123	1123	1123	-	-
Fatty acid ester [1,2]	-	53.16	53.16	53.16	53.16			281	281	281	281		
Ethoxylated fatty acid ester [1,2]	-	53.16	53.16	53.16	53.16	-	-	281	281	281	281	-	-
Guar gum [1]	9000-30-0	453.59	453.59	453.59	453.59	-	-	2397	2397	2397	2397	-	-
Monoethanolamine borate	26038-87-9	329.13	329.13	-	-	-	-	1739	1739	-	-	-	-
Polyethylene glycol oleate ester [1]	56449-46-8	4.54	4.54	4.54	4.54	-	-	24	24	24	24	-	-
Silica gel	112926-00-8	4.54	4.54	4.54	4.54	-	-	24	24	24	24	-	-
Sodium chloride	7647-14-5	12.47	12.47	6.24	6.24	-	-	66	66	33	33	-	-
Sodium hydroxide	1310-73-2	86.18	86.18	-	-	-	-	455	455	-	-	-	-
THPS	55566-30-8	15.88	15.88	15.88	15.88	15.88	15.88	84	84	84	84	84	84
Sodium sulfate	7757-82-6	1.45	1.45	1.45	1.45	-	-	8	8	8	8	-	-
Sodium sulfite	7757-83-7	0.73	0.73	0.73	0.73	-	-	4	4	4	4	-	-
Sodium thiosulfate	7772-98-7	43.25	43.25	43.25	43.25	-	-	229	229	229	229	-	-
Terpene hydrocarbon by-products	68956-56-9	17.71	17.71	17.71	17.71	-	-	94	94	94	94	-	-
Terpene and Terpenoids, sweet orange oil [1]	68647-72-3	17.71	17.71	17.71	17.71	-	-	94	94	94	94	-	-
Coco dimethylaminopropyl betaine	61789-40-0	-	236.03	-	236.03	-	236.03		1247	-	1247	-	1247
Total chemical mass injected per coal seam (kg):		***1791***	***2027***	***1369***	***1605***	***407***	***643***						
Residual chemical mass assuming 60% recovery (kg):		***716***	***811***	***548***	***642***	***163***	***257***						

Notes:

1. Estimated concentration in pre-injection fracturing fluid may exceed the effective solubility of the compound.
2. The CAS numbers for fatty acid ester and ethoxylated fatty acid ester have not been included in this table due to commercial confidentiality.

Santos

Appendix C2-2

Table C-1. Comparison of Estimated DeltaFoam 140 Theoretical Concentrations to Human Health Drinking Water Guidelines

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)					Estimated Initial Concentration in flowback (150% of injected fluid volume) per coal seam per percent of mass returned calculated using equation: Initial Flowback Concentration = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L)				Drinking Water Guideline (mg/L)	Ratio of COPC Concentrations and Screening Criteria (Ratio greater than one = unacceptable potential risk)			
							DeltaFoam 140					DeltaFoam 140			
		Delta 140	DeltaFoam 140	Linear Gel	Linear Gel Foamed	Water	20%	40%	60%	80%		20%	40%	60%	80%
1,2-Benzisothiazolin-3-one	2634-33-5	2	2	1	1	-	0.27	0.53	0.80	1.07	0.18	1.5E+00	3.0E+00	4.4E+00	5.9E+00
Acetic acid	64-19-7	210	210	210	210	-	28.00	56.00	84.00	112.00	NA	2.8E-02	5.6E-02	8.4E-02	1.1E-01
Alcohols, C10-12, ethoxylated	67254-71-1	24	24	24	24	-	3.20	6.40	9.60	12.80	2	1.6E+00	3.2E+00	4.8E+00	6.4E+00
Alkylated quaternary chloride	75-57-0	2,068	2,068	2,069	2,069	2,069	275.73	551.47	827.20	1102.93	3.5	7.9E+01	1.6E+02	2.4E+02	3.2E+02
Bentonite	121888-68-4	240	240	240	240	-	32.00	64.00	96.00	128.00	35	9.1E-01	1.8E+00	2.7E+00	3.7E+00
Calcium chloride	10043-52-4	2	2	1	1	-	0.27	0.53	0.80	1.07	200	1.3E-03	2.7E-03	4.0E-03	5.3E-03
Coffee Extract	-	0.4	0.4	0.4	0.4	-	0.05	0.11	0.16	0.21	100	5.3E-04	1.1E-03	1.6E-03	2.1E-03
Crystalline silica, quartz	14808-60-7	12	12	12	12	-	1.60	3.20	4.80	6.40	NA	1.6E-03	3.2E-03	4.8E-03	6.4E-03
Enzyme X	-	2	2	2	2	-	0.27	0.53	0.80	1.07	2	1.3E-01	2.7E-01	4.0E-01	5.3E-01
Ethanol	64-17-5	1,123	1,123	1,123	1,123	-	149.73	299.47	449.20	598.93	8	1.9E+01	3.7E+01	5.6E+01	7.5E+01
Fatty acid ester 1,2	-	281	281	281	281	-	37.47	74.93	112.40	149.87	87.5	4.3E-01	8.6E-01	1.3E+00	1.7E+00
Ethoxylated fatty acid ester 1,2	-	281	281	281	281	-	37.47	74.93	112.40	149.87	11	3.4E+00	6.8E+00	1.0E+01	1.4E+01
Guar gum	9000-30-0	2,397	2,397	2,397	2,397	-	319.60	639.20	958.80	1278.40	44	7.3E+00	1.5E+01	2.2E+01	2.9E+01
Monoethanolamine borate	26038-87-9	1,739	1,739	-	-	-	231.87	463.73	695.60	927.47	3.5	6.6E+01	1.3E+02	2.0E+02	2.6E+02
Polyethylene glycol oleate ester 1	56449-46-8	24	24	24	24	-	3.20	6.40	9.60	12.80	3.5	9.1E-01	1.8E+00	2.7E+00	3.7E+00
Silica gel	112926-00-8	24	24	24	24	-	3.20	6.40	9.60	12.80	87.5	3.7E-02	7.3E-02	1.1E-01	1.5E-01
Sodium chloride	7647-14-5	66	66	33	33	-	8.80	17.60	26.40	35.20	180	4.9E-02	9.8E-02	1.5E-01	2.0E-01
Sodium hydroxide	1310-73-2	455	455	-	-	-	60.67	121.33	182.00	242.67	180	3.4E-01	6.7E-01	1.0E+00	1.3E+00
Tetrakis(hydroxylmethyl) phosphonium sulfate (THPS)	55566-30-8	84	84	84	84	84	11.20	22.40	33.60	44.80	0.01	1.1E+03	2.2E+03	3.4E+03	4.5E+03
Sodium sulfate	7757-82-6	8	8	8	8	-	1.07	2.13	3.20	4.27	500	2.1E-03	4.3E-03	6.4E-03	8.5E-03
Sodium sulfite	7757-83-7	4	4	4	4	-	0.53	1.07	1.60	2.13	500	1.1E-03	2.1E-03	3.2E-03	4.3E-03
Sodium thiosulfate	7772-98-7	229	229	229	229	-	30.53	61.07	91.60	122.13	500	6.1E-02	1.2E-01	1.8E-01	2.4E-01
Terpene hydrocarbon by-products	68956-56-9	94	94	94	94	-	12.53	25.07	37.60	50.13	3.8	3.3E+00	6.6E+00	9.9E+00	1.3E+01
Terpene and Terpenoids, sweet orange oil 1	68647-72-3	94	94	94	94	-	12.53	25.07	37.60	50.13	3.8	3.3E+00	6.6E+00	9.9E+00	1.3E+01
Coco dimethylaminopropyl betaine	61789-40-0	-	1,247	-	1,247	-	166.27	332.53	498.80	665.07	0.19	8.8E+02	1.8E+03	2.6E+03	3.5E+03
												2181	**4361**	**6542**	**8722**

Highlighted cells are ratios greater than one and indicate a potentially unacceptable risk

CAS = Chemical Abstracts Service

COPC = constituent of potential concern

mg/L = milligrams per litre

NA = not applicable

Table C-2. Comparison of Estimated Theoretical DeltaFoam 140 Concentrations to Aquatic Life Water Guidelines

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)					Estimated Initial Concentration in flowback (150% of injected fluid volume) per coal seam per percent of mass returned calculated using equation: Initial Flowback Concentration = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L)				PNEC aquatic (mg/L)	Ratio of COPC Concentrations and Screening Criteria (Ratio greater than one = unacceptable potential risk)			
							DeltaFoam 140					DeltaFoam 140			
		Delta 140	DeltaFoam 140	Linear Gel	Linear Gel Foamed	Water	20%	40%	60%	80%		20%	40%	60%	80%
1,2-Benzisothiazolin-3-one	2634-33-5	2	2	1	1	-	0.27	0.53	0.80	1.07	8.40E-05	3.2E+03	6.3E+03	9.5E+03	1.3E+04
Acetic acid	64-19-7	210	210	210	210	-	28.00	56.00	84.00	112.00	0.46	6.1E+01	1.2E+02	1.8E+02	2.4E+02
Alcohols, C10-12, ethoxylated	67254-71-1	24	24	24	24	-	3.20	6.40	9.60	12.80	1.07	3.0E+00	6.0E+00	9.0E+00	1.2E+01
Alkylated quaternary chloride	75-57-0	2,068	2,068	2,069	2,069	2,069	275.73	551.47	827.20	1102.93	0.0015	1.8E+05	3.7E+05	5.5E+05	7.4E+05
Bentonite	121888-68-4	240	240	240	240	-	32.00	64.00	96.00	128.00	NA				
Calcium chloride	10043-52-4	2	2	1	1	-	0.27	0.53	0.80	1.07	3.2	8.3E-02	1.7E-01	2.5E-01	3.3E-01
Coffee Extract	-	0.4	0.4	0.4	0.4	-	0.05	0.11	0.16	0.21	1	5.3E-02	1.1E-01	1.6E-01	2.1E-01
Crystalline silica, quartz	14808-60-7	12	12	12	12	-	1.60	3.20	4.80	6.40	NA				
Enzyme X	-	2	2	2	2	-	0.27	0.53	0.80	1.07	0.33	8.1E-01	1.6E+00	2.4E+00	3.2E+00
Ethanol	64-17-5	1,123	1,123	1,123	1,123	-	149.73	299.47	449.20	598.93	0.96	1.6E+02	3.1E+02	4.7E+02	6.2E+02
Fatty acid ester 1,2	-	281	281	281	281	-	37.47	74.93	112.40	149.87	0.0191	2.0E+03	3.9E+03	5.9E+03	7.8E+03
Ethoxylated fatty acid ester 1,2	-	281	281	281	281	-	37.47	74.93	112.40	149.87	0.01914	2.0E+03	3.9E+03	5.9E+03	7.8E+03
Guar gum	9000-30-0	2,397	2,397	2,397	2,397	-	319.60	639.20	958.80	1278.40	0.042	7.6E+03	1.5E+04	2.3E+04	3.0E+04
Monoethanolamine borate	26038-87-9	1,739	1,739	-	-	-	231.87	463.73	695.60	927.47	0.013	1.8E+04	3.6E+04	5.4E+04	7.1E+04
Polyethylene glycol oleate ester 1	56449-46-8	24	24	24	24	-	3.20	6.40	9.60	12.80	0.093	3.4E+01	6.9E+01	1.0E+02	1.4E+02
Silica gel	112926-00-8	24	24	24	24	-	3.20	6.40	9.60	12.80	NA				
Sodium chloride	7647-14-5	66	66	33	33	-	8.80	17.60	26.40	35.20	NA				
Sodium hydroxide	1310-73-2	455	455	-	-	-	60.67	121.33	182.00	242.67	NA				
Tetrakis(hydroxylmethyl) phosphonium sulfate (THPS)	55566-30-8	84	84	84	84	84	11.20	22.40	33.60	44.80	2.00E-04	5.6E+04	1.1E+05	1.7E+05	2.2E+05
Sodium sulfate	7757-82-6	8	8	8	8	-	1.07	2.13	3.20	4.27	1.9	5.6E-01	1.1E+00	1.7E+00	2.2E+00
Sodium sulfite	7757-83-7	4	4	4	4	-	0.53	1.07	1.60	2.13	0.26	2.1E+00	4.1E+00	6.2E+00	8.2E+00
Sodium thiosulfate	7772-98-7	229	229	229	229	-	30.53	61.07	91.60	122.13	0.1	3.1E+02	6.1E+02	9.2E+02	1.2E+03
Terpene hydrocarbon by-products	68956-56-9	94	94	94	94	-	12.53	25.07	37.60	50.13	4.21E-04	3.0E+04	6.0E+04	8.9E+04	1.2E+05
Terpene and Terpenoids, sweet orange oil 1	68647-72-3	94	94	94	94	-	12.53	25.07	37.60	50.13	4.21E-04	3.0E+04	6.0E+04	8.9E+04	1.2E+05
Coco dimethylaminopropyl betaine	61789-40-0	-	1,247	-	1,247	-	166.27	332.53	498.80	665.07	0.0186	8.9E+03	1.8E+04	2.7E+04	3.6E+04
											Cumulative Ratio	**338,169**	**676,338**	**1,014,507**	**1,352,675**

Highlighted cells are ratios greater than one and indicate a potentially unacceptable risk

CAS = Chemical Abstracts Service

COPC = constituent of potential concern
PNEC = predicted no-effects concentration
mg/L = milligrams per litre
NA = not applicable

Appendix C2-3

Table A-1 Surface Water Quality Data for Theoretical Scenario in Initial Flowback for DeltaFoam 140

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)					Estimated Initial Mud Pit Concentration in flowback (150% of injected fluid volume) per coal seam per percent of mass returned calculated using equation: Mud Pitcon = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L)			
							DeltaFoam 140			
		Delta 140	DeltaFoam 140	Linear Gel	Linear Gel Foamed	Water	20%	40%	60%	80%
1,2-Benzisothiazolin-3-one	2634-33-5	2	2	1	1	-	0.27	0.53	0.80	1.07
Acetic acid	64-19-7	210	210	210	210	-	28.00	56.00	84.00	112.00
Alcohols, C10-12, ethoxylated	67254-71-1	24	24	24	24	-	3.20	6.40	9.60	12.80
Alkylated quaternary chloride	75-57-0	2,068	2,068	2,069	2,069	2,069	275.73	551.47	827.20	1102.93
Bentonite	121888-68-4	240	240	240	240	-	32.00	64.00	96.00	128.00
Calcium chloride	10043-52-4	2	2	1	1	-	0.27	0.53	0.80	1.07
Crystalline silica, quartz	14808-60-7	12	12	12	12	-	1.60	3.20	4.80	6.40
Enzyme X	-	2	2	2	2	-	0.27	0.53	0.80	1.07
Ethanol	64-17-5	1,123	1,123	1,123	1,123	-	149.73	299.47	449.20	598.93
Fatty acid ester 1,2	-	281	281	281	281	-	37.47	74.93	112.40	149.87
Ethoxylated fatty acid ester 1,2	-	281	281	281	281	-	37.47	74.93	112.40	149.87
Guar gum 1	9000-30-0	2,397	2,397	2,397	2,397	-	319.60	639.20	958.80	1278.40
Monoethanolamine borate	26038-87-9	1,739	1,739	-	-	-	231.87	463.73	695.60	927.47
Polyethylene glycol oleate ester 1	56449-46-8	24	24	24	24	-	3.20	6.40	9.60	12.80
Silica gel	112926-00-8	24	24	24	24	-	3.20	6.40	9.60	12.80
Sodium chloride	7647-14-5	66	66	33	33	-	8.80	17.60	26.40	35.20
Sodium hydroxide	1310-73-2	455	455	-	-	-	60.67	121.33	182.00	242.67
THPS	55566-30-8	84	84	84	84	84	11.20	22.40	33.60	44.80
Sodium sulfate	7757-82-6	8	8	8	8	-	1.07	2.13	3.20	4.27
Sodium sulfite	7757-83-7	4	4	4	4	-	0.53	1.07	1.60	2.13
Sodium thiosulfate	7772-98-7	229	229	229	229	-	30.53	61.07	91.60	122.13
Terpene hydrocarbon by-products	68956-56-9	94	94	94	94	-	12.53	25.07	37.60	50.13
Terpene and Terpenoids, sweet orange oil 1	68647-72-3	94	94	94	94	-	12.53	25.07	37.60	50.13
Coco dimethylaminopropyl betaine	61789-40-0	-	1,247	-	1,247	-	166.27	332.53	498.80	665.07

CAS = Chemical Abstracts Service

mg/L = milligrams per liter

Source for Table A-1: EHS Support, Inc. 2013. “Coal Seam Gas Hydraulic Fracturing Quantitative Risk Assessment Report for Halliburton Delta 140 Chemistry Report” Dated 4 August 2013.

Santos

Appendix C3
Halliburton CleanStimAUs System

C1.0 Introduction

As presented in **Section 5.0** of the Hydraulic Fracturing Risk Assessment , a weight-of-evidence approach was used by Santos Ltd. (Santos) to evaluate the potential for human health and environmental (e.g., ecological) risks as a result of the hydraulic fracturing processes and the Halliburton CleanStimAUS fluid system.

Golder Associates Pty Ltd. (Golder), on behalf of Santos, completed a human health and ecological toxicity assessment (Golder, 2013e) that evaluated the nature of the geology in the areas undergoing stimulation, the potential for impacts on water resources, the process and chemicals used.

A Quantitative Risk Assessment (QRA), completed by EHS Support, LLC (EHS Support), supplemented the qualitative risk assessment (EHS Support, 2013a). The QRA was conducted to meet Conditions 49e and 49f of the 2 October 2011 approval under the Environmental Protection and Biodiversity Conservation Act 1999 (EPBC 2008/4059) and the Environmental Amendment (EA) conditions to assess the toxicity of the mixtures.

Key reports and studies previously submitted for these fluid systems comprise:

- Golder Associates (2013e). Coal Seam Hydraulic Fracturing Risk Assessment. Human Health and Ecological Risk Assessment - CleanStim-AU. Golder Associates Report. 1 July 2013..
- EHS Support. (2013a). Gladstone Liquefied Natural Gas (GLNG) Project. Coal Seam Gas Hydraulic Fracturing Quantified Risk Assessment for Halliburton CleanStim AUS Chemistry. 16 July 2013.. .

The results and conclusions of the qualitative risk assessment components and the QRA are summarised below. Refer to the text of this report for detailed discussions on methodologies employed for each component; specific tables referred to in this summary are included for review with this document. Table numbers specific to the original reports were retained for consistency between documents.

C2.0 Qualitative Risk Assessment and Evaluation

C2.1 Chemicals Evaluated

Chemical constituents identified in the CleanStimAUS fracturing fluid system were evaluated in the hydraulic fracturing risk assessments. The list of individual chemicals is presented in **Table 1**. A mass balance of the chemicals within each of the hydraulic fracturing fluid systems was provided in Table C-1 (Golder, 2013e).

Information regarding the chemical and physical properties of the individual chemicals listed below can be found on the Safety Data Sheets in **Appendix E**.

It is noted, while none of the fracturing fluid chemicals identified contain benzene, toluene, ethylbenzene, xylenes (BTEX) or polycyclic aromatic hydrocarbons (PAHs), that PAHs occur naturally in coal and it is possible that certain PAHs may naturally be present in the coal seam groundwater used in the hydraulic fracturing process.

Table 1: Hydraulic fracturing chemicals

Chemical	CAS Number
Carbohydrate	-*
Food coating	64-19-7
Sodium lauryl sulfate	75-57-0
Fatty acid ester™	-*
Hemicellulase enzyme™	9012-54-8
Saccharide	-*
Polysaccharide	-*
Tri tetradecyl phosphonium chloride (TTPC)	81741-28-8
Inorganic salt	-*
Potassium chloride	7447-40-7
Sulfuric acid	7664-93-9
Talc	14807-96-6
Cyrstalline silica, quartz	14808-60-7

* The CAS numbers have not been included in this table due to commercial confidentiality.

C2.2 Risk Assessment Framework and Findings

As discussed in **Section 5.0** of the systematic weight of evidence approach was utilised to complete the risk assessment for the Halliburton fluid systems. The work has involved the following evaluations:

Qualitative Assessment Methodologies

- Environmental Hazard Assessment
- Exposure Assessment
- Mass Balance of the fluid systems.

As noted in **Section 7.2**, fate and transport of previously modelled fluid systems was not sensitive to the variability in physical properties of chemicals. Due to the broad range of physical properties assessed, the limited transport observed in the model and limited impact that physical properties has

on transport distances, fate and transport of the chemicals present in this fluid system was not considered warranted.

Quantitative Risk Assessment Methodologies

- Quantitative Human Health Risk Assessment
- Quantitative Ecological Risk Assessment for Terrestrial and Aquatic Receptors.

C2.3 Environmental Hazard Assessment

The environmental hazard assessment approach outlined in **Section 6.2** was undertaken to rank the hydraulic fracturing chemicals based on persistence (P), bioaccumulation (B) and toxic (T) potential (hereafter referred to as PBT).

A combination of data sets were used in the PBT assessment including chemical information sheets (**Appendix E** and **Appendix G**) were compiled for each chemical from published guidelines, the Hazardous Substance Database, and modelled data from United States Environmental Protection Agency (USEPA) (2009) EPISUITE modelling software, when data not available from other sources.

Of the 13 chemicals listed above, three were not considered for PBT ranking. Physico-chemical and/or toxicological data were not available, and surrogates could not be identified for saccharide, talc, polysaccharide, and tri tetradecyl phosphonium chloride (TTPC) (81741-28-8)[1]. Crystalline silica (14808-60-7) relate to the sand used as the proppant, and therefore is not considered to represent an environmental hazard.

C2.4 Exposure Assessment

As discussed in **Section 7.0**, the exposure assessment identified receptors potentially exposed to COPCs identified for the study and outlines the exposure pathways by which the receptors may come in to contact with the COPCs. A detailed exposure assessment was not conducted in the qualitative risk assessment; however, hazards from potential exposures were determined to be primarily occupational concerns with some limited environmental matters (Golder, 2013e).

C2.5 Mass Balance of Fluid System

A quantitative mass balance calculation was undertaken to identify the amount of each chemical additive of the hydraulic fracturing fluid system. The results of the mass balance calculations are presented in the referenced Table C-1 (Golder, 2013e).

C2.6 Fate and Transport Modelling

As noted in previously, fate and transport of previously modelled fluid systems was not sensitive to the variability in physical properties of chemicals. Due to the broad range of physical properties assessed, the limited transport observed in the model and limited impact that physical properties has on transport distances, fate and transport of the chemicals present in this fluid system was not considered warranted. Additionally, the modelling demonstrated that there is limited potential for chemicals to migrate within the coal seams.

[1] TTPC assessed in subsequent fluid systems. Refer to Appendix C8, Appendix C9 and C11 for PBT assessments of TTPC.

C3.0 Quantitative Risk Assessment

In accordance with the methodologies presented in **Section 8.0**, a QRA was conducted on theoretical datasets for those chemicals identified in the human health and ecological toxicity evaluation (EHS Support, 2013a). The QRA approach evaluates the toxicity of the individual substances and characterises the cumulative risks of the total effluent toxicity and ecotoxicity.

Generally, this methodology includes the identification of the hazards posed by constituents in the flowback water, compilation of the toxicity criteria for each constituent, development of exposure models to estimate the daily intake of the constituents, and calculations of individual constituent hazard quotients (daily intake divided by the toxicity criteria) and a cumulative constituent hazard index (HI) for each potentially complete exposure pathway for each human or terrestrial receptor.

Potential complete exposure pathways to the storage of flowback from hydraulically stimulated wells and potential risks to humans, terrestrial and aquatic receptors from the potential storage and accidental releases are evaluated in the QRA.

No further assessment of groundwater was determined to be necessary due to lack of potentially complete exposure pathways. Detailed operational procedures have been provided that are designed to contain the hydraulic fracturing fluids within the coal sequences, and no connection exists between groundwater in the coal seams and surface-water or springs (and therefore Matters of National Environmental Significance [MNES]). Further, the potential risks to workers involved with the hydraulic fracturing process were not considered as detailed Health and Safety (H&S) procedures are employed to manage exposures. The QRA considered the following specific exposure pathways:

1. Exposure of trespassers to flowback water contained within flowback storage ponds.
2. Exposure of terrestrial receptors (e.g., livestock, wildlife) to flowback water contained within the flowback storage ponds.
3. Exposure of aquatic receptors to flowback water in the situation of an accidental release, such as from piping or a release from the flowback storage pond. These potential releases could include a failure of containment systems, overtopping of the dam or in an extreme situation (considered highly unlikely) structural failure of the dam itself.

C3.1 Exposure Assessment

The purpose of the exposure assessment in the QRA was to predict the magnitude and frequency of potential human exposure to each COPC following the methodologies presented in **Section 8.1**. A conceptual site model (CSM) was developed which describes the potential receptors and exposure scenarios for the flowback water used in this exposure assessment. The potential exposures to receptors were evaluated based on the potential for a complete exposure pathway.

As discussed in **Section 8.3**, exposure point concentrations (EPCs) were derived for the theoretical assessment; empirical data were not available for evaluation. The EPCs for the theoretical assessment were calculated by estimating the mass and discharge flow of the COPCs from the flowback water monitoring data were used **Appendix C3-1** (Appendix A, Table A-1; EHS Support, 2013a).

C3.2 Human Health QRA

A human health hazard assessment was conducted according to the methodologies presented in **Section 8.4**. The purpose of the hazard assessment process was to summarise the environmental data, and to address the toxicological assessment of the COPCs that will be evaluated further in the risk assessment process.

Exposure assumptions for the human trespasser scenario were developed based on default or site-specific assumptions (**Section 8.4**). This receptor exposure pathway includes a small child to teenager that may come in contact with the above grade water exposure scenario for approximately 20 days/year for a 10-year period with potential incidental ingestion (of 50 millilitre [mL] water) and dermal contact (e.g., swimming where the whole body gets wet) for half an hour (Table 4; EHS Support, 2013a).

Calculation of intake of COPCs was performed using the equations presented below:

Ingestion of water:

$$Intake\ (mg/kg-day)\ =\ (CW\ x\ IR\ X\ EF\ X\ ED)\ /\ (BW\ x\ AT)$$

Dermal contact with water:

$$Absorbed\ dose\ (mg/kg-day)\ =\ (CW\ x\ SA\ x\ DP\ x\ ET\ x\ EF\ x\ ED\ x\ CF)\ /\ (BW\ x\ AT)$$

Where:

CW = concentration in water (mg/l)
ET = exposure time (hr/day or hours/hours)
EF = exposure frequency (day/year)
ED = exposure duration (years)
CF = correction factor (1 x 10-3 l/cm3)
AT = averaging time (days)
IR = ingestion rate (l/hr)
BW = body weight (kg)
SA = skin surface area available for contact (cm2/d)
DP = dermal permeability factor (Kp – cm/hr)

C3.3 Toxicity Assessment

A toxicity assessment was conducted to determine the relationship between the dose of a COPC taken into the body, and the probability that an adverse effect will result from that dose. Quantitative estimates of the potency of COPCs include two sets of toxicity values, one for genotoxic carcinogens and one for other non-genotoxic carcinogens and non-carcinogenic effects. As discussed in **Section 8.4,** detailed toxicological profiles were developed for the chemicals. The toxicological profiles are included as **Appendix F**.

The assessment of toxicity of the COPCs was used to develop initial screening criteria for human health exposure scenarios as discussed in **Section 8.4**. Refer to Tables 1 and 2 of the EHS Support QRA for details regarding the toxicity assessment of the COPCs (EHS Support, 2013a, attached).

C3.4 Risk Estimation

Risk estimation was performed in accordance with the methodologies outlined in **Section 8.4**. The total target risk range for carcinogens was 1 x 10^{-4} to 1 x 10^{-6}; the target HI for non-threshold effects is less than or equal to 1.0.

No carcinogenic compounds are present in the stimulation fluids injected into the subsurface and as a result, only non-carcinogenic risks were calculated. The exposure scenarios include 20 percent mass recovery from the fracturing fluid well flowback from 0 to 150 days from injection of fluid. The modelled risks from injected chemicals in the flowback water in both scenarios were acceptable (Tables 5 and 6; EHS Support, 2013a, attached).

C3.5 Ecological Risk Assessment

As discussed in **Section 8.5**, a screening level ecological risk assessment (ERA) was conducted to evaluate the potential for adverse ecological effects to terrestrial and aquatic ecological receptors that may be exposed to residual levels of hydraulic fracturing fluids in surface water used in the coal seam gas (CSG) fields.

Terrestrial receptors evaluated in the ERA include domesticated livestock, large mammalian wildlife and small mammalian wildlife. Beef cattle were used to evaluate domesticated livestock, kangaroos evaluated for large mammalian wildlife, and dingos for small mammalian wildlife. Aquatic receptors evaluated included invertebrates and fishes.

Ecological effects were characterised following the methodologies outlined in **Section 8.5.3** (Table 7; EHS Support, 2013a, attached). Exposure scenarios were the same for ecological receptors as human receptors; EPCs were estimated in accordance with the methodology presented in **Section 8.5.4** (**Appendix C3-1**; Table A-1; EHS Support, 2013a). Environmental fate information is provided in Table 3 (EHS Support, 2013a).

Risks were characterised in accordance with the methodologies discussed in **Section 8.5.5**. The resulting ecological hazard quotient must be less than or equal to 1.0 for risks to be considered acceptable.

C3.5.1 Estimation of Risk

The HI calculated for flowback water for aquatic risk were elevated above the acceptable level for the majority of COPCs evaluated (**Appendix C3-2**, Table C-2; EHS Support, 2013a). Where large discharges of flowback water occur to surface water and/or flux dilution within the surface-water was insufficient, potential impacts on aquatic receptors could occur. As noted in the toxicity assessment section, the lack of a robust aquatic toxicological database resulted in aquatic screening values for the theoretical exposure scenario COPCs to be conservatively very low.

The modelled risks from injected chemicals in the flowback water were all acceptable for each of the ecological receptors modelled (Tables 11 through 16; EHS Support, 2013a, attached). Therefore, there were no estimated potential risks to domesticated wildlife or mammalian wildlife that are either present on operational areas infrequently or in the vicinity of the well pads.

C4.0 Summary of QRA Findings

The QRA was completed as discussed in **Section 8.0**. An assessment was conducted using highly conservative theoretical calculations based on the chemicals utilised by Halliburton in hydraulic fracturing. This assessment assumed that a range of theoretical percentages of injected chemicals would be present in the flowback water.

Consistent with the risk assessment and groundwater fate and transport modelling conducted by Golder, no potentially complete exposure pathways were identified for groundwater. Potential exposures are limited to the aboveground storage and handling of flowback water as part of the CSG Water Management Plan (WMP). Management of CSG water involves the temporary storage of flowback water in flowback storage ponds.

On the basis of the quantitative risk calculations, no elevated potential risks were identified for the trespasser scenarios. No potential risks exist for livestock or native mammals. Potential impacts could occur if releases of flowback water were to occur to aquatic environments. Based on the use of clay liners and operational controls that limit the potential for turkey nest and dam overflows, the potential for these risks are also considered limited.

A combination of management and operational controls are being implemented to eliminate and control the potential for exposures. These include:

- Worker training and hazard identification
- Use of appropriate personal protective equipment (gloves, etc.)
- Flowback storage pond fencing to prevent entry of livestock and minimise trespassing
- Installation of clay dam liners and routine dam inspections to prevent releases from flowback storage ponds
- Routine operational and security patrols to prevent trespassing.

C5.0 Conclusions

A weight-of-evidence evaluation of potential risks as described in **Section 5.0** was performed for the Halliburton CleanStimAUS. Based on the qualitative and quantitative risk characterisations, the overall risk to human health and the environment is low. Existing operational control activities employed by Santos are in place that will limit the potential risks to human health and the environment. These measures include:

- Occupational health and safety procedures implemented during hydraulic fracturing operations to prevent workers from direct contact with chemicals during spills and when handling flowback water or sediments;
- Environmental authority conditions that preclude the construction of well pads within 100 metres of a watercourse of water body;
- Implementation of spill containment procedures during operations to prevent migration of and exposure to chemicals;
- Disposal or capping of sediments contained within drained mud pits and turkey nests, to prevent exposure to contaminates in windborne dust;
- Fencing of drill pads to prevent trespassers and installation of signs to indicate that the water in the turkey's nest and mud pit is not potable and may contain contaminants;
- Installation and maintenance of fences around the well pad to prevent access to the drill pad by livestock and large native fauna;
- Santos operational procedures to ensure well integrity and design of fracture to stay within the target seam; and
- Mud pits and turkey's nests with clay liners, or similar material, to prevent seepage of flowback water into underlying aquifers.

Regular monitoring of water supply bores and surface water for a representative suite of chemicals within 2 kilometre of wells that are fractured is required to confirm the conclusion of incomplete exposure pathways and low risk.

No additional risks, other than those previously discussed, were identified with the chemicals or systems employed by Halliburton in hydraulic fracturing. Evaluation of other potential risks associated with hydraulic fracturing (i.e., noise and vibration) was conducted. Refer to **Section 9.0** for methodology specifics and results of this evaluation

Santos

EHS Support Tables

Santos

Table 1 Oral Reference Doses and Drinking Water Guidelines Derived for Hydraulic Fracturing Chemicals

Chemical	Study	Critical Effect/Target Organ(s)	NOAEL (mg/kg/day)	Uncertainty Factors	Oral Reference Dose (mg/kg/day)	Drinking Water Guideline (ppm)
Aluminum sulfate					0.05	0.18 ppm [as Al]
Hemicellulase enzyme	13-wk rat dietary	General toxicity/liver	600	1,000	0.6	2
Lactose[a]	2-yr rat dietary	Effects not considered chemical-specific	1,580	1,000	1.0	3.5
Maltodextrin[b]	-	-	-	-	-	-
Sodium chloride[c]					-	180 for Na+ and 250 for Cl- (aesthetics)
Shellac, ammonium salt[e]	One –generation rat reproductive	None	500	1,000	0.5	1.8
Sodium carboxymethyl cellulose[f]	-	-	-	-	-	-
Sodium lauryl sulfate	2-yr rat dietary	Liver	113	100	1.1	4
Sorbitan, monododecanoate, poly(oxy-1,2-diethanediyl)	2-yr rat dietary	Marked diarrhea; distention of cecum	2,500[g]	100[g]	25[g]	88
Sulfuric acid					-	pH; 500 (health) and 250 (aesthetic) for $SO4^{2-}$
Talc[h]	-	-	-	-	-	-
Tributyl tetradecyl phosphonium chloride	No data	-	-	-	-	-
Potassium chloride[c]	2-yr rat dietary	Systemic effects	1820[d]	100	18.2	63.7

[a]Based on animal toxicity studies only.

[b]No toxicity data found. GRAS substance by FDA (no limitation in food).

[c]There is an Australian drinking water standard for chloride.

[d]the highest dose tested

[e]Food coating is a biopolymer and is insoluble in water. It is not expected to be bioavailable and therefore not hazardous to human health. There is an Australian drinking water standard for ammonium.

[f]ADI classified as "Not Specified" (formerly "Not Limited") by Joint WHO/FAO Expert Committee on Food Additives (JECFA).

[g]ADI (Joint WHO/FAO Expert Committee on Food Additives or JECFA).

[h]Talc is a mineral that is insoluble in water. It is not expected to be bioavailable and therefore not hazardous to human health by oral ingestion.

Table 2 Australian Drinking Water Screening Values for Hydraulic Fracturing Chemicals

Constituent	Drinking Water Screening Guideline	Drinking Water Screening Value (ppm)[a]
Aluminum sulfate	aluminum, sulfate	0.2 (aesthetic) for aluminum; 500 (health) and 250 (aesthetic) for sulfate
Sodium chloride	chloride and sodium	180 for Na^+ and 250 for Cl^- (aesthetics)
Potassium chloride	Potassium chloride	64
Sulfuric acid	pH, sulfate	6.5 to 8.5; 500 (health) and 250 (aesthetic) for sulfate

[a]Except for pH values.

Table 3 Environmental Fate Information

Aluminum sulfate	Dissociates completely in aqueous media
Hemicellulase enzyme	Readily biodegradable (half-life = 15 days)
Lactose	Readily biodegradable (half-life = 15 days)
Maltodextrin	Readily biodegradable (half-life = 15 days)
Sodium chloride	Dissociates completely in aqueous media
Shellac, ammonium salte	Not biodegradable
Sodium carboxymethyl cellulose	Inherently biodegradable (half-life = 150 days)
Sodium lauryl sulfate	Readily biodegradable (half-life = 15 days)
Sorbitan, monododecanoate, poly(oxy-1,2-diethanediyl)	Inherently biodegradable (half-life = 150 days)
Sulfuric acid	Dissociates completely in aqueous media
Talch	Water-insoluble mineral (does not biodegrade)
Tributyl tetradecyl phosphonium chloride	No data
Potassium chloride	Dissociates completely in aqueous media

Source: EU Guidance Document: Half-life estimates from in vitro biodegradation test results

Table 4 Exposure Assumptions - Trespasser

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/hr	0.05
	ET	Exposure time	hr/day	0.5
	EF	Exposure frequency	day/yr	20
	ED	Exposure duration	yr	10
	BW	Body weight	kg	47
	AT-NC	Averaging time - noncancer	days	3,650
	AT-C	Averaging time - cancer	days	25,550
Dermal	SA	Surface area for contact	cm^2/day	13,000
	DP	Dermal permeability factor	cm/h	chemical-specific
	ET	Exposure time	hr/day	1
	EF	Exposure frequency	day/yr	20
	ED	Exposure duration	yr	10
	BW	Body weight	kg	47
	AT-NC	Averaging time - noncancer	days	3,650
	AT-C	Averaging time - cancer	days	25,550
	CF	Conversion factor	l/cm^3	1.0E-03

Table 5 Risk Estimates for Trespasser Halliburton CleanStimAUS Theoretical Exposure for Day 0

		Day		Toxicity	CleanStimAUS			
							Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**PC (cm/hr)**	**RfDo**	**$CADD_{oral}$**	**$CADD_{derm}$**	**Incidental Ingestion**	**Dermal**
Aluminum sulfate	10043-01-3	8.4E+01	NA	0.057	4.9E-03		8.6E-02	
Hemicellulase enzyme	9012-54-8	4.8E-01	NA	0.6	2.8E-05		4.7E-05	
Lactose	63-42-3	3.7E+01	9.2E-09	1.6	2.2E-03	2.6E-09	1.4E-03	1.6E-09
Maltodextrin	9050-36-6	4.7E+01	NA	-	-		-	
Sodium chloride	7447-40-7	3.2E+02	NA	51	1.9E-02		3.7E-04	
Shellac, ammonium salt	68308-35-8	9.6E+00	2.7E-15	0.5	5.6E-04	2.0E-16	1.1E-03	4.0E-16
Sodium carboxymethyl cellulose	9004-32-4	6.4E+02	NA	-	-			
Sodium lauryl sulfate	151-21-3	1.3E+01	4.4E-04	1	7.8E-04	4.4E-05	7.8E-04	4.4E-05
Sorbitan, monododecanoate, poly(oxy-1,2-diethanediyl)	9005-65-5	2.4E+01	NA	25	1.4E-03		5.6E-05	
Sulfuric acid	7664-93-9	2.1E+01	NA	142.9	1.2E-03		8.6E-06	
Talc	14807-96-6	4.8E-01	NA	-	-		-	
Tributyl tetradecyl phosphonium chloride	81741-28-8	4.8E-01	NA	-	-		-	
Crystalline silica, quartz	14808-60-7	-	NA	-	-		-	
						Hazard Index	9.0E-02	

EHS Support consider it done

Table 6 Risk Estimates for Trespasser Halliburton CleanStimAUS Theoretical Exposure for Day 150

		Day 150		Toxicity	CleanStimAUS			
							Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**PC (cm/hr)**	**RfDo**	**$CADD_{oral}$**	**$CADD_{derm}$**	**Incidental Ingestion**	**Dermal**
Aluminum sulfate	10043-01-3	8.4E+01	NA	0.057	4.9E-03		8.6E-02	
Hemicellulase enzyme	9012-54-8	4.7E-04	NA	0.6	2.7E-08		4.6E-08	
Lactose	63-42-3	3.6E-02	9.2E-09	1.6	2.1E-06	2.5E-12	1.3E-06	1.6E-12
Maltodextrin	9050-36-6	4.6E-02	NA	-	-		-	
Sodium chloride	7447-40-7	3.2E+02	NA	51	1.9E-02		3.7E-04	
Shellac, ammonium salt	68308-35-8	9.6E+00	2.7E-15	0.5	5.6E-04	2.0E-16	1.1E-03	4.0E-16
Sodium carboxymethyl cellulose	9004-32-4	3.2E+02	NA	-	-			
Sodium lauryl sulfate	151-21-3	1.3E-02	4.4E-04	1	7.6E-07	4.3E-08	7.6E-07	4.3E-08
Sorbitan, monododecanoate, poly(oxy-1,2-diethanediyl)	9005-65-5	1.2E+01	NA	25	7.0E-04		2.8E-05	
Sulfuric acid	7664-93-9	2.1E+01	NA	142.9	1.2E-03		8.6E-06	
Talc	14807-96-6	4.8E-01	NA	-	-		-	
Tributyl tetradecyl phosphonium chloride	81741-28-8	4.8E-01	NA	-	-		-	
Crystalline silica, quartz	14808-60-7	-	NA	-	-		-	
						Hazard Index	8.8E-02	

Table 7 Aquatic Toxicity Values (PNECs)

Chemical	Endpoint	NOEC (mg/L)	Assessment Factor	$PNEC_{aquatic}$ (mg/L)
Aluminum sulfate [a]	Chronic fish	0.06	1	0.06 [as Al]
Hemicellulase enzyme	96-hr LC50 (fish)	330	1,000	0.33
Lactose	96-hr LC50 (fish) [ECOSAR]	81, 045	1,000	81
Maltodextrin[b]	-	-	-	-
Sodium chloride	-	-	-	-
Shellac, ammonium salt[c]	-	-	-	-
Sodium carboxymethyl cellulose	96-hr EC50 (algae)	500	1,000	0.5
Sodium lauryl sulfate	Chronic Daphnia	0.88	10	0.09
Sorbitan, monododecanoate, poly(oxy-1,2-diethanediyl)	Acute algae	100	1,000	0.1
Sulfuric acid	Chronic fish	0.13	50	0.0026
Talc[d]	-	-	-	-
Tributyl tetradecyl phosphonium chloride	48-hr LC50 (Daphnia)	0.025	1,000	2.5 x 10-5
Potassium chloride	72-hr EC50 (algae)	100	1,000	0.1

a CEPA Priority Substance List Assessment Report (2010)

b Saccharide is a oligosaccharide composed of D-glucose sugars (molecular weights ranging from 550-3000). There are no data; however, it is not expected to be toxic to aquatic organisms due to molecular weight considerations and that D-glucose is a sugar found in the body and is an energy source.

c Food coating is a biopolymer and is insoluble in water. It is not expected to be bioavailable and therefore not hazardous to aquatic organisms.

d Talc is an inert mineral and is insoluble in water. It is not expected to be harmful to aquatic organisms.

Table 11 Risk Estimates for Cattle Halliburton CleanStimAUS Theoretical Exposure for Day 0

		Day 0	Toxicity	CleanStimAUS	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**TI**	**Incidental Ingestion**
Aluminum sulfate	10043-01-3	8.4E+01			
Hemicellulase enzyme	9012-54-8	4.8E-01	1.0E+02	3.7E-03	3.7E-05
Lactose	63-42-3	3.7E+01	2.6E+02	2.9E-01	1.1E-03
Maltodextrin	9050-36-6	4.7E+01			
Sodium chloride	7447-40-7	3.2E+02			
Shellac, ammonium salt	68308-35-8	9.6E+00	8.3E+01	7.5E-02	9.0E-04
Sodium carboxymethyl cellulose	9004-32-4	6.4E+02			
Sodium lauryl sulfate	151-21-3	1.3E+01	1.9E+01	1.0E-01	5.5E-03
Sorbitan, monododecanoate, poly(oxy-1,2-diethanediyl)	9005-65-5	2.4E+01	4.2E+02	1.9E-01	4.5E-04
Sulfuric acid	7664-93-9	2.1E+01			
Talc	14807-96-6	4.8E-01			
Tributyl tetradecyl phosphonium chloride	81741-28-8	4.8E-01			
Crystalline silica, quartz	14808-60-7	-			

Hazard Index

8.0E-03

Table 12 Risk Estimates for Cattle Halliburton CleanStimAUS Theoretical Exposure for Day 150

		Day 150	Toxicity	CleanStimAUS	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**TI**	**Incidental Ingestion**
Aluminum sulfate	10043-01-3	8.4E+01			
Hemicellulase enzyme	9012-54-8	4.7E-04	1.0E+02	3.6E-06	3.6E-08
Lactose	63-42-3	3.6E-02	2.6E+02	2.8E-04	1.1E-06
Maltodextrin	9050-36-6	4.6E-02			
Sodium chloride	7447-40-7	3.2E+02			
Shellac, ammonium salt	68308-35-8	9.6E+00	8.3E+01	7.5E-02	9.0E-04
Sodium carboxymethyl cellulose	9004-32-4	3.2E+02			
Sodium lauryl sulfate	151-21-3	1.3E-02	1.9E+01	1.0E-04	5.4E-06
Sorbitan, monododecanoate, poly(oxy-1,2-diethanediyl)	9005-65-5	1.2E+01	4.2E+02	9.4E-02	2.3E-04
Sulfuric acid	7664-93-9	2.1E+01			
Talc	14807-96-6	4.8E-01			
Tributyl tetradecyl phosphonium chloride	81741-28-8	4.8E-01			
Crystalline silica, quartz	14808-60-7	-			

Hazard Index
1.1E-03

Table 13 Risk Estimates for Kangaroo Halliburton CleanStimAUS Theoretical Exposure for Day 0

		Day 0	Toxicity	CleanStimAUS	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**TI**	**Incidental Ingestion**
Aluminum sulfate	10043-01-3	8.4E+01			
Hemicellulase enzyme	9012-54-8	4.8E-01	2.1E+02	1.6E-03	7.6E-06
Lactose	63-42-3	3.7E+01	5.4E+02	1.2E-01	2.3E-04
Maltodextrin	9050-36-6	4.7E+01			
Sodium chloride	7447-40-7	3.2E+02			
Shellac, ammonium salt	68308-35-8	9.6E+00	1.7E+02	3.2E-02	1.8E-04
Sodium carboxymethyl cellulose	9004-32-4	6.4E+02			
Sodium lauryl sulfate	151-21-3	1.3E+01	3.9E+01	4.4E-02	1.1E-03
Sorbitan, monododecanoate, poly(oxy-1,2-diethanediyl)	9005-65-5	2.4E+01	8.6E+02	7.9E-02	9.2E-05
Sulfuric acid	7664-93-9	2.1E+01			
Talc	14807-96-6	4.8E-01			
Tributyl tetradecyl phosphonium chloride	81741-28-8	4.8E-01			
Crystalline silica, quartz	14808-60-7	-			

Hazard Index
1.6E-03

Table 14 Risk Estimates for Kangaroo Halliburton CleanStimAUS Theoretical Exposure for Day 150

		Day 150	Toxicity	CleanStimAUS	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**TI**	**Incidental Ingestion**
Aluminum sulfate	10043-01-3	8.4E+01			
Hemicellulase enzyme	9012-54-8	4.7E-04	2.1E+02	1.5E-06	7.5E-09
Lactose	63-42-3	3.6E-02	5.4E+02	1.2E-04	2.2E-07
Maltodextrin	9050-36-6	4.6E-02			
Sodium chloride	7447-40-7	3.2E+02			
Shellac, ammonium salt	68308-35-8	9.6E+00	1.7E+02	3.2E-02	1.8E-04
Sodium carboxymethyl cellulose	9004-32-4	3.2E+02			
Sodium lauryl sulfate	151-21-3	1.3E-02	3.9E+01	4.3E-05	1.1E-06
Sorbitan, monododecanoate, poly(oxy-1,2-diethanediyl)	9005-65-5	1.2E+01	8.6E+02	4.0E-02	4.6E-05
Sulfuric acid	7664-93-9	2.1E+01			
Talc	14807-96-6	4.8E-01			
Tributyl tetradecyl phosphonium chloride	81741-28-8	4.8E-01			
Crystalline silica, quartz	14808-60-7	-			

Hazard Index
2.3E-04

Table 15 Risk Estimates for Dingo Halliburton CleanStimAUS Theoretical Exposure for Day 0

		Day 0	Toxicity	CleanStimAUS	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**TI**	**Incidental Ingestion**
Aluminum sulfate	10043-01-3	8.4E+01			
Hemicellulase enzyme	9012-54-8	4.8E-01	2.4E+02	7.6E-04	3.1E-06
Lactose	63-42-3	3.7E+01	6.4E+02	5.9E-02	9.2E-05
Maltodextrin	9050-36-6	4.7E+01			
Sodium chloride	7447-40-7	3.2E+02			
Shellac, ammonium salt	68308-35-8	9.6E+00	2.0E+02	1.5E-02	7.5E-05
Sodium carboxymethyl cellulose	9004-32-4	6.4E+02			
Sodium lauryl sulfate	151-21-3	1.3E+01	4.6E+01	2.1E-02	4.6E-04
Sorbitan, monododecanoate, poly(oxy-1,2-diethanediyl)	9005-65-5	2.4E+01	1.0E+03	3.8E-02	3.8E-05
Sulfuric acid	7664-93-9	2.1E+01			
Talc	14807-96-6	4.8E-01			
Tributyl tetradecyl phosphonium chloride	81741-28-8	4.8E-01			
Crystalline silica, quartz	14808-60-7	-			

Hazard Index
6.7E-04

Table 16 Risk Estimates for Dingo Halliburton CleanStimAUS Theoretical Exposure for Day 150

		Day 150	Toxicity	CleanStimAUS	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**TI**	**Incidental Ingestion**
Aluminum sulfate	10043-01-3	8.4E+01			
Hemicellulase enzyme	9012-54-8	4.7E-04	2.4E+02	7.4E-07	3.0E-09
Lactose	63-42-3	3.6E-02	6.4E+02	5.8E-05	9.0E-08
Maltodextrin	9050-36-6	4.6E-02			
Sodium chloride	7447-40-7	3.2E+02			
Shellac, ammonium salt	68308-35-8	9.6E+00	2.0E+02	1.5E-02	7.5E-05
Sodium carboxymethyl cellulose	9004-32-4	3.2E+02			
Sodium lauryl sulfate	151-21-3	1.3E-02	4.6E+01	2.1E-05	4.5E-07
Sorbitan, monododecanoate, poly(oxy-1,2-diethanediyl)	9005-65-5	1.2E+01	1.0E+03	1.9E-02	1.9E-05
Sulfuric acid	7664-93-9	2.1E+01			
Talc	14807-96-6	4.8E-01			
Tributyl tetradecyl phosphonium chloride	81741-28-8	4.8E-01			
Crystalline silica, quartz	14808-60-7	-			

Hazard Index

9.4E-05

Appendix C3-1

Table A-1 Surface Water Quality Data for Theoretical Scenario in Initial Flowback for DeltaFoam 140

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)					Estimated Initial Mud Pit Concentration in flowback (150% of injected fluid volume) per coal seam per percent of mass returned calculated using equation: Mud Pitcon = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (%)			
							DeltaFoam 140			
		Delta 140	DeltaFoam 140	Linear Gel	Linear Gel Foamed	Water	20%	40%	60%	80%
1,2-Benzisothiazolin-3-one	2634-33-5	2	2	1	1	-	0.27	0.53	0.80	1.07
Acetic acid	64-19-7	210	210	210	210	-	28.00	56.00	84.00	112.00
Alcohols, C10-12, ethoxylated	67254-71-1	24	24	24	24	-	3.20	6.40	9.60	12.80
Alkylated quaternary chloride	75-57-0	2,068	2,068	2,069	2,069	2,069	275.73	551.47	827.20	1102.93
Bentonite	121888-68-4	240	240	240	240	-	32.00	64.00	96.00	128.00
Calcium chloride	10043-52-4	2	2	1	1	-	0.27	0.53	0.80	1.07
Crystalline silica, quartz	14808-60-7	12	12	12	12	-	1.60	3.20	4.80	6.40
Enzyme X	-	2	2	2	2	-	0.27	0.53	0.80	1.07
Ethanol	64-17-5	1,123	1,123	1,123	1,123	-	149.73	299.47	449.20	598.93
Fatty acid ester 1,2	-	281	281	281	281	-	37.47	74.93	112.40	149.87
Ethoxylated fatty acid ester 1,2	-	281	281	281	281	-	37.47	74.93	112.40	149.87
Guar gum 1	9000-30-0	2,397	2,397	2,397	2,397	-	319.60	639.20	958.80	1278.40
Monoethanolamine borate	26038-87-9	1,739	1,739	-	-	-	231.87	463.73	695.60	927.47
Polyethylene glycol oleate ester 1	56449-46-8	24	24	24	24	-	3.20	6.40	9.60	12.80
Silica gel	112926-00-8	24	24	24	24	-	3.20	6.40	9.60	12.80
Sodium chloride	7647-14-5	66	66	33	33	-	8.80	17.60	26.40	35.20
Sodium hydroxide	1310-73-2	455	455	-	-	-	60.67	121.33	182.00	242.67
THPS	55566-30-8	84	84	84	84	84	11.20	22.40	33.60	44.80
Sodium sulfate	7757-82-6	8	8	8	8	-	1.07	2.13	3.20	4.27
Sodium sulfite	7757-83-7	4	4	4	4	-	0.53	1.07	1.60	2.13
Sodium thiosulfate	7772-98-7	229	229	229	229	-	30.53	61.07	91.60	122.13
Terpene hydrocarbon by-products	68956-56-9	94	94	94	94	-	12.53	25.07	37.60	50.13
Terpene and Terpenoids, sweet orange oil 1	68647-72-3	94	94	94	94	-	12.53	25.07	37.60	50.13
Coco dimethylaminopropyl betaine	61789-40-0	-	1,247	-	1,247	-	166.27	332.53	498.80	665.07

Appendix C3-2

Table C-2. Comparison of Estimated Theoretical Halliburton CleanStimAUS Concentrations to Aquatic Life Water Guidelines

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Mud Pit Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Mud Pitcon = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)				PNEC aquatic (mg/L)	Ratio of COPC Concentrations and Screening Criteria (Ratio greater than one = unacceptable potential risk)			
				Temporal Scenario (days)					Temporal Scenario (days)			
		CleanStimAUS	Half-Life	0	30	150	300		0	30	150	300
Aluminum sulfate	10043-01-3	633	NA	84.40	84.4	84.4	84.4	6.0E-02	1.4E+03	1.4E+03	1.4E+03	1.4E+03
Hemicellulase enzyme	9012-54-8	3.6	15	0.5	0.1	0.0005	0.0000005	3.3E-01	1.5E+00	3.6E-01	1.4E-03	1.4E-06
Lactose	63-42-3	280	15	37.3	9.3	0.036	0.00004	8.1E+01	4.6E-01	1.2E-01	4.5E-04	4.4E-07
Maltodextrin	9050-36-6	356	15	47.5	11.9	0.046	0.00005	-				
Sodium chloride	7447-40-7	2,397	NA	319.6	319.6	319.6	319.6	-				
Shellac, ammonium salt	68308-35-8	72	NA	9.6	9.6	9.6	9.6	-				
Sodium carboxymethyl cellulose	9004-32-4	4,793	150	639.1	556.3	319.5	159.8	5.0E-01	1.3E+03	1.1E+03	6.4E+02	3.2E+02
Sodium lauryl sulfate	151-21-3	100	15	13.3	3.3	0.0	0.0	9.0E-02	1.5E+02	3.7E+01	1.4E-01	1.4E-04
Sorbitan, monododecanoate, poly(oxy-1,2-diethanediyl)	9005-65-5	181	150	24.1	21.0	12.1	6.0	1.0E-01	2.4E+02	2.1E+02	1.2E+02	6.0E+01
Sulfuric acid	7664-93-9	158	NA	21.1	21.1	21.1	21.1	2.6E-03	8.1E+03	8.1E+03	8.1E+03	8.1E+03
Talc	14807-96-6	3.6	NA	0.5	0.5	0.5	0.5	-				
Tributyl tetradecyl phosphonium chloride	81741-28-8	3.6	NA	0.5	0.5	0.5	0.5	2.5E-05	1.9E+04	1.9E+04	1.9E+04	1.9E+04
Crystalline silica, quartz	14808-60-7	-		-	-	-	-	-				
Water	7732-18-5	-		-	-	-	-	-				
								Cumulative Ratio	**3.0E+04**	**3.0E+04**	**2.9E+04**	**2.9E+04**

Highlighted cells are ratios greater than one and indicate a potentially unacceptable risk

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Appendix C4
Schlumberger Clearfrac XT Fluid System

C1.0 Introduction

As presented in **Section 5.0** of the Hydraulic Fracturing Risk Assessment (RA Compendium), a weight-of-evidence approach was used by Santos to evaluate the potential for human health and environmental (e.g., ecological) risks as a result of the hydraulic fracturing processes and the Schlumberger ClearFRAC XT fluid system.

EHS Support, LLC (EHS Support) conducted a persistence, bioaccumulation, and toxicity (PBT) assessment and compared ClearFRAC XT fluid system to the Schlumberger water and guar-based system discussed in **Appendix C1** (EHS Support, 2013c). The assessment was conducted to meet Conditions 49e and 49f of the 2 October 2011 approval under the Environmental Protection and Biodiversity Conservation Act 1999 (EPBC 2008/4059) and the Environmental Amendment (EA) conditions to assess the toxicity of the mixtures.

Key reports and studies previously submitted for these fluid systems comprise:

- EHS Support. (2013c). ClearFRAC PBT Assessment and Comparison to Primary Hydraulic Fracturing Fluid. Memorandum. 27 June 2013.

The results and conclusions of the fluid system evaluation are summarised below. Refer to the text of this report for detailed discussions on methodologies employed for each component; specific tables referred to in this summary are included for review with this document. Table numbers specific to the original reports were retained for consistency between documents.

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C2.0 Qualitative Risk Assessment and Evaluation

C2.1 Chemicals Evaluated

Chemical constituents identified in the ClearFRAC XT fracturing fluid system were evaluated in the hydraulic fracturing risk assessments. The list of individual chemicals is presented in **Table 1**. A mass balance of the chemicals within each of the hydraulic fracturing fluid systems is provided as **Appendix C4-1** (Attachment 1; EHS Support, 2013c).

It is noted, while none of the fracturing fluid chemicals identified contain benzene, toluene, ethylbenzene, xylenes (BTEX), or polycyclic aromatic hydrocarbons (PAHs), that PAHs occur naturally in coal, and it is possible that certain PAHs will naturally be present in the coal seam groundwater used in the hydraulic fracturing process.

Table 1: Hydraulic fracturing chemicals

Chemical	CAS Number
Water (including mix water supplied by client)	-
Cyrstalline silica	14808-60-7
Erucic amidopropyl dimethyl betaine	149879-98-1
Propan-2-ol	67-63-0
Cholinium chloride	67-48-1
Sodium chloride	7647-14-5
Benzenesulfonic acid, 4-ethenyl-, sodium salt, homopolymer	25704-18-1
Hydrochloric acid	7647-01-1
Vinylidene chloride/methalacrylate copolymer	25038-72-6
Sodium chloroacetate	3926-62-3
Acetic acid ethenyl ester, polymer with ethenol	25213-24-5
Diatomaceous earth, calcined	91053-39-3
Polyvinyl acetate, partially hydrolyzed	304443-60-5
Magnesium silicate hydrate (talc)	14807-96-6
Magnesium nitrate	13077-60-3
5-chloro-2-methyl-2h-isothiazolol-3-one	26172-55-4
Magnesium chloride	7786-30-3
2-methyl-2h-isothiazol-3-one	2682-20-4
Cristobalite	14464-46-1

C2.2 Risk Assessment Framework and Findings

As discussed in **Section 5.0** of the systematic weight of evidence approach was utilised to complete the risk assessment for the Schlumberger ClearFRAC XT Fluid System. The work has involved the following evaluations:

Qualitative Assessment Methodologies

- PBT Assessment

- Exposure Assessment
- Mass Balance of the fluid system.

As noted in **Section 7.2**, fate and transport of previously modelled fluid systems was not sensitive to the variability in physical properties of chemicals. Due to the broad range of physical properties assessed, the limited transport observed in the model and limited impact that physical properties has on transport distances, fate and transport of the chemicals present in this fluid system was not considered warranted.

Quantitative Risk Assessment Methodologies

A quantitative risk assessment (QRA) was conducted for the original Schlumberger fluid system (**Appendix C1**) to estimate potential risks from exposures to the fluid system as discussed in Section **8.0**. The constituents of the ClearFRAC XT fluid system were compared to those present in the original fluid system to determine if toxicological information or projected chemical concentrations would result in a greater risk to human health or the environment than those in the Schlumberger water and guar-based system.

C2.3 PBT Assessment

The PBT approach outlined in **Section 6.1** was undertaken to rank the hydraulic fracturing chemicals based on persistence (P), bioaccumulation (B) and toxic (T) potential. As a result of this assessment, no chemical constituents identified in the ClearFRAC XT fluid system was classified as a PBT chemical and is therefore not considered to be inherently hazardous (Table 1; EHS Support, 2013c)

C2.4 Toxicity Assessment

As discussed in **Section 8.0**, detailed human health and environmental toxicological profiles and supporting documents were developed for the chemicals within the ClearFRAC XT system (**Appendices F and G**; Attachment 2, EHS Support, 2013c). Physical, chemical, and toxicoloigical data on the ClearFRAC XT constituents were collected in accordance with the methodology outlined in **Section 6.0** and the Schlumberger water and guar-based fluid system (**Appendix C1**).

C2.5 Summary of Qualitative PBT and Human Toxicity Assessment

In accordance with the methodology outlined in **Section 6.1**, the chemicals identified in the Schlumberger ClearFRAC XT fluid system were assessed for their potential persistence, bioaccumulation, and toxicity in the PBT assessment. None of the chemicals was considered to be inherently hazardous.

C2.6 Exposure Assessment

As discussed in **Section 7.0**, the exposure assessment identified receptors potentially exposed to chemicals of potential concern (COPC) identified for the study and outlines the exposure pathways by which the receptors may come in to contact with the COPCs. A detailed exposure assessment was not conducted in the qualitative risk assessment; however, hazards from potential exposures were determined to be consistent with exposures identified in the Schlumberger water and guar-based fluid system (**Appendix C1**): primarily occupational concerns with some limited environmental matters.

C2.7 Mass Balance of Fluid System

A quantitative mass balance calculation was undertaken to identify the amount of each chemical additive of the hydraulic fracturing fluid system. Specific details regarding the methodology of the calculation are presented in **Section 4.7** of this report. The results of the mass balance calculations are presented in the referenced Attachment 1 (EHS Support, 2013c) which is included in **Appendix C3-1**.

C2.8 Fate and Transport Modelling

As noted in previously, fate and transport of previously modelled fluid systems was not sensitive to the variability in physical properties of chemicals. Due to the broad range of physical properties assessed, the limited transport observed in the model and limited impact that physical properties has on transport distances, fate and transport of the chemicals present in this fluid system was not considered warranted. Additionally, the modelling demonstrated that there is limited potential for chemicals to migrate within the coal seams.

C3.0 Quantitative Risk Assessment

In accordance with the methodologies presented in **Section 8.0**, a QRA was conducted on theoretical and empirical datasets for those chemicals identified in the human health and ecological toxicity evaluation for the Schlumberger water and guar-based system (**Appendix C1**; EHS Support, 2013c). A QRA specific to ClearFRAC XT fluid system chemicals was not conducted; however, the chemicals were compared to the original Schlumberger fluid system components to identify relative risks in the ClearFRAC XT fluid system (Table 2; EHS Support, 2013c). The QRA approach evaluates the toxicity of the individual substances and characterises the cumulative risks of the total effluent toxicity and ecotoxicity.

Generally, this methodology includes the identification of the hazards posed by constituents in the flowback water, compilation of the toxicity criteria for each constituent, development of exposure models to estimate the daily intake of the constituents, and calculations of individual constituent hazard quotients (daily intake divided by the toxicity criteria) and a cumulative constituent hazard index (HI) for each potentially complete exposure pathway for each human or terrestrial receptor.

Potential complete exposure pathways to the storage of flowback from hydraulically stimulated wells and potential risks to humans, terrestrial and aquatic receptors from the potential storage and accidental releases are evaluated in the QRA.

No further assessment of groundwater was determined to be necessary due to lack of potentially complete exposure pathways. Detailed operational procedures have been provided that are designed to contain the hydraulic fracturing fluids within the coal sequences, and no connection exists between groundwater in the coal seams and surface-water or springs (and therefore Matters of National Environmental Significance [MNES]). Further, the potential risks to workers involved with the hydraulic fracturing process were not considered as detailed Health and Safety (H&S) procedures are employed to manage exposures. Similar to the original formulation, the following are considered specific exposure pathways:

1. Exposure of trespassers to flowback water contained within flowback storage ponds
2. Exposure of terrestrial receptors (e.g., livestock and wildlife) to flowback water contained within the flowback storage ponds
3. Exposure of aquatic receptors to flowback water in the situation of an accidental release, such as from piping or a release from the flowback storage pond. These potential releases could include a failure of containment systems, overtopping of the dam or in an extreme situation (considered highly unlikely) structural failure of the dam itself.

C3.1 Exposure Assessment

The purpose of the exposure assessment in the QRA was to predict the magnitude and frequency of potential human exposure to each COPC following the methodologies presented in **Section 8.1**. A conceptual site model (CSM) was developed which describes the potential receptors and exposure scenarios for the flowback water used in this exposure assessment. The potential exposures to receptors were evaluated based on the potential for a complete exposure pathway.

As discussed in **Section 8.3**, exposure point concentrations (EPCs) were derived for the theoretical assessment for ClearFRAC XT fluid system and compared to the theoretical EPCs developed for the Schlumberger water and guar-based system (Table 3; EHS Support, 2013c). In general, there were

fewer constituents in the ClearFRAC XT system, including fewer solvents. In addition, the estimated concentrations were less for chemicals present in both systems.

C3.2 Human Health QRA

A detailed human health hazard assessment was not conducted on the ClearFRAC XT chemicals. The QRA conducted on the previous Schlumberger fluid system (refer to **Appendix C1**) identified potential risks to human health that would be expected to be similar to or greater than the potential risks from ClearFRAC XT due to the toxicological properties previously discussed and the estimated EPCs (**Appendix C4-1**).

C3.3 Toxicity Assessment

A toxicity assessment was conducted to determine the relationship between the dose of a COPC taken into the body, and the probability that an adverse effect will result from that dose. Quantitative estimates of the potency of COPCs include two sets of toxicity values, one for genotoxic carcinogens and one for other non-genotoxic carcinogens and non-carcinogenic effects. As discussed in **Section 8.4,** detailed toxicological profiles were developed for the chemicals. The toxicological profiles are included as **Appendix F**.

The assessment of toxicity of the COPCs was used to develop initial screening criteria for human health exposure scenarios as discussed in **Section 8.4**. Refer to Table 2 for details regarding the toxicity assessment of the ClearFRAC XT chemicals (EHS Support, 2013c).

C3.4 Risk Estimation

A specific estimate of risk was not conducted for exposure to the ClearFRAC XT chemicals as the potential risks to human health and the environment presented in the Schlumberger water and guar-based system were expected to be similar or greater than the potential risks from the ClearFRAC XT chemicals (EHS Support, 2013c). Refer to **Appendix C1** for risk estimation on potential exposures to the water and guar-based system.

C3.5 Ecological Risk Assessment

Similar to the human health assessment, a detailed ecological risk assessment (ERA) was not conducted specifically for the ClearFRAC XT chemicals. Rather, an environmental health toxicological review was conducted, theoretical chemical concentrations in flowback water were estimated, and results were compared to the QRA conducted on the Schlumberger water and guar-based system (**Appendix C1**), which follows the approach outlined in **Section 8.5**.

C4.0 Summary of QRA Findings

The detailed QRA was not completed for the ClearFRAC XT chemicals as discussed in **Section C3.0**. However, a detailed QRA was conducted on the original Schlumberger fluid system (**Appendix C1**) in accordance with the methodology outlined in **Section 8.0**. As the ClearFRAC XT fluid system was developed by Schlumberger as a more environmentally fluid system than their original formulation, the composition is similar with substitutions for less hazardous chemicals.

Consistent with the risk assessment and groundwater fate and transport modelling conducted by Golder Associates Pty Ltd. (Golder), no potentially complete exposure pathways were identified for groundwater. Potential exposures are limited to the aboveground storage and handling of flowback water as part of the CSG Water Management Plan (WMP). Management of CSG water involves the temporary storage of flowback water in flowback storage ponds.

The ClearFRAC XT replacement chemicals were found to exhibit lower toxicity than those in the original formulation. Estimated concentrations in the pre-injection fluid system were found to be less than those in the original formulation. In addition, fewer constituents are present in the ClearFRAC XT fluid system than the water and guar-based system. On this basis, the potential risks from exposure to chemicals in ClearFRAC XT were expected to be less than or equal to those estimated for the water and guar-based system discussed in **Appendix C1**.

A combination of management and operational controls are being implemented to eliminate and control the potential for exposures. These include:

- Worker training and hazard identification
- Use of appropriate personal protective equipment (gloves, etc.)
- Flowback storage pond fencing to prevent entry of livestock and minimise trespassing.
- Installation of clay dam liners and routine dam inspections to prevent releases from flowback storage ponds
- Routine operational and security patrols to prevent trespassing.

C5.0 Conclusions

A weight-of-evidence evaluation of potential risks as described in **Section 5.0** was performed for the Schlumberger ClearFRAC XT fluid system. Based on the qualitative and comparison to the Schlumberger water and guar based quantitative risk characterisations, the overall risk to human health and the environment is low. Existing operational control activities employed by Santos are in place that will limit the potential risks to human health and the environment. These measures include:

- Occupational health and safety procedures implemented during hydraulic fracturing operations to prevent workers from direct contact with chemicals during spills and when handling flowback water or sediments;
- Environmental authority conditions that preclude the construction of well pads within 100 metres of a watercourse of water body;
- Implementation of spill containment procedures during operations to prevent migration of and exposure to chemicals;
- Disposal or capping of sediments contained within drained mud pits and turkey's nests , to prevent exposure to contaminates in windborne dust;
- Fencing of drill pads to prevent trespassers and installation of signs to indicate that the water in the turkey's nest and mud pit is not potable and may contain contaminants;
- Installation and maintenance of fences around the well pad to prevent access to the drill pad by livestock and large native fauna;
- Santos operational procedures to ensure well integrity and design of fracture to stay within the target seam; and
- Mud pits and turkey's nests with clay liners, or similar material, to prevent seepage of flowback water into underlying aquifers.

Regular monitoring of water supply bores and surface water for a representative suite of chemicals within 2 kilometre of wells that are fractured is required to confirm the conclusion of incomplete exposure pathways and low risk.

No additional risks, other than those previously discussed, were identified with the chemicals or systems employed by Schlumberger in hydraulic fracturing. Evaluation of other potential risks associated with hydraulic fracturing (i.e., noise and vibration) was conducted. Refer to **Section 9.0** for methodology specifics and results of this evaluation.

Tables

Table 1. PBT Assessment of the ClearFRAC XT Fluid System

Substance	P/vP criteria fulfilled?	B/vB criteria fulfilled?	T criteria fulfilled?	Overall Conclusion
Crystalline silica	Yes (naturally-occurring inorganic mineral)	No (water insoluble mineral; not bioavailable)	No (water insoluble mineral; not bioavailable)	Not PBT
Erucic amidopropyl dimethyl betaine	No (screening data available)	No (screening data available)	Yes (estimated)	Not PBT (based on screening and measured data)
2-Propanol	No (screening data available)	No (screening data available)	No (measured)	Not PBT (based on screening and measured data)
Sodium chloride	Inorganic salt (biodegradation not applicable)	No (inorganic salt)	Long-term data not available (acute $EC(L)_{50}$ >0.1 mg/L); potentially not T	Not PBT
Cholinium chloride	No (screening data available)	No (screening data available)	No (measured)	Not PBT (based on screening and measured data)
Benzenesulfonic acid, 4-ethenyl-, sodium salt, homopolymer	Yes (polymer)	No (polymer)	No (polymer)	Not PBT
Hydrochloric acid	Inorganic salt (biodegradation not applicable)	No (inorganic salt)	Long-term data not available (acute $EC(L)_{50}$ >0.1 mg/L); potentially not T	Not PBT
Vinylidene chloride/methacrylate copolymer	Yes (polymer)	No (polymer)	No (polymer)	Not PBT
Sodium chloroacetate	No (screening data available)	No (screening data available)	Long-term data not available (acute $EC(L)_{50}$ >0.01 and <0.1 mg/L); potentially T	Not PBT (based on screening and measured data)

Substance	P/vP criteria fulfilled?	B/vB criteria fulfilled?	T criteria fulfilled?	Overall Conclusion
Acetic acid ethenyl ester, polymer with ethanol	Yes (polymer)	No (polymer)	No (polymer)	Not PBT
Diatomaceous earth, calcined	Yes (naturally-occurring inorganic mineral)	No (water insoluble mineral; not bioavailable)	No (water insoluble mineral; not bioavailable)	Not PBT
Polyvinyl acetate, partially hydroysed	Yes (polymer)	No (polymer)	No (polymer)	Not PBT
Magnesium silicate hydrate (talc)	Yes (naturally-occurring inorganic mineral)	No (water insoluble mineral; not bioavailable)	No (water insoluble mineral; not bioavailable)	Not PBT
Magnesium nitrate	Inorganic salt (biodegradation not applicable)	No (inorganic salt)	Long-term data not available (acute $EC(L)_{50}$ >0.1 mg/L); potentially not T	Not PBT
5-chloro-3-methyl-4-isothiazolin-3-one	No (measured)	No (measured)	Long-term data not available (acute $EC(L)_{50}$ >0.01 and <0.1 mg/L); potentially T	Not PBT (based on screening and measured data)
Magnesium chloride	Inorganic salt (biodegradation not applicable)	No (inorganic salt)	Long-term data not available (acute $EC(L)_{50}$ >0.1 mg/L); potentially not T	Not PBT
2-methyl-4-isothiazolin-3-one	No (measured)	No (measured)	Long-term data not available (acute $EC(L)_{50}$ >0.01 and <0.1 mg/L); potentially T	Not PBT (based on screening and measured data)
Cristobalite	Yes (naturally-occurring inorganic mineral)	No (water insoluble mineral; not bioavailable)	No (water insoluble mineral; not bioavailable)	Not PBT

Table 2. Comparison of Previous Schlumberger Fluid System with ClearFRAC XT Fluid System

Constituent	Original	ClearFRAC XT	Drinking water guideline (ppm)	PNECaq (mg/L)
5-chloro-3-methyl-4-isothiazolin-3-one	**X**	**X**	**0.07**	**0.000027**
2-methyl-4-isothiazolin-3-one	**X**	**X**	**0.07**	**0.000027**
Magnesium nitrate	**X**	**X**	**50**	**0.7**
Magnesium chloride	**X**	**X**	**250**	**0.1**
Diatomaceous earth, calcined	**X**	**X**	**-**	**-**
Crystalline silica (cristobalite)	**X**	**X**	**-**	**-**
Crystalline silica (quartz)	X		-	-
Sodium carbonate	X		180 (Na), pH	0.2
Diammonium peroxidisulphate	X		180 (Na); 500/250 (SO4)	0.076
Boric acid	X		0.5	1.5 (boron)
Tetramethylammonium chloride	X		1	0.0015
Carbohydrate polymer (guar gum)	X		44	0.042
Non-crystalline silica	X		88	-
2-Butoxyethanol	X		0.5	10
Ethanol	X		8	0.96
Acetic acid	X		pH	0.46
Polypropylene glycol	X		2	0.1
Ammonium C6-10 alcohol ethoxysulfate	X		2.6	0.27
2-Propanol	**X**	**X**	**15**	**0.3**

Constituent	Original	ClearFRAC XT	Drinking water guideline (ppm)	PNECaq (mg/L)
Alcohols C6-10 ethoxylated	X		2	2.6 (0.1 – 12)
Carbonic acid	X		180 (Na), pH	0.2
Hydrochloric acid	**X**	**X**	**pH**	**-**
Vinylidene chloride/methacrylate copolymer	**X**	**X**	**-**	**-**
Tetrasodium ethylenediaminetetraacetate (EDTA)	X		-	2.2
Magnesium silicate hydrate (talc)	**X**	**X**	**-**	**-**
Sodium hydroxide	X		pH	-
Erucic amidopropyl dimethyl betaine		**X**	**0.19**	**0.00024**
Sodium chloride		**X**	**180 (Na), 250 (Cl)**	**-**
Cholinium chloride		**X**	**248**	**0.6**
Benzenesulfonic acid, 4-ethenyl-, sodium salt, homopolymer		**X**	**-**	**-**
Sodium chloroacetate		**X**	**0.11**	**0.000033**
Acetic acid ethenyl ester, polymer with ethanol		**X**	**-**	**-**
Polyvinyl acetate, partially hydroysed		**X**	**-**	**-**

Table 3 Surface Water Quality Data for Theoretical Scenario in Initial Flowback for Schlumberger and ClearFRAC

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)					
		Waterfrac / Slickwater	WF130 Linear Gel	WF130 Linear Base Gel for Foam Fluid	YF125LG Crosslinked Gel	Maximum of All Stimulation Events	ClearFRAC
5-chloro-2-methyl-4-isothiazolin-3-one	26172-55-4	3	3	3	4	4	0.01
2-methyl-4-isothiazolin-3-one	2682-20-4	1	1	1	1	1	0.001
Magnesium nitrate	10377-60-3	6	6	6	4	6	0.01
Magnesium chloride	7786-30-3	3	3	3	1	3	0.01
Diatomaceous earth, calcined	91053-39-3	30	30	30	22	30	0.1
Crystalline silica (cristobalite)	14464-46-1	-	-	-	-	-	-
Crystalline silica (quartz)	14808-60-7	-	-	-	-	-	-
Sodium carbonate	497-19-8	-	-	-	652	652	-
Diammonium peroxodisulphate (ammonium persulphate)	7727-54-0	-	410	-	712	712	-
Boric acid	10043-35-3	-	-	-	245	245	-
Tetramethylammonium chloride	75-57-0	-	511	1,008	587	1,008	-
Carbohydrate polymer (guar gum[1])	9000-30-0	-	3,540	3,323	2,884	3,540	-
Non-crystalline silica (amorphous silica surrogate)	7631-86-9	-	10	9	8	10	-
2-Butoxyethanol (Ethylene glycol monobutyl ether)	111-76-2	-	-	305	-	305	-
Ethanol	64-17-5	-	-	262	-	262	-
Acetic acid	64-19-7	43	-	-	-	43	-
Polypropylene glycol	25322-69-4	-	30		-	30	-
Ammonium C6-C10 alcohol ethoxysulfate	68187-17-7	-	-	1,048	-	1,048	-
Propan-2-ol	67-63-0	8	-	-	38	38	10
Alcohols C6-C10 ethoxylated	68439-45-2	-	-	18	-	18	-
Carbonic acid	533-96-0	-	-	-	1,609	1,609	-
Hydrochloric acid	7647-01-0	-	-	-	635	635	-
Vinylidene chloride/methylacrylate	25038-72-6	-	-	-	18	18	1
Tetrasodium ethylenediaminetetraacetate (EDTA)	64-02-8	-	-	-	8	8	1
magnesium silicate hydrate (talc)	14807-96-6	-	-	-	1	1	-
Sodium hydroxide	1310-73-2	-	-	-	1	1	-
Erucic amidopropyl dimethyl betaine	149879-98-1	-	-	-	-	-	10
Sodium chloride	7647-14-5	-	-	-	-	-	1
Cholinium chloride	67-48-1	-	-	-	-	-	10
Benzenesulfonic acid, 4-ethenyl-, sodium salt, homopolymer	25704-18-1	-	-	-	-	-	1
Sodium chloroacetate	7647-14-5	-	-	-	-	-	0.1

Table 3 Surface Water Quality Data for Theoretical Scenario in Initial Flowback for Schlumberger and ClearFRAC

Acetic acid ethenyl ester, polymer with ethanol	25213-24-5	-	-	-	-	-	0.1
Polyvinyl acetate, partially hydroysed	304443-60-5	-	-	-	-	-	0.1

Table 3 Surface Water Quality Data for Theoretical Scenario in Initial Flowback for Schlumberger and ClearFRAC

Constituent Name	Estimated Initial Mud Pit Concentration in flowback (150% of injected fluid volume) per coal seam per percent of mass returned calculated using equation: Mud Pitcon = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L)											
	YF125LG Crosslinked Gel				Maximum of All Stimulation Events				ClearFRAC			
	20%	40%	60%	80%	20%	40%	60%	80%	20%	40%	60%	80%
5-chloro-2-methyl-4-isothiazolin-3-one	0.53	1.1	1.6	2.1	0.5	1.1	1.6	2.1	0.0013	0.0027	0.0040	0.0053
2-methyl-4-isothiazolin-3-one	0.1	0.3	0.4	0.5	0.1	0.3	0.4	0.5	0.0001	0.0003	0.0004	0.0005
Magnesium nitrate	0.5	1.1	1.6	2.1	0.8	1.6	2.4	3.2	0.0013	0.0027	0.0040	0.0053
Magnesium chloride	0.1	0.3	0.4	0.5	0.4	0.8	1.2	1.6	0.0013	0.0027	0.0040	0.0053
Diatomaceous earth, calcined	2.9	5.9	8.8	11.7	4.0	8.0	12.0	16.0	0.0133	0.0267	0.0400	0.0533
Crystalline silica (cristobalite)												
Crystalline silica (quartz)												
Sodium carbonate	86.9	173.9	260.8	347.7	86.9	173.9	260.8	347.7				
Diammonium peroxodisulphate (ammonium persulphate)	94.9	189.9	284.8	379.7	94.9	189.9	284.8	379.7				
Boric acid	32.7	65.3	98.0	130.7	32.7	65.3	98.0	130.7				
Tetramethylammonium chloride	78.3	156.5	234.8	313.1	134.4	268.8	403.2	537.6				
Carbohydrate polymer (guar gum[1])	384.5	769.1	1153.6	1538.1	472.0	944.0	1416.0	1888.0				
Non-crystalline silica (amorphous silica surrogate)	1.1	2.1	3.2	4.3	1.3	2.7	4.0	5.3				
2-Butoxyethanol (Ethylene glycol monobutyl ether)	-	-	-	-	40.7	81.3	122.0	162.7				
Ethanol	-	-	-	-	34.9	69.9	104.8	139.7				
Acetic acid	-	-	-	-	5.7	11.5	17.2	22.9				
Polypropylene glycol	-	-	-	-	4.0	8.0	12.0	16.0				
Ammonium C6-C10 alcohol ethoxysulfate	-	-	-	-	139.7	279.5	419.2	558.9				
Propan-2-ol	5.1	10.1	15.2	20.3	5.1	10.1	15.2	20.3	1.3	2.7	4.0	5.3
Alcohols C6-C10 ethoxylated	-	-	-	-	2.4	4.8	7.2	9.6				
Carbonic acid	214.5	429.1	643.6	858.1	214.5	429.1	643.6	858.1				
Hydrochloric acid	84.7	169.3	254.0	338.7	84.7	169.3	254.0	338.7				
Vinylidene chloride/methylacrylate	2.4	4.8	7.2	9.6	2.4	4.8	7.2	9.6	0.1	0.3	0.4	0.5
Tetrasodium ethylenediaminetetraacetate (EDTA)	1.1	2.1	3.2	4.3	1.1	2.1	3.2	4.3	0.1	0.3	0.4	0.5
magnesium silicate hydrate (talc)	0.1	0.3	0.4	0.5	0.1	0.3	0.4	0.5				
Sodium hydroxide	0.1	0.3	0.4	0.5	0.1	0.3	0.4	0.5				
Erucic amidopropyl dimethyl betaine									1.3	2.7	4.0	5.3
Sodium chloride									0.1	0.3	0.4	0.5
Cholinium chloride									1.3	2.7	4.0	5.3
Benzenesulfonic acid, 4-ethenyl-, sodium salt, homopolymer									0.1	0.3	0.4	0.5
Sodium chloroacetate									0.01	0.03	0.04	0.1

Table 3 Surface Water Quality Data for Theoretical Scenario in Initial Flowback for Schlumberger and ClearFRAC

Acetic acid ethenyl ester, polymer with ethanol									0.01	0.03	0.04	0.1
Polyvinyl acetate, partially hydroysed									0.01	0.03	0.04	0.1

Appendix C4-1

Schlumberger

Client:	Santos
Well:	Example CSG Well
Basin / Field:	Roma RUGS
Country:	Australia
State:	Queensland
Case:	Single Zone
Disclosure Type:	Prejob
Well Completed:	-
Date Prepared:	5/8/2013 12:36 PM
Report ID:	RPT-13564

Fluid Description(s)	
ClearFRAC XT 31,500 Gal	Contains: Water, Bactericide, Breaker, Clay Control, Gelling Agent, pH Control, Propping Agent, Rheology Modifier

The total volume listed in the tables above represents the summation of water and additives. Water is supplied by client.

CAS Number	Chemical Name	Mass Fraction
-	Water (Including Mix Water Supplied by Client)*	~ 87 %
14808-60-7	Crystalline silica	~ 12 %
149879-98-1	Erucic amidopropyl dimethyl betaine	< 1 %
67-63-0	Propan-2-ol	< 1 %
67-48-1	Cholinium chloride	< 1 %
7647-14-5	Sodium chloride	< 0.1 %
25704-18-1	Benzenesulfonic acid, 4-ethenyl-, sodium salt, homopolymer	< 0.1 %
7647-01-0	Hydrochloric acid	< 0.1 %
25038-72-6	Vinylidene chloride/methylacrylate copolymer	< 0.1 %
3926-62-3	Sodium chloroacetate	< 0.01 %
25213-24-5	Acetic acid ethenyl ester, polymer with ethenol	< 0.01 %
91053-39-3	Diatomaceous earth, calcined	< 0.01 %
304443-60-5	Polyvinyl acetate, partially hydrolyzed	< 0.01 %
14807-96-6	Magnesium silicate hydrate (talc)	< 0.001 %
10377-60-3	Magnesium nitrate	< 0.001 %
26172-55-4	5-chloro-2-methyl-2h-isothiazolol-3-one	< 0.001 %
7786-30-3	Magnesium chloride	< 0.001 %
2682-20-4	2-methyl-2h-isothiazol-3-one	< 0.0001 %
14464-46-1	Cristobalite	< 0.0001 %
		100%

* *Mix water is supplied by the client. Schlumberger has performed no analysis of the water and cannot provide a breakdown of components that may have been added to the water by third-parties.*

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Appendix C5
Halliburton Alternative System (Delta 140 Formulation)

C1.0 Introduction

As presented in **Section 5.0** of the Hydraulic Fracturing Risk Assessment, a weight-of-evidence approach was used by Santos Ltd. (Santos) to evaluate the potential for human health and environmental (e.g., ecological) risks as a result of the hydraulic fracturing processes and the Halliburton alternative fluid system (Delta 140 formulation).

Golder Associates Pty Ltd. (Golder), on behalf of Santos, completed a qualitative risk assessment (Golder, 2013f) that evaluated the nature of the geology in the areas undergoing stimulation, the potential for impacts on water resources, the process and chemicals used.

A Quantitative Risk Assessment (QRA), completed by EHS Support, LLC (EHS Support), supplemented the qualitative risk assessment (EHS Support, 2013b). The QRA was conducted to meet Conditions 49e and 49f of the 2 October 2011 approval under the Environmental Protection and Biodiversity Conservation Act 1999 (EPBC 2008/4059) and the Environmental Amendment (EA) conditions to assess the toxicity of the mixtures.

Key reports and studies previously submitted for these fluid systems comprise:

- Golder Associates (2013f). Coal Seam Hydraulic Fracturing Risk Assessment. Human Health and Ecological Risk Assessment – Delta 140. Golder Associates Report. 1 August 2013.
- EHS Support. (2013b). Coal Seam Gas Hydraulic Fracturing Quantitative Risk Assessment Report for Halliburton Delta 140 Chemistry Report. 4 August 2013.

The QRA evaluated both the original DeltaFoam 140 and Delta 140 formulations; refer to **Appendix C2** for discussion of the results of the EHS Support QRA for the original DeltaFoam 140 fluid system.

The results and conclusions of the qualitative risk assessment components and the QRA are summarised below. Refer to the text of this report for detailed discussions on mythologies employed for each component; specific tables referred to in this summary are included for review with this document. Table numbers specific to the original reports were retained for consistency between documents.

C2.0 Qualitative Risk Assessment and Evaluation

C2.1 Chemicals Evaluated

Three 'fluid systems' were assessed, each having a foamed and non-foamed version, for a total of six hydraulic fracturing fluid mixtures. Chemical constituents identified in each hydraulic fracturing fluid system were evaluated in the hydraulic fracturing risk assessments. The list of individual chemicals is presented in **Table 1**. A mass balance of the chemicals within each of the hydraulic fracturing fluid systems is provided as **Appendix C5-1** (Table C-1; Golder, 2013f).

Information regarding the chemical and physical properties of the individual chemicals listed below can be found on the Saftey Data Sheets in **Appendix E**.

It is noted, while none of the fracturing fluid chemicals identified contain benzene, toluene, ethylbenzene, xylenes (BTEX) or polycyclic aromatic hydrocarbons (PAHs), that PAHs occur naturally in coal and it is possible that certain PAHs may naturally be present in the coal seam groundwater used in the hydraulic fracturing process.

Table 1: Hydraulic fracturing chemicals

Chemical	CAS Number
Guar Gum	9000-30-0
Acetic Acid	64-19-7
Coco dimethylaminopropyl betaine	61789-40-0
Tetrakis (hydroxymethyl) phosphonium sulphate (THPS)	55566-30-8
Sodium hydroxide [1]	1310-73-2
Crystalline silica	14808-60-7
Monoethanolamine borate	26038-87-9
Crystalline silica, quartz	14808-60-7
Hydrochloric acid	7647-01-0
Alcohols, C6-C-12, ethoxylated propoxylated	68937-66-6
Alcohols, C10-C16, ethoxylated propoxylated	69227-22-1
Choline chloride [2]	67-48-1
Ethylene glycol	107-21-1
Hemicellulase enzyme	9012-54-8
Maltodextrin	9050-36-6
Polyethylene glycol	25322-68-3
Coffee beans (green coffee bean extract; chlorogenic acid)	327-97-9
Coffee beans (caffeine)	58-08-2

1. Chemical excluded from linear gel formulation.
2. Chemical included in water formulation.

C2.2 Risk Assessment Framework and Findings

As discussed in **Section 5.0** of the systematic weight of evidence approach was utilised to complete the risk assessment for the Schlumberger fluid systems. The work has involved the following evaluations:

Qualitative Assessment Methodologies

- Environmental Hazard Assessment
- Exposure Assessment including Fate and Transport Assessment in Groundwater
- Mass Balance of the fluid systems
- Groundwater Fate and Transport Modelling.

Quantitative Risk Assessment Methodologies

- Quantitative Human Health Risk Assessment (HHRA)
- Quantitative Ecological Risk Assessment for Terrestrial and Aquatic Receptors.

C2.3 Environmental Hazard Assessment

The environmental hazard assessment approach outlined in **Section 6.1** was undertaken to rank the hydraulic fracturing chemicals based on persistence (P), bioaccumulation (B) and toxic (T) potential (hereafter referred to as PBT).

A combination of data sets were used in the PBT assessment including chemical information sheets (**Appendix E** and **Appendix G**), the Hazardous Substance Database, and modelled data from United States Environmental Protection Agency (USEPA) (2009) EPISUITE modelling software, when data not available from other sources.

Of the 18 chemicals listed above, three were not considered for PBT ranking: sodium hydroxide and hydrochloric acid due to their propensity to readily dissociate; crystalline silica due to its similarity to sand, which is used as a proppant. Physico-chemical and/or toxicological data were not available, and surrogates could not be identified for maltodextrin (9050-36-6). Limited toxicological data were available for polyethylene glycol (25322-68-3) and guar gum (9000-30-0); however, physico-chemical data were lacking for these constituents. Therefore, they were ranked solely on their respective toxicity data.

C2.4 Summary of Qualitative PBT and Human Toxicity Assessment

In accordance with the methodology outlined in **Section 6.1**, eighteen chemicals identified in the Halliburton alternative fluid system (Delta 140) were assessed for their potential persistence, bioaccumulation and toxicity in the PBT assessment. None of the chemicals was considered to be a PBT substance.

C2.5 Exposure Assessment

As discussed in **Section 7.0**, the exposure assessment identified receptors potentially exposed to COPCs identified for the study and outlines the exposure pathways by which the receptors may come in to contact with the COPCs. A detailed exposure assessment was not conducted in the qualitative risk assessment; however, hazards from potential exposures were determined to be primarily occupational concerns with some limited environmental matters (Golder, 2013f).

C2.6 Mass Balance of Fluid System

A quantitative mass balance calculation was undertaken to identify the amount of each chemical additive of the hydraulic fracturing fluid in the following fluid systems:

- Delta 140
- Linear Gel

- Water
- Acid.

The results of the mass balance calculations are presented in the referenced Table C-1 (Golder, 2013f) which is included in **Appendix C5-1**.

C2.7 Fate and Transport Modelling

As discussed in **Section 7.2** fate and transport modelling was conducted on key constituents of interest in the hydraulic fracturing fluid systems. These results provided the framework for assessing potential mobility of all constituents used in hydraulic fracturing. The modelling demonstrated that there is limited potential for chemicals to migrate within the coal seams. Refer to **Section 7.2** for further detail.

C3.0 Quantitative Risk Assessment

In accordance with the methodologies presented in **Section 8.0**, a QRA was conducted on a theoretical dataset for those chemicals identified in the Golder Human Health and Ecological Risk Assessment (EHS Support, 2013b). The QRA approach evaluates the toxicity of the individual substances and characterises the cumulative risks of the total effluent toxicity and ecotoxicity.

Generally, this methodology includes the identification of the hazards posed by constituents in the flowback water, compilation of the toxicity criteria for each constituent, development of exposure models to estimate the daily intake of the constituents, and calculations of individual constituent hazard quotients (daily intake divided by the toxicity criteria) and a cumulative constituent hazard index (HI) for each potentially complete exposure pathway for each human or terrestrial receptor.

Potential complete exposure pathways to the storage of flowback from hydraulically stimulated wells and potential risks to humans, terrestrial and aquatic receptors from the potential storage and accidental releases are evaluated in the QRA.

No further assessment of groundwater was determined to be necessary due to lack of potentially complete exposure pathways. Detailed operational procedures have been provided that are designed to contain the hydraulic fracturing fluids within the coal sequences, and no connection exists between groundwater in the coal seams and surface-water or springs (and therefore Matters of National Environmental Significance [MNES]). Further, the potential risks to workers involved with the hydraulic fracturing process were not considered as detailed Health and Safety (H&S) procedures are employed to manage exposures. The QRA considered the following specific exposure pathways:

1. Exposure of trespassers to flowback water contained within flowback storage ponds.
2. Exposure of terrestrial receptors (e.g., livestock and wildlife) to flowback water contained within the flowback storage ponds.
3. Exposure of aquatic receptors to flowback water in the situation of an accidental release, such as from piping or a release from the flowback storage pond. These potential releases could include a failure of containment systems, overtopping of the dam or in an extreme situation (considered highly unlikely) structural failure of the dam itself.

C3.1 Exposure Assessment

The purpose of the exposure assessment in the QRA was to predict the magnitude and frequency of potential human exposure to each COPC following the methodologies presented in **Section 8.1**. A conceptual site model (CSM) was developed which describes the potential receptors and exposure scenarios for the flowback water used in this exposure assessment. The potential exposures to receptors were evaluated based on the potential for a complete exposure pathway.

As discussed in **Section 8.3**, exposure point concentrations (EPCs) were derived for the theoretical assessment; empirical data were not available for evaluation. The EPCs for the theoretical assessment were calculated by estimating the mass and discharge flow of the COPCs from the flowback water monitoring data were used **Appendix C5-2** (Appendix C, Table C-2; EHS Support, 2013b).

C3.2 Human Health QRA

A human health hazard assessment was conducted according to the methodologies presented in **Section 8.4**. The purpose of the hazard assessment process was to summarise the environmental data, and to address the toxicological assessment of the COPCs that will be evaluated further in the risk assessment process.

Exposure assumptions for the human trespasser scenario were developed based on default or site-specific assumptions (**Section 8.4**). This receptor exposure pathway includes a small child to teenager that may come in contact with the above grade water exposure scenario for approximately 20 days/year for a 10-year period with potential incidental ingestion (of 50 millilitre [mL] water) and dermal contact (e.g., swimming where the whole body gets wet) for one half hour (Table 3; EHS Support, 2013b, attached).

Calculation of intake of COPCs was performed using the equations presented below:

Ingestion of water:

$$Intake\ (mg/kg-day)\ =\ (CW\ x\ IR\ X\ EF\ X\ ED)\ /\ (BW\ x\ AT)$$

Dermal contact with water:

$$Absorbed\ dose\ (mg/kg-day)\ =\ (CW\ x\ SA\ x\ DP\ x\ ET\ x\ EF\ x\ ED\ x\ CF)\ /\ (BW\ x\ AT)$$

Where:

CW = concentration in water (mg/l)
ET = exposure time (hr/day or hours/hours)
EF = exposure frequency (day/year)
ED = exposure duration (years)
CF = correction factor (1 x 10-3 l/cm3)
AT = averaging time (days)
IR = ingestion rate (l/hr)
BW = body weight (kg)
SA = skin surface area available for contact (cm2/d)
DP = dermal permeability factor (Kp – cm/hr)

C3.3 Toxicity Assessment

A toxicity assessment was conducted to determine the relationship between the dose of a COPC taken into the body, and the probability that an adverse effect will result from that dose. Quantitative estimates of the potency of COPCs include two sets of toxicity values, one for genotoxic carcinogens and one for other non-genotoxic carcinogens and non-carcinogenic effects. As discussed in **Section 8.4,** detailed toxicological profiles were developed for the chemicals. The toxicological profiles are included as **Appendix F**.

The assessment of toxicity of the COPCs was used to develop initial screening criteria for human health exposure scenarios as discussed in **Section 8.4**. Refer to Tables 1 and 2 of the EHS Support QRA for details regarding the toxicity assessment of the COPCs (EHS Support, 2013b).

C3.4 Risk Estimation

Risk estimation was performed in accordance with the methodologies outlined in **Section 8.4**. The total target risk range for carcinogens was 1 x 10^{-4} to 1 x 10^{-6}; the target HI for non-threshold effects is less than or equal to 1.0.

No carcinogenic compounds are present in the stimulation fluids injected into the subsurface and as a result, only non-carcinogenic risks were calculated. The exposure scenarios include the specific fracturing fluids event from Golder (2013f) Table C-1, attached, for the 20 and 80 percent (%) mass recovery from the fracturing fluid well flowback. The modelled risks from injected chemicals in the flowback water at 20 % mass recovery were acceptable (HI=0.94); the modelled risks to the trespasser for the maximum exposure to COPCs at the 80 % recovery predicted a HI of 3.8 (Tables 6 and 7; EHS

Support, 2013b, attached). The primary risk drivers for this scenario were coco dimethylaminopropyl betaine and THPS via incidental ingestion, and C6-C12 ethozylanted propoxylated alcohols via dermal contact.

Based on field observations, the risk assessment conducted on 80 % mass recovery in the flowback water diverted to the flowback storage ponds, is highly conservative. These conditions are not observed in the fields as the combination of biodegradation and sorption in the subsurface and biodegradation, complexation and settling of suspended solids in the flowback storage ponds results in lower concentrations. Based on stimulation flowback monitoring conducted by Santos and the QRA completed for the Schlumberger fluid systems (EHS Support, 2013b), 20 % of the total mass of constituents injected is assumed to be recovered in the flowback water. On this basis and using the theoretical concentrations, no adverse effects are predicted on trespassers.

C3.5 Ecological Risk Assessment

As discussed in **Section 8.5**, a screening level ecological risk assessment (ERA) was conducted to evaluate the potential for adverse ecological effects to terrestrial and aquatic ecological receptors that may be exposed to residual levels of hydraulic fracturing fluids in surface water used in the coal seam gas (CSG) fields.

Terrestrial receptors evaluated in the ERA include domesticated livestock, large mammalian wildlife and small mammalian wildlife. Beef cattle were used to evaluate domesticated livestock, kangaroos evaluated for large mammalian wildlife, and dingos for small mammalian wildlife. Aquatic receptors evaluated included invertebrates and fishes.

Ecological effects were characterised following the methodologies outlined in **Section 8.5.3** (Table 8; EHS Support, 2013b, attached). Exposure scenarios were the same for ecological receptors as human receptors; EPCs were estimated in accordance with the methodology presented in **Section 8.5.4** (**Appendix C5-3**; Table A-2; EHS Support, 2013b). Environmental fate information is provided in Table 9 (EHS Support, 2013b), attached.

Risks were characterised in accordance with the methodologies discussed in **Section 8.5.5**. The resulting ecological hazard quotient must be less than or equal to 1.0 for risks to be considered acceptable.

C3.5.1 Estimation of Risk

The HI calculated for flowback water for aquatic risk were elevated above the acceptable level for the majority of COPCs evaluated (**Appendix C2-2**, Table C-4; EHS Support, 2013b). Where large discharges of flowback water occur to surface water and/or flux dilution within the surface-water was insufficient, potential impacts on aquatic receptors could occur. As noted in the toxicity assessment section above, the lack of a robust aquatic toxicological database resulted in aquatic screening values for the theoretical exposure scenario COPCs to be conservatively very low.

The modelled risks from injected chemicals in the flowback water were all acceptable for each of the ecological receptors modelled, except livestock cattle for the maximum exposure to COPCs at the 80 % recovery indicating a HI equal to 2.0 (Tables 15 and 6, 19 and 20, 23 and 24; EHS Support, 2013b, attached). Primary risk drivers were coco dimethylaminopropyl betaine and THPS via incidental ingestion. As discussed in the HHRA, 80 % recovery conditions are not observed in the fields. A recovery of 20 % is more realistic based on stimulation flowback monitoring conducted by Santos (EHS Support, 2013b).

C4.0 Summary of QRA Findings

The QRA was completed as discussed in **Section 8.0**. An assessment was conducted using highly conservative theoretical calculations based on the chemicals utilised by Halliburton in hydraulic fracturing. This assessment assumed that a range of theoretical percentages of injected chemicals would be present in the flowback water.

Consistent with the risk assessment and groundwater fate and transport modelling conducted by Golder, no potentially complete exposure pathways were identified for groundwater. Potential exposures are limited to the aboveground storage and handling of flowback water as part of the CSG Water Management Plan (WMP). Management of CSG water involves the temporary storage of flowback water in flowback storage ponds.

On the basis of the quantitative risk calculations, the potential risks associated with the flowback water are generally limited. Potential risks to trespassers could occur with repeated exposures to flowback water. However, the cumulative risks are only slightly above the non-carcinogenic threshold discussed above where management and operational controls can be implemented to control potential exposures. There were no carcinogenic risks identified.

Limited to no risks to cattle and native mammals were identified in the risk assessment; and only in the most conservative theoretical calculations (80 % chemical mass in the flowback water) were potentially unacceptable risks identified. Based on contractor experience and stimulation flowback monitoring, 20 % of the total mass constituents injected is assumed to be recovered in flowback water. Additionally, environmental fate information indicated primary risk drivers are readily biodegradable. Therefore, no potential risks exist for livestock or native mammals.

Similarly, potential impacts could occur if releases of flowback water were to occur to aquatic environments. Based on the use of clay liners and operational controls that limit the potential for turkey's nest and dam overflows, the potential for these risks are also considered limited.

A combination of management and operational controls are being implemented to eliminate and control the potential for exposures. These include:

- Worker training and hazard identification
- Use of appropriate personal protective equipment (gloves, etc.)
- Flowback storage pond fencing to prevent entry of livestock and minimise trespassing
- Installation of clay dam liners and routine dam inspections to prevent releases from flowback storage ponds
- Routine operational and security patrols to prevent trespassing.

C5.0 . Conclusions

A weight-of-evidence evaluation of potential risks as described in **Section 5.0** was performed for the Halliburton alternative fluid system (Delta 140). Based on the qualitative and quantitative risk characterisations, the overall risk to human health and the environment is low. Existing operational control activities employed by Santos are in place that will limit the potential risks to human health and the environment. These measures include:

- Occupational health and safety procedures implemented during hydraulic fracturing operations to prevent workers from direct contact with chemicals during spills and when handling flowback water or sediments;
- Environmental authority conditions that preclude the construction of well pads within 100 metres of a watercourse of water body.
- Implementation of spill containment procedures during operations to prevent migration of and exposure to chemicals;
- Disposal or capping of sediments contained within drained mud pits and turkey nests , to prevent exposure to contaminates in windborne dust;
- Fencing of drill pads to prevent trespassers and installation of signs to indicate that the water in the turkeys nest and mud pit is not potable and may contain contaminants;
- Installation and maintenance of fences around the well pad to prevent access to the drill pad by livestock and large native fauna;
- Santos operational procedures to ensure well integrity and design of fracture to stay within the target seam; and
- Mud pits and turkeys nests with clay liners, or similar material, to prevent seepage of flowback water into underlying aquifers.

Regular monitoring of water supply bores and surface water for a representative suite of chemicals within 2 kilometre of wells that are fractured is required to confirm the conclusion of incomplete exposure pathways and low risk.

No additional risks, other than those previously discussed, were identified with the chemicals or systems employed by Halliburton in hydraulic fracturing. Evaluation of other potential risks associated with hydraulic fracturing (i.e., noise and vibration) was conducted. Refer to **Section 9.0** for methodology specifics and results of this evaluation.

Santos

EHS Support Tables

Table 1 Oral Reference Doses and Drinking Water Guidelines Derived for Hydraulic Fracturing Chemicals

Chemical	Study	Critical Effect/Target Organ(s)	NOAEL (mg/kg/day)	Uncertainty Factors	Oral Reference Dose (mg/kg/day)	Drinking Water Guideline (ppm)
DeltaFoam 140						
Cocoamidopropyl betaine	90-d rat oral gavage	Forestomach (irritation)	53.6	1,000	0.05	0.19
Guar gum	2-yr rat dietary	General toxicity	1250	100	1.3	44
Enzyme X	13-wk rat dietary	General toxicity	600	1,000	0.6	2
Ethanol	90-d rat dietary	Liver	2,400	1,000	2.4	8
Bentonite (Zeolite as surrogate)	104-wk rat dietary	-	1,000	100	10	35
C6-C10 Alcohol Ethoxylates	2-yr rat dietary	-	50	100	0.5	2
Monoethanolamine borate (Read-across from CASRN 68512-53-8)	28-day rat oral gavage	-	1,000	1,000	1	3.5
Noncrystalline Silica/Silica Gel	2-yr rat dietary	-	2,500	100	2.5	87.5
Terpene hydrocarbons, processing by-products / Terpenes & Terpenoids, sweet orange peel	2-yr rat and mouse oral gavage	Liver	107	100	1.1	3.8
Tetrakis(hydroxylmethyl) phosphonium sulfate (THPS)	2-yr rat and mouse	Liver	4[a]	1,000	0.004	0.01
Ethoxylated fatty acid ester	2-yr mouse dietary	forestomach	3,250[a]	1,000	3	11
Fatty acid ester	2-yr rat dietary	-	2,500	100	2.5	87.5
PEG oleate ester	2-yr rat dietary	Liver	1,000[a]	1,000	1	3.5
Alkylated quaternary chloride (DDAC as surrogate)	Rat 2-yr dietary	General toxicity	32	100	0.3	1
1,2-Benzothiazolin-3-one	Dog oral subchronic	Emesis/clinical chemistry	5	100	0.02	0.18
Crystalline silica, quartz	NA	NA	NA	NA	NA	NA

Table 1 Oral Reference Doses and Drinking Water Guidelines Derived for Hydraulic Fracturing Chemicals

Chemical	Study	Critical Effect/Target Organ(s)	NOAEL (mg/kg/day)	Uncertainty Factors	Oral Reference Dose (mg/kg/day)	Drinking Water Guideline (ppm)
Delta 140						
Acetic acid	Australian drinking water standard for pH					
Alcohols, C6-C12, ethoxylated propoxylated	2-yr rat dietary	-	50	100	0.5	2
Alcohols, C10-C16, ethoxylated propoxylated	2-yr rat dietary	-	50	100	0.5	2
Choline chloride	Human study	Hypotension	142	2	71	248
Cocoamidopropyl betaine	90-d rat oral gavage	Forestomach (irritation)	53.6	1,000	0.05	0.19
Crystalline silica	-	-	-	-	-	-
Ethylene glycol	1-yr rat dietary	Kidney	150	100	1.5	5.3
Guar gum	2-yr rat dietary	General toxicity	1,250	100	12.5	44
Hemicellulase	13-wk rat dietary	General toxicity	600	1,000	0.6	2
Maltodextrin	No data	-	-	-	-	-
Monoethanolamine borate	28-day rat oral gavage	-	1,000	1,000	1	3.5
Polyethylene glycol	2-yr rat dietary	No toxicity at highest dose tested	1,880	100	19	66
Sodium hydroxide	Australian drinking water standard for pH					
Tetrakis(hydroxylmethyl) phosphonium sulfate	2-yr rat and mouse	Liver	4[a]	1,000	0.004	0.01
Acid						
Caffeine (based on 2.4% content in coffee beans)	-	-	-	-	-	100[b]

a LOAEL

b Based on American College of Obstetricians and Gynecologists (2010) recommended 200 mg per day and 2 liters per day water intake level (see Appendix B)

NA = Not applicable

Table 2 Australian Drinking Water Screening Values for Hydraulic Fracturing Chemicals

Constituent	Drinking Water Screening Guideline	Drinking Water Screening Value (ppm)
Acetic acid	pH	6.5 to 8.5
Calcium chloride	Chloride; Hardness as $CaCO_3$	250 (aesthetic); 200 (aesthetic)
Sodium chloride	Sodium; Chloride	180 (aesthetic); 250 (aesthetic)
Sodium hydroxide	Sodium; pH	180 (aesthetic); 6.5 to 8.5
Sodium sulfate	Sodium; Sulfate	180 (aesthetic); 500 (health), 250 (aesthetic)
Sodium sulfite	Sodium; Sulfate	180 (aesthetic); 500 (health), 250 (aesthetic)
Sodium thiosulfate	Sodium; Sulfate	180 (aesthetic); 500 (health), 250 (aesthetic)

Table 3 Exposure Assumptions - Trespasser

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/hr	0.05
	ET	Exposure time	hr/day	0.5
	EF	Exposure frequency	day/yr	20
	ED	Exposure duration	yr	10
	BW	Body weight	kg	47
	AT-NC	Averaging time - noncancer	days	3,650
	AT-C	Averaging time - cancer	days	25,550
Dermal	SA	Surface area for contact	cm^2/day	13,000
	DP	Dermal permeability factor	cm/h	chemical-specific
	ET	Exposure time	hr/day	1
	EF	Exposure frequency	day/yr	20
	ED	Exposure duration	yr	10
	BW	Body weight	kg	47
	AT-NC	Averaging time - noncancer	days	3,650
	AT-C	Averaging time - cancer	days	25,550
	CF	Conversion factor	l/cm^3	1.0E-03

Table 6 Risk Estimates for Trespasser Delta 140 Theoretical Exposure for 20% Mass Returned

		20% Mass Returned			Toxicity	Delta 140			
								Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**		**PC (cm/hr)**	**RfDo**	**$CADD_{oral}$**	**$CADD_{derm}$**	**Incidental Ingestion**	**Dermal**
Acetic acid	64-19-7	1.9E+01		5.6E-04	NA	NA	NA		
Alcohols, C10-16, ethoxylated propoxylated	69227-22-1	8.8E+00		5.8E-05	0.5	5.2E-04	3.9E-06	1.0E-03	7.8E-06
Alcohols, C6-12, ethoxylated propoxylated	68937-66-6	1.9E+01		9.1E-02	0.5	1.1E-03	1.3E-02	2.2E-03	2.7E-02
Choline chloride	67-48-1	9.0E+01		8.5E-07	71	5.2E-03	5.8E-07	7.4E-05	8.2E-09
Coco dimethylaminopropyl betaine	61789-40-0	7.5E+01		5.4E-05	0.05	4.4E-03	3.1E-05	8.8E-02	6.2E-04
Ethylene glycol	107-21-1	1.3E+00		9.0E-05	1.5	7.6E-05	8.9E-07	5.1E-05	5.9E-07
Guar gum	9000-30-0	1.4E+02		NA	12.5	8.4E-03	-	6.8E-04	-
Hemicellulase enzyme	9012-54-8	1.1E+00		NA	0.6	6.3E-05	-	1.1E-04	-
Maltodextrin	9050-36-6	2.1E+01		NA	-	-	-	-	-
Monoethanolamine borate	26038-87-9	8.4E+01		NA	1	4.9E-03	-	4.9E-03	-
Polyethylene glycol	25322-68-3	1.4E+00		5.8E-06	19	8.4E-05	6.3E-08	4.4E-06	3.3E-09
Sodium hydroxide	1310-73-2	1.3E+01		NA	-	-	-	-	-
THPS	7681-52-9	5.6E+01		2.9E-19	0.004	3.3E-03	1.2E-19	8.2E-01	3.1E-17

Hazard Index 9.4E-01

Table 7 Risk Estimates for Trespasser Delta 140 Theoretical Exposure for 80% Mass Returned

		80% Mass Returned			Toxicity	Delta 140			
								Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**		**PC (cm/hr)**	**RfDo**	**$CADD_{oral}$**	**$CADD_{derm}$**	**Incidental Ingestion**	**Dermal**
Acetic acid	64-19-7	7.6E+01		5.6E-04	NA	NA	NA		
Alcohols, C10-16, ethoxylated propoxylated	69227-22-1	3.5E+01		5.8E-05	0.5	2.1E-03	1.6E-05	4.1E-03	3.1E-05
Alcohols, C6-12, ethoxylated propoxylated	68937-66-6	7.7E+01		9.1E-02	0.5	4.5E-03	5.3E-02	9.0E-03	1.1E-01
Choline chloride	67-48-1	3.6E+02		8.5E-07	71	2.1E-02	2.3E-06	3.0E-04	3.3E-08
Coco dimethylaminopropyl betaine	61789-40-0	3.0E+02		5.4E-05	0.05	1.8E-02	1.2E-04	3.5E-01	2.5E-03
Ethylene glycol	107-21-1	5.2E+00		9.0E-05	1.5	3.0E-04	3.6E-06	2.0E-04	2.4E-06
Guar gum	9000-30-0	5.8E+02		NA	12.5	3.4E-02	-	2.7E-03	-
Hemicellulase enzyme	9012-54-8	4.3E+00		NA	0.6	2.5E-04	-	4.2E-04	-
Maltodextrin	9050-36-6	8.3E+01		NA	-	-	-	-	-
Monoethanolamine borate	26038-87-9	3.4E+02		NA	1	2.0E-02	-	2.0E-02	-
Polyethylene glycol	25322-68-3	5.8E+00		5.8E-06	19	3.4E-04	2.5E-07	1.8E-05	1.3E-08
Sodium hydroxide	1310-73-2	5.2E+01		NA	-	-	-	-	-
THPS	7681-52-9	2.2E+02		2.9E-19	0.004	1.3E-02	4.9E-19	3.3E+00	1.2E-16
								Hazard Index	3.8E+00

Table 15 Risk Estimates for Cattle Delta 140 Theoretical Exposure for 20% Mass Returned

		20% Mass Returned		Toxicity	Delta 140	
						Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**		**TRVs**	**$CADD_{oral}$**	**Incidental Ingestion**
Acetic acid	64-19-7	1.9E+01				
Alcohols, C10-16, ethoxylated propoxylated	69227-22-1	8.8E+00		8.3E+00	4.4E-02	5.3E-03
Alcohols, C6-12, ethoxylated propoxylated	68937-66-6	1.9E+01		8.3E+00	9.6E-02	1.1E-02
Choline chloride	67-48-1	9.0E+01		8.9E+01	4.5E-01	5.0E-03
Coco dimethylaminopropyl betaine	61789-40-0	7.5E+01		8.9E+00	3.8E-01	4.2E-02
Ethylene glycol	107-21-1	1.3E+00		2.5E+01	6.5E-03	2.6E-04
Guar gum	9000-30-0	1.4E+02		2.1E+02	7.2E-01	3.5E-03
Hemicellulase enzyme	9012-54-8	1.1E+00		1.0E+02	5.4E-03	5.4E-05
Maltodextrin	9050-36-6	2.1E+01		-	-	-
Monoethanolamine borate	26038-87-9	8.4E+01		1.7E+02	4.2E-01	2.5E-03
Polyethylene glycol	25322-68-3	1.4E+00		3.1E+02	7.2E-03	2.3E-05
Sodium hydroxide	1310-73-2	1.3E+01		-	-	-
THPS	7681-52-9	5.6E+01		6.7E-01	2.8E-01	4.2E-01

Hazard Index
4.9E-01

Table 16 Risk Estimates for Cattle Delta 140 Theoretical Exposure for 80% Mass Returned

		80% Mass Returned		Toxicity	Delta 140	
						Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**		**TRVs**	**$CADD_{oral}$**	**Incidental Ingestion**
Acetic acid	64-19-7	7.6E+01				
Alcohols, C10-16, ethoxylated propoxylated	69227-22-1	3.5E+01		8.3E+00	1.8E-01	2.1E-02
Alcohols, C6-12, ethoxylated propoxylated	68937-66-6	7.7E+01		8.3E+00	3.8E-01	4.6E-02
Choline chloride	67-48-1	3.6E+02		8.9E+01	1.8E+00	2.0E-02
Coco dimethylaminopropyl betaine	61789-40-0	3.0E+02		8.9E+00	1.5E+00	1.7E-01
Ethylene glycol	107-21-1	5.2E+00		2.5E+01	2.6E-02	1.0E-03
Guar gum	9000-30-0	5.8E+02		2.1E+02	2.9E+00	1.4E-02
Hemicellulase enzyme	9012-54-8	4.3E+00		1.0E+02	2.2E-02	2.2E-04
Maltodextrin	9050-36-6	8.3E+01		-	-	-
Monoethanolamine borate	26038-87-9	3.4E+02		1.7E+02	1.7E+00	1.0E-02
Polyethylene glycol	25322-68-3	5.8E+00		3.1E+02	2.9E-02	9.2E-05
Sodium hydroxide	1310-73-2	5.2E+01		-	-	-
THPS	7681-52-9	2.2E+02		6.7E-01	1.1E+00	1.7E+00

Hazard Index
2.0E+00

Table 19 Risk Estimates for Kangaroo
Delta 140 Theoretical Exposure for 20% Mass Returned

		20% Mass Returned		Toxicity	Delta 140	
						Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**		**TRVs**	**$CADD_{oral}$**	**Incidental Ingestion**
Acetic acid	64-19-7	1.9E+01				
Alcohols, C10-16, ethoxylated propoxylated	69227-22-1	8.8E+00		1.7E+01	2.9E-02	1.7E-03
Alcohols, C6-12, ethoxylated propoxylated	68937-66-6	1.9E+01		1.7E+01	6.3E-02	3.7E-03
Choline chloride	67-48-1	9.0E+01		1.8E+02	3.0E-01	1.6E-03
Coco dimethylaminopropyl betaine	61789-40-0	7.5E+01		1.8E+01	2.5E-01	1.3E-02
Ethylene glycol	107-21-1	1.3E+00		5.2E+01	4.3E-03	8.3E-05
Guar gum	9000-30-0	1.4E+02		4.3E+02	4.8E-01	1.1E-03
Hemicellulase enzyme	9012-54-8	1.1E+00		2.1E+02	3.6E-03	1.7E-05
Maltodextrin	9050-36-6	2.1E+01			-	-
Monoethanolamine borate	26038-87-9	8.4E+01		3.4E+02	2.8E-01	8.0E-04
Polyethylene glycol	25322-68-3	1.4E+00		6.5E+02	4.8E-03	7.4E-06
Sodium hydroxide	1310-73-2	1.3E+01			-	-
THPS	7681-52-9	5.6E+01		1.4E+00	1.8E-01	1.3E-01

Hazard Index
1.6E-01

Table 20 Risk Estimates for Kangaroo Delta 140 Theoretical Exposure for 20% Mass Returned

		80% Mass Returned		Toxicity	Delta 140	
						Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**		**TRVs**	**$CADD_{oral}$**	**Incidental Ingestion**
Acetic acid	64-19-7	7.6E+01				
Alcohols, C10-16, ethoxylated propoxylated	69227-22-1	3.5E+01		1.7E+01	1.2E-01	6.8E-03
Alcohols, C6-12, ethoxylated propoxylated	68937-66-6	7.7E+01		1.7E+01	2.5E-01	1.5E-02
Choline chloride	67-48-1	3.6E+02		1.8E+02	1.2E+00	6.4E-03
Coco dimethylaminopropyl betaine	61789-40-0	3.0E+02		1.8E+01	9.9E-01	5.4E-02
Ethylene glycol	107-21-1	5.2E+00		5.2E+01	1.7E-02	3.3E-04
Guar gum	9000-30-0	5.8E+02		4.3E+02	1.9E+00	4.4E-03
Hemicellulase enzyme	9012-54-8	4.3E+00		2.1E+02	1.4E-02	6.9E-05
Maltodextrin	9050-36-6	8.3E+01			-	-
Monoethanolamine borate	26038-87-9	3.4E+02		3.4E+02	1.1E+00	3.2E-03
Polyethylene glycol	25322-68-3	5.8E+00		6.5E+02	1.9E-02	2.9E-05
Sodium hydroxide	1310-73-2	5.2E+01			-	-
THPS	7681-52-9	2.2E+02		1.4E+00	7.4E-01	5.3E-01

Hazard Index
6.2E-01

Table 23 Risk Estimates for Dingo
Delta 140 Theoretical Exposure for 20% Mass Returned

		20% Mass Returned		Toxicity	Delta 140	
						Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**		**TRVs**	**$CADD_{oral}$**	**Incidental Ingestion**
Acetic acid	64-19-7	1.9E+01				
Alcohols, C10-16, ethoxylated propoxylated	69227-22-1	8.8E+00		2.0E+01	1.4E-02	6.9E-04
Alcohols, C6-12, ethoxylated propoxylated	68937-66-6	1.9E+01		2.0E+01	3.0E-02	1.5E-03
Choline chloride	67-48-1	9.0E+01		2.2E+02	1.4E-01	6.6E-04
Coco dimethylaminopropyl betaine	61789-40-0	7.5E+01		2.2E+01	1.2E-01	5.5E-03
Ethylene glycol	107-21-1	1.3E+00		6.1E+01	2.1E-03	3.4E-05
Guar gum	9000-30-0	1.4E+02		5.1E+02	2.3E-01	4.5E-04
Hemicellulase enzyme	9012-54-8	1.1E+00		2.4E+02	1.7E-03	7.1E-06
Maltodextrin	9050-36-6	2.1E+01			-	-
Monoethanolamine borate	26038-87-9	8.4E+01		4.1E+02	1.3E-01	3.3E-04
Polyethylene glycol	25322-68-3	1.4E+00		7.6E+02	2.3E-03	3.0E-06
Sodium hydroxide	1310-73-2	1.3E+01			-	-
THPS	7681-52-9	5.6E+01		1.6E+00	8.8E-02	5.5E-02

Hazard Index
6.4E-02

Table 24 Risk Estimates for Dingo Delta 140 Theoretical Exposure for 80% Mass Returned

		80% Mass Returned		Toxicity	Delta 140	
						Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**		**TRVs**	**$CADD_{oral}$**	**Incidental Ingestion**
Acetic acid	64-19-7	7.6E+01				
Alcohols, C10-16, ethoxylated propoxylated	69227-22-1	3.5E+01		2.0E+01	5.6E-02	2.8E-03
Alcohols, C6-12, ethoxylated propoxylated	68937-66-6	7.7E+01		2.0E+01	1.2E-01	6.0E-03
Choline chloride	67-48-1	3.6E+02		2.2E+02	5.7E-01	2.6E-03
Coco dimethylaminopropyl betaine	61789-40-0	3.0E+02		2.2E+01	4.8E-01	2.2E-02
Ethylene glycol	107-21-1	5.2E+00		6.1E+01	8.2E-03	1.4E-04
Guar gum	9000-30-0	5.8E+02		5.1E+02	9.2E-01	1.8E-03
Hemicellulase enzyme	9012-54-8	4.3E+00		2.4E+02	6.9E-03	2.8E-05
Maltodextrin	9050-36-6	8.3E+01			-	-
Monoethanolamine borate	26038-87-9	3.4E+02		4.1E+02	5.3E-01	1.3E-03
Polyethylene glycol	25322-68-3	5.8E+00		7.6E+02	9.2E-03	1.2E-05
Sodium hydroxide	1310-73-2	5.2E+01			-	-
THPS	7681-52-9	2.2E+02		1.6E+00	3.5E-01	2.2E-01

Hazard Index
2.5E-01

Santos

Appendix C5-1

Table C1: Chemical mass balance and estimated concentrations in typical hydraulic fracturing fluids

Name For Report	CAS Number	Delta 140				Linear Gel				Water				Acid			
		Constituent Mass in Fluid (kg)	Mass percent (ignores Proppant and Water)	Additive Mass Percent (total)	Equivalent Concentration (mg/L)	Constituent Mass in Fluid (kg)	Additive mass percent (ignores Proppant and Water)	Additive Mass Percent (total)	Equivalent Concentration (mg/L)	Constituent Mass in Fluid (kg)	Additive mass percent (ignores Proppant and Water)	Additive Mass Percent (total)	Equivalent Concentration (mg/L)	Constituent Mass in Fluid (kg)	Additive mass percent (ignores Proppant and Water)	Additive Mass Percent (total)	Equivalent Concentration (mg/L)
Chemical Additives - Fluid Systems																	
Acetic acid	**64-19-7**	59.42	3.5%	0.028%	142.40	59.42	4.2%	0.028%	142.40								
Alcohols, C10-16, ethoxylated propoxylated	**69227-22-1**	27.67	1.7%	0.013%	66.31	27.67	2.0%	0.013%	66.31					0.56	0.1%	0.014%	1.34
Alcohols, C6-12, ethoxylated propoxylated	**68937-66-6**	60.10	3.6%	0.029%	144.03	60.10	4.3%	0.029%	144.03					1.20	0.2%	0.031%	2.88
Choline chloride	**67-48-1**	281.68	16.8%	0.134%	675.06	281.68	20.0%	0.135%	675.06	5.63	61.7%	0.148%	13.49				
Coco dimethylaminopropyl betaine	**61789-40-0**	236.03	14.1%	0.113%	565.64	236.03	16.7%	0.113%	565.64								
Coffee beans														1.00	0.2%	0.026%	2.40
Ethylene glycol	**107-21-1**	4.08	0.2%	0.002%	9.78	4.08	0.3%	0.002%	9.78								
Guar gum	**9000-30-0**	453.59	27.1%	0.217%	1087.05	453.59	32.1%	0.217%	1087.05								
Hemicellulase enzyme	**9012-54-8**	3.40	0.2%	0.002%	8.15	3.40	0.2%	0.002%	8.15								
Hydrochloric acid	**7647-01-0**													607.03	99.5%	15.7%	1454.76
Maltodextrin	**9050-36-6**	64.64	3.9%	0.031%	154.90	64.64	4.6%	0.031%	154.90								
Monoethanolamine borate	**26038-87-9**	263.08	15.7%	0.126%	630.49		0.0%	0.000%	0.00								
Polyethylene glycol	**25322-68-3**	4.54	0.3%	0.002%	10.87	4.54	0.3%	0.002%	10.87					0.09	0.01%	0.002%	0.22
Sodium hydroxide	**1310-73-2**	41.05	2.5%	0.020%	98.38	41.05	2.9%	0.020%	98.38								
THPS	**7681-52-9**	175.09	10.5%	0.084%	419.60	175.09	12.4%	0.084%	419.60	3.50	38.3%	0.092%	8.39				
Proppants																	
Crystalline silica, quartz	**14808-60-7**	18144	NA	8.663%	43482.61	18144	NA	8.674%	144942.05	NA	NA	NA	NA	NA	NA	NA	NA
Water																	
Water in additives	**7732-18-5**	348.5	NA	0.166%	NA	348.5	NA	0.167%	NA	3.58	NA	NA	NA	955.37	NA	24.7%	NA
Makeup water	**7732-18-5**	189271	NA	90.371%	NA	189271	NA	90.5%	NA	3785.41	NA	99.7%	NA	2307	NA	59.6%	NA
Total Mass Additives	kg	1674				1411				9				610			
Total Mass Proppant		18144				18144				NA				NA			
Total Mass Water (in additives)		349				349				3.6				955			
Total Mass Makeup Water		189271				189271				3785				2307			
Total Mass Additives	%	0.8%				0.7%				0.2%				15.8%			
Total Mass Proppant		8.7%				8.7%				NA				NA			
Total Mass Water (in additives)		0.2%				0.2%				0.1%				24.7%			
Total Mass Makeup Water		90.4%				90.5%				99.7%				59.6%			

Notes:

Constituent mass and concentration calculations for Delta 140 and Linear Gel assume a conservative "typical" 50,000 gallon (189,271 L) fluid mixture. Water, proppant and additive mass may vary to accommodate site-specific requirements.

Constituent mass and concentration calculations for Water and Acid assume a 1000 gallon (3785 L) fluid mixture. Fluid volume and additive mass may vary to accommodate site-specific requirements.

Formulation reflects Delta 140 foamed version (maximum additives). Non-foamed version excludes coco dimethylaminopropyl betaine.

Appendix C5-2

Table C-4. Comparison of Estimated Delta 140 Theoretical Concentrations to Aquatic Life Water Guidelines

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)				Estimated Initial Concentration in flowback (150% of injected fluid volume) per coal seam per percent of mass returned calculated using equation: Initial Flowback Concentration = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (%)				PNEC aquatic (mg/L)	Ratio of Chemical Concentrations and Screening Criteria (Ratio greater than one = unacceptable potential risk)			
		Delta 140	Linear Gel	Water	Acid	Delta 140					Delta 140			
						20%	40%	60%	80%		20%	40%	60%	80%
Acetic acid	64-19-7	142	142			18.99	37.97	56.96	75.95	0.5	3.8E+01	7.6E+01	1.1E+02	1.5E+02
Alcohols, C10-16, ethoxylated propoxylated	69227-22-1	66	66		1	8.84	17.68	26.52	35.37	1.69	5.2E+00	1.0E+01	1.6E+01	2.1E+01
Alcohols, C6-12, ethoxylated propoxylated	68937-66-6	144	144		3	19.20	38.41	57.61	76.82	0.54	3.6E+01	7.1E+01	1.1E+02	1.4E+02
Choline chloride	67-48-1	675	675	13		90.01	180.01	270.02	360.03	0.6	1.5E+02	3.0E+02	4.5E+02	6.0E+02
Coco dimethylaminopropyl betaine	61789-40-0	566	566			75.42	150.84	226.26	301.68	0.0186	4.1E+03	8.1E+03	1.2E+04	1.6E+04
Ethylene glycol	107-21-1	10	10			1.30	2.61	3.91	5.22	347	3.8E-03	7.5E-03	1.1E-02	1.5E-02
Guar gum	9000-30-0	1,087	1,087			144.94	289.88	434.82	579.76	0.042	3.5E+03	6.9E+03	1.0E+04	1.4E+04
Hemicellulase enzyme	9012-54-8	8	8			1.09	2.17	3.26	4.35	0.33	3.3E+00	6.6E+00	9.9E+00	1.3E+01
Maltodextrin	9050-36-6	155	155			20.65	41.31	61.96	82.62	NA	NA	NA	NA	NA
Monoethanolamine borate	26038-87-9	630	0			84.06	168.13	252.19	336.26	0.013	6.5E+03	1.3E+04	1.9E+04	2.6E+04
Polyethylene glycol	25322-68-3	11	11		0	1.45	2.90	4.35	5.80	2	7.2E-01	1.4E+00	2.2E+00	2.9E+00
Sodium hydroxide	1310-73-2	98	98			13.12	26.23	39.35	52.47	NA	NA	NA	NA	NA
Tetrakis(hydroxylmethyl) phosphonium sulfate (THPS)	55566-30-8	420	420	8		55.95	111.89	167.84	223.79	0.0002	2.8E+05	5.6E+05	8.4E+05	1.1E+06
Hydrochloric acid	7647-01-0				1,455	193.97	387.94	581.91	775.87	NA	NA	NA	NA	NA
Coffee beans					2	0.32	0.64	0.96	1.28	NA	NA	NA	NA	NA
Caffeine (based on 2.4% content in coffee beans)	58-08-2				0.06	0.01	0.02	0.02	0.03	0.087	8.8E-02	1.8E-01	2.6E-01	3.5E-01
Proppants														
Crystalline silica, quartz	14808-60-7	43,483	144,942	NA	NA	5797.68	11595.36	17393.05	23190.73	NA	NA	NA	NA	NA
Water														
Water in additives	7732-18-5	NA	NA	NA	NA									
Makeup water	7732-18-5	NA	NA	NA	NA									

Highlighted cells are ratios greater than one and indicate a potentially unacceptable risk

293938 **587877** **881815** **1175754**

Table C-2. Comparison of Estimated Delta 140 Theoretical Concentrations to Human Health Drinking Water Guidelines

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)				Estimated Initial Concentration in flowback (150% of injected fluid volume) per coal seam per percent of mass returned calculated using equation: Initial Flowback Concentration = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (%)				Drinking Water Guideline (mg/L)	Ratio of Chemical Concentrations and Screening Criteria (Ratio greater than one = unacceptable potential risk)			
		Delta 140	Linear Gel	Water	Acid	Delta 140					Delta 140			
						20%	40%	60%	80%		20%	40%	60%	80%
Acetic acid	64-19-7	142	142			18.99	37.97	56.96	75.95	NA	NA	NA	NA	NA
Alcohols, C10-16, ethoxylated propoxylated	69227-22-1	66	66		1	8.84	17.68	26.52	35.37	2	4.4E+00	8.8E+00	1.3E+01	1.8E+01
Alcohols, C6-12, ethoxylated propoxylated	68937-66-6	144	144		3	19.20	38.41	57.61	76.82	2	9.6E+00	1.9E+01	2.9E+01	3.8E+01
Choline chloride	67-48-1	675	675	13		90.01	180.01	270.02	360.03	248	3.6E-01	7.3E-01	1.1E+00	1.5E+00
Coco dimethylaminopropyl betaine	61789-40-0	566	566			75.42	150.84	226.26	301.68	0.19	4.0E+02	7.9E+02	1.2E+03	1.6E+03
Ethylene glycol	107-21-1	10	10			1.30	2.61	3.91	5.22	5.3	2.5E-01	4.9E-01	7.4E-01	9.8E-01
Guar gum	9000-30-0	1,087	1,087			144.94	289.88	434.82	579.76	44	3.3E+00	6.6E+00	9.9E+00	1.3E+01
Hemicellulase enzyme	9012-54-8	8	8			1.09	2.17	3.26	4.35	2	5.4E-01	1.1E+00	1.6E+00	2.2E+00
Maltodextrin	9050-36-6	155	155			20.65	41.31	61.96	82.62	NA	NA	NA	NA	NA
Monoethanolamine borate	26038-87-9	630	0			84.06	168.13	252.19	336.26	3.5	2.4E+01	4.8E+01	7.2E+01	9.6E+01
Polyethylene glycol	25322-68-3	11	11		0	1.45	2.90	4.35	5.80	66	2.2E-02	4.4E-02	6.6E-02	8.8E-02
Sodium hydroxide	1310-73-2	98	98			13.12	26.23	39.35	52.47	NA	NA	NA	NA	NA
Tetrakis(hydroxylmethyl) phosphonium sulfate (THPS)	55566-30-8	420	420	8		55.95	111.89	167.84	223.79	0.01	5.6E+03	1.1E+04	1.7E+04	2.2E+04
Hydrochloric acid	7647-01-0				1,455	193.97	387.94	581.91	775.87	NA	NA	NA	NA	NA
Coffee beans					2	0.32	0.64	0.96	1.28	NA	NA	NA	NA	NA
Caffeine (based on 2.4% content in coffee beans)	58-08-2				0.06	0.01	0.02	0.02	0.03	100	7.7E-05	1.5E-04	2.3E-04	3.1E-04
Proppants														
Crystalline silica, quartz	14808-60-7	43,483	144,942	NA	NA	5797.68	11595.36	17393.05	23190.73	NA	NA	NA	NA	NA
Water														
Water in additives	7732-18-5	NA	NA	NA	NA									
Makeup water	7732-18-5	NA	NA	NA	NA									

Highlighted cells are ratios greater than one and indicate a potentially unacceptable risk

6034	**12068**	**18102**	**24136**

Appendix C5-3

Table A-2 Surface Water Quality Data for Theoretical Scenario in Initial Flowback for Delta 140

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)				Estimated Initial Mud Pit Concentration in flowback (150% of injected fluid volume) per coal seam per percent of mass returned calculated using equation: Mud Pitcon = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (%)			
						Delta 140			
		Delta 140	Linear Gel	Water	Acid	20%	40%	60%	80%
Acetic acid	64-19-7	142	142			18.99	37.97	56.96	75.95
Alcohols, C10-16, ethoxylated propoxylated	69227-22-1	66	66		1.3	8.84	17.68	26.52	35.37
Alcohols, C6-12, ethoxylated propoxylated	68937-66-6	144	144		2.9	19.20	38.41	57.61	76.82
Choline chloride	67-48-1	675	675	13		90.01	180.01	270.02	360.03
Coco dimethylaminopropyl betaine	61789-40-0	566	566			75.42	150.84	226.26	301.68
Ethylene glycol	107-21-1	10	10			1.30	2.61	3.91	5.22
Guar gum	9000-30-0	1,087	1,087			144.94	289.88	434.82	579.76
Hemicellulase enzyme	9012-54-8	8	8			1.09	2.17	3.26	4.35
Maltodextrin	9050-36-6	155	155			20.65	41.31	61.96	82.62
Monoethanolamine borate	26038-87-9	630	0			84.06	168.13	252.19	336.26
Polyethylene glycol	25322-68-3	11	11		0.2	1.45	2.90	4.35	5.80
Sodium hydroxide	1310-73-2	98	98			13.12	26.23	39.35	52.47
THPS	7681-52-9	420	420	8		55.95	111.89	167.84	223.79
Hydrochloric acid	7647-01-0				1,455	193.97	387.94	581.91	775.87
Coffee beans					2.4	0.32	0.64	0.96	1.28
Caffeine (based on 2.4% content in coffee beans)	58-08-2				0.06	0.01	0.02	0.02	0.03
Proppants									
Crystalline silica, quartz	14808-60-7	43,483	144,942	NA	NA	5797.68	11595.36	17393.05	23190.73
Water									
Water in additives	7732-18-5	NA	NA	NA	NA				
Makeup water	7732-18-5	NA	NA	NA	NA				

Santos

Appendix C6
Schlumberger YF120Flex with J318 System

C1.0 Introduction

As presented in **Section 5.0** of the Hydraulic Fracturing Risk Assessment, Santos Ltd. (Santos) used a weight-of-evidence approach to evaluate the potential for human health and environmental (e.g., ecological) risks as a result of the hydraulic fracturing processes and the Schlumber YF120Flex with J318 System.

Golder Associates Pty Ltd. (Golder), on behalf of Santos, completed a qualitative risk assessment (Golder, 2013c) that evaluated the nature of the geology in the areas undergoing stimulation, the potential for impacts on water resources, the process and chemicals used and the potential risks associated with chemicals and backflow water handled and stored above grade.

EHS Support, LLC (EHS Support) conducted a persistence, bioaccumulation and toxicity (PBT) assessment and and a Quantitative Risk Assessment (QRA) to meet Conditions 49e and 49f of the 2 October 2011 approval under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC 2008/4059) and the Environmental Amendment (EA) conditions to assess the toxicity of the mixtures.

The results and conclusions of the qualitative risk assessment components and the QRA are presented below. Refer to **Section 6.0** through **Section 8.0** for detailed discussions on the methodologies employed for the qualitative risk assessment and QRA components, which are referenced in the sections below.

C2.0 Qualitative Risk Assessment and Evaluation

C2.1 Chemicals Evaluated

The Schlumberger YF120Flex with J318 'fluid system' was assessed. The list of individual chemicals is presented in **Table 1** below. A mass balance of the chemicals is provided as **Appendix C6-1**. Information regarding the chemical and physical properties of the individual chemicals listed below are included in **Appendix E** and **Appendix G** of this report.

While none of the fracturing fluid chemicals identified contain benzene, toluene, ethylbenzene, xylenes (BTEX) or polycyclic aromatic hydrocarbons (PAHs), PAHs occur naturally in coal and it is possible that certain PAHs may naturally be present in the coal seam groundwater used in the hydraulic fracturing process.

Table 1: Hydraulic fracturing chemicals

Chemical	CAS Number
Crystalline silica	14808-60-7
Guar gum	9000-30-0
Potassium borate	1332-77-0
Cholinium chloride	67-48-1
2,2`,2"-nitrilotriethanol	102-71-6
Diammonium peroxidisulphate	7727-54-0
Diatomaceous earth, calcined	91053-39-3
Magnesium nitrate	10377-60-3
Potassium hydroxide	1310-58-3
Glycerol	56-81-5
Hydrochloric acid	7647-01-0
Cristobalite	14464-46-1
Non-crystalline silica	7631-86-9
5-chloro-2-methyl-2h-isothiazolol-3-one	26172-55-4
Magnesium chloride	7786-30-3
Magnesium silicate hydrate (talc)	14807-96-6
2-methyl-2h-isothiazol-3-one	2682-20-4
Vinylidene chloride/methylacrylate copolymer	25038-72-6

C2.2 Risk Assessment Framework and Findings

As discussed in **Section 5.0**, a systematic weight of evidence approach was utilised to complete the risk assessment for the Schlumberger fluid systems. The work has involved the following evaluations:

Qualitative Assessment Methodologies

- PBT Assessment
- Exposure Assessment
- Mass Balance of Fluid System
- Fate and Transport Modeling.

Quantitative Risk Assessment Methodologies

- Quantitative Human Health Risk Assessment (HHRA)
- Quantitative Ecological Risk Assessment for Terrestrial and Aquatic Receptors.

C2.3 PBT Assessment

The PBT approach outlined in **Section 6.1** was undertaken to rank the hydraulic fracturing chemicals based on persistence (P), bioaccumulation (B) and toxic (T) potential (**Appendix G**). As a result of this assessment, no chemical constituents identified in the YF120Flex with J318 fluid system were classified as a PBT chemical and are therefore not considered to be inherently hazardous. The results of the PBT Assessment are presented in **Table 2**, attached.

C2.4 Exposure Assessment

As discussed in **Section 7.0**, the exposure assessment identified receptors potentially exposed to chemicals of potential concern (COPC) identified for the study and outlines the exposure pathways by which the receptors may come in to contact with the COPCs. A detailed exposure assessment was not conducted in the qualitative risk assessment.

C2.5 Mass Balance of Fluid System

A quantitative mass balance calculation was undertaken to identify the amount of each chemical additive of the hydraulic fracturing fluid system. The results of the mass balance calculations are presented in **Appendix C6-1**.

C2.6 Fate and Transport Modelling

As discussed in **Section 7.2**, fate and transport modelling was conducted on a range of key constituents of interest in typical hydraulic fracturing fluid systems. These results provided the framework for assessing potential mobility of all constituents used in hydraulic fracturing. The modelling demonstrated that despite the variability in chemical properties between fluid systems there is limited potential for chemicals to migrate within the coal seams. Refer to **Section 7.2** for further detail.

C3.0 Quantitative Risk Assessment

In accordance with the methodologies presented in **Section 8.0**, a QRA was conducted on theoretical datasets for those chemicals identified in the YF120Flex with J318 fluid system. The QRA approach evaluates the toxicity of the individual substances and characterises the cumulative risks of the total effluent toxicity and ecotoxicity.

Generally, this methodology includes the identification of the hazards posed by constituents in the flowback water, compilation of the toxicity criteria for each constituent, development of exposure models to estimate the daily intake of the constituents, and calculations of individual constituent hazard quotients (daily intake divided by the toxicity criteria) and a cumulative constituent hazard index (HI) for each potentially complete exposure pathway for each human or terrestrial receptor.

Potential complete exposure pathways to the storage of flowback from hydraulically stimulated wells and potential risks to humans, terrestrial and aquatic receptors from the potential storage and accidental releases are evaluated in the QRA.

No further assessment of groundwater was determined to be necessary due to lack of potentially complete exposure pathways. Detailed operational procedures have been provided that are designed to contain the hydraulic fracturing fluids within the coal sequences, and no connection exists between groundwater in the coal seams and surface-water or springs (and therefore Matters of National Environmental Significance [MNES]). Further, the potential risks to workers involved with the hydraulic fracturing process were not considered as detailed Health and Safety (H&S) procedures are employed to manage exposures. The QRA considered the following specific exposure pathways:

1. Exposure of trespassers to flowback water contained within flowback storage ponds.
2. Exposure of terrestrial receptors (e.g., livestock and wildlife) to flowback water contained within the flowback storage ponds.
3. Exposure of aquatic receptors to flowback water in the situation of an accidental release, such as from piping or a release from the flowback storage pond. These potential releases could include a failure of containment systems, overtopping of the dam or in an extreme situation (considered highly unlikely) structural failure of the dam itself.

C3.1 Exposure Assessment

The purpose of the exposure assessment in the QRA was to predict the magnitude and frequency of potential human exposure to each COPC following the methodologies presented in **Section 8.1**. A conceptual site model (CSM) was developed which describes the potential receptors and exposure scenarios for the flowback water used in this exposure assessment. The potential exposures to receptors were evaluated based on the potential for a complete exposure pathway.

As discussed in **Section 8.3**, exposure point concentrations (EPCs) were derived for the theoretical assessment; empirical data were not available for evaluation. The EPCs for the theoretical assessment were calculated by estimating the mass and discharge flow of the COPCs in the flowback water.

C3.2 Human Health QRA

A human health hazard assessment was conducted according to the methodologies presented in **Section 8.4**. The purpose of the hazard assessment process was to summarise the environmental data, and to address the toxicological assessment of the COPCs that will be evaluated further in the risk assessment process.

Exposure assumptions for the human trespasser scenario were developed based on default or site-specific assumptions (**Section 8.4**). This receptor exposure pathway includes a small child to teenager that may come in contact with the above grade water exposure scenario for approximately 20 days/year for a 10-year period with potential incidental ingestion (of 50 millilitres [ML] of water) and dermal contact (e.g., swimming where the whole body gets wet) for one half hour. The exposure parameters used in the QRA are presented on **Table 3**, attached.

Calculation of intake of COPCs was performed using the equations presented below:

Ingestion of water:

$$Intake\ (mg/kg-day)\ =\ (CW\ x\ IR\ X\ EF\ X\ ED)\ /\ (BW\ x\ AT)$$

Dermal contact with water:

$$Absorbed\ dose\ (mg/kg-day)\ =\ (CW\ x\ SA\ x\ DP\ x\ ET\ x\ EF\ x\ ED\ x\ CF)\ /\ (BW\ x\ AT)$$

Where:

CW = concentration in water (mg/l)
ET = exposure time (hr/day or hours/hours)
EF = exposure frequency (day/year)
ED = exposure duration (years)
CF = correction factor (1 x 10-3 l/cm3)
AT = averaging time (days)
IR = ingestion rate (l/hr)
BW = body weight (kg)
SA = skin surface area available for contact (cm2/d)
DP = dermal permeability factor (Kp – cm/hr).

C3.3 Toxicity Assessment

A toxicity assessment was conducted to determine the relationship between the dose of a COPC taken into the body, and the probability that an adverse effect will result from that dose. Quantitative estimates of the potency of COPCs include two sets of toxicity values, one for genotoxic carcinogens and one for other non-genotoxic carcinogens and non-carcinogenic effects. As discussed in **Section 8.4,** detailed toxicological profiles were developed for the chemicals. The toxicological profiles are included as **Appendix F**.

The assessment of toxicity of the COPCs was used to develop initial screening criteria for human health exposure scenarios as discussed in **Section 8.4**. The derivation of Oral Reference Dose and Drinking Water Guideline Values are presented in **Table 4**, attached, and the Australian Drinking Water Screening Values are presented inn **Table 5**, attached.

C3.4 Exposure Point Concentration

As presented above, the exposure scenarios are based on anticipated conditions, and the potential for exposure to the theoretical estimate of exposure. EPCs for the exposure assessment were calculated using the results of theoretical fate and transport modelling calculations and the existing environmental conditions within the fracturing fluids sump or mud pit, and the flowback storage ponds.

For the theoretical calculations, the mass and estimated chemical concentrations of the COPCs in the YF120Flex with J318 fluids, as presented in **Appendix C6-1**, were used to estimate the potential concentrations in water within the fracturing fluids sump or flare pit, or flowback storage ponds. Based on stimulation flow back monitoring conducted by Santos and the QRA completed for the Schlumberger

Fluid Systems (**Appendix C**), 20 percent (%) of the total mass of constituents injected is assumed to be recovered in the flowback water. This mass is diluted within 150% of the injected volume (the minimum volume that must be flowed back) to establish an "estimated" concentration (i.e., concentration expected due to full dilution of the back flow water) within the flowback storage ponds.

The flowback water will be contained within the flowback storage ponds for a projected maximum period of one year of operational activity before transfer or conveyance to the water treatment facilities. Therefore, the concentration of COPCs in the flowback storage pond water was adjusted, where applicable, to account for the biodegradation and photolytic degradation of constituents over time. The biodegradation information was obtained from the Organisation for Economic Cooperation and Development (OECD) ready tests (OECD, 1992) that were developed as a first-tier testing scheme to provide preliminary screening of organic chemicals. The ready tests are stringent screening tests that are conducted under aerobic conditions in which a high concentration of the test substance is used, and biodegradation is measured by non-specific parameters including dissolved organic carbon, biochemical oxygen demand and carbon dioxide production. **Table 6**, attached, presents the environmental fate information that was used to assess biodegradation of COPCs, and that was applied at the time periods of 0, 30, 150 and 300 days from initial flowback.

The water quality data derived using these assumptions for the theoretical COPCs are presented in **Appendix C6-1**.

The theoretical EPCs for the four exposure time periods (0, 30, 150 and 300 days) were compared to human health toxicity-based screening levels, and the results of this comparison, including the ratio of exceedance of screening levels, is presented in **Appendix C6-2**.

C3.5 Risk Estimation

Risk estimation was performed in accordance with the methodologies outlined in **Section 8.4**. The total target risk range for carcinogens was 1×10^{-4} to 1×10^{-6}; the target HI for non-threshold effects is less than or equal to 1.0.

No carcinogenic compounds are present in the stimulation fluids injected into the subsurface and as a result, only non-carcinogenic risks were calculated.

The results of the theoretical assessments for YF120Flex with J318 fluid systems for the trespasser exposure scenarios (day 0 and day 150, YF120Flex with J318 events) are summarized in **Tables 7** and **8**, attached. As discussed above, the theoretical assessment was only conducted at the well pad sites.

The exposure scenarios include the YF120Flex with J318 fluid system event, as presented in **Appendix C6-1** for day 0 and day 150 from the flowback storage pond. The trespasser for day 0 did not have unacceptable risks for the YF120Flex with J318 fluid system (HI=0.49, **Table 7**, attached). The trespasser for day 150 did not have unacceptable risks for the YF120Flex with J318 fluid system (HI=0.47, **Table 8**, attached).

On this basis and using the theoretical concentrations, no adverse effects are predicted on trespassers.

C3.6 Ecological Risk Assessment

As discussed in **Section 8.5**, a screening level ecological risk assessment (ERA) was conducted to evaluate the potential for adverse ecological effects to terrestrial and aquatic ecological receptors that may be exposed to residual levels of hydraulic fracturing fluids in surface water used in the coal seam gas (CSG) fields.

C3.7 Exposure Assessment

Terrestrial receptors evaluated in the ERA include domesticated livestock, large mammalian wildlife and small mammalian wildlife. Beef cattle were used to evaluate domesticated livestock, kangaroos evaluated for large mammalian wildlife, and dingos for small mammalian wildlife. Aquatic receptors evaluated included invertebrates and fishes.

The estimate for dose-based or intake rates for the assessment endpoints for wildlife representing domestic livestock and native mammalian species used the following general equation:

TI = Cwater x IRwater x EF x ED / BW x ED x 365 days/year

Where:

TI = Total intake of COPC (mg/kg/day)
Cwater = Concentration of COPC in water (mg/l)
IRwater = Ingestion rate (litres/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg).

The exposure assumptions are presented in **Tables 9** through **11**.

C3.8 Toxicity Assessment

To evaluate the potential for adverse ecological effects, toxicity reference values (TRVs) are selected as measurement endpoints for the ERA that will be used in the risk analysis. The TRVs are based on COPC levels that imply no adverse effects or levels that represent the lowest concentration at which adverse effects may occur. The ERA used two types of TRVs. The first TRV is a concentration-based TRV to evaluate the concentration of the selected COPC in the surface water and direct exposure by the aquatic ecological receptor. The determination of TRVs for freshwater was conducted according to the predicted no-effects concentration (PNEC) guidance in the Environmental Risk Assessment Guidance Manual for Industrial Chemicals prepared by the Australian Environmental Agency (AEA, 2009). As discussed in **Section 8.4**, detailed environmental profiles were developed for the chemicals. The environmental profiles are included in the risk dossiers in **Appendix G**. **Table 12**, attached, presents the COPC, the endpoint, NOEC [milligrams per litre (mg/L)], assessment factor and the aquatic PNEC (mg/L). The second TRV is a dose-based TRV to evaluate the intake dose of the selected COPC from exposure to surface water by ingestion. The calculated TRVs for each of the mammalian ecological receptors evaluated in the ERA are presented in the species-specific ecological risk models.

C3.9 Exposure Point Concentration

EPCs for the exposure assessment were calculated using the results of theoretical fate and transport modelling calculations. The potentially affected flowback water that represents complete exposure pathways for the ecological receptors includes the surface water systems (e.g., flowback storage ponds and mud pits) that were used to estimate the EPCs for the human health receptors. Similar to the EPCs for the human health receptors, the EPCs for the ecological receptors assumed 20 % of mass returned in the flowback water was diluted within 150 % of the injected volume of return water, and was then adjusted based on biodegradation rates to calculate the theoretical EPCs for the four exposure time periods (0, 30, 150, and 300 days). **Appendix C6-1** presents the calculated EPCs for the ecological receptor exposure scenarios. The theoretical EPCs for the four exposure time periods (0, 30, 150, and 300 days) were compared to ecological based toxicity-based screening levels, and the results of this comparison, including the ratio of exceedance of screening levels, is presented in **Appenidix C6-3**.

Risks were characterised in accordance with the methodologies discussed in **Section 8.5.6**. The resulting ecological hazard quotient must be less than or equal to 1.0 for risks to be considered acceptable.

C3.10 Estimation of Risk

The HI calculated for flowback water for aquatic risk were elevated above the acceptable level for the majority of COPCs evaluated (**Appendix C6-3**). Where large discharges of flowback water occur to surface water and/or flux dilution within the surface-water was insufficient, potential impacts on aquatic receptors could occur. As noted in the toxicity assessment section above, the lack of a robust aquatic toxicological database resulted in highly conservative aquatic screening values for the theoretical exposure scenario COPCs to be conservatively very low.

The results of the theoretical assessments for YF120Flex with J318 fluid systems for the livestock cattle, kangaroo and dingo are summarized in **Tables 13** through **18**, attached. The exposure scenarios include the YF120Flex with J318 fluid systems EPCs presented in **Appendix C6-1** for day 0 and day 150 from the fracturing fluid well flowback. The modelled risks from YF120Flex with J318 fluid system chemicals in the flowback water were unacceptable for the livestock cattle (HI=6.8 to 6.9, **Table 13** and **14**, attached) and kangaroo (HI=1.4, **Table 15** and **16**, attached) for both exposure scenarios. The primary risk driver was potassium borate via incidental ingestion. The modelled risks from YF120Flex with J318 fluid system chemicals in the flowback water were acceptable for the dingo (HI=0.58 to 0.57, **Table 17** and **18**, attached) for both exposure scenarios.

C4.0 Summary of QRA Findings

The QRA was completed as discussed in **Section 8.0**. An assessment was conducted using highly conservative theoretical calculations based on the chemicals utilised by Schlumberger in hydraulic fracturing. This assessment assumed that a range of theoretical concentrations of injected chemicals would be present in the flowback water based on biodegradation rates, where applicable.

Consistent with the risk assessment and groundwater fate and transport modelling conducted by Golder, no potentially complete exposure pathways were identified for groundwater. Potential exposures are limited to the aboveground storage and handling of flowback water as part of the CSG Water Management Plan (WMP). Management of CSG water involves the temporary storage of flowback water in flowback storage ponds.

The results of the qualitative PBT Assessment indicated that no chemical constituents identified in the YF120Flex with J318 fluid system was classified as a PBT chemical and therefore fluids containing these chemicals are not considered inherently hazardous.

The two exposure scenarios modelled for the QRA were 20 % flowback return, and either 0 or 150-day retention with EPC based on applicable degradation rates. Based on quantitative risk calculations, the potential risks to the trespasser associated with the flowback water are acceptable. There were no carcinogenic risks identified.

The modelled risks from YF120Flex with J318 fluid system chemicals in the flowback water were unacceptable for the livestock cattle and kangaroo for both exposure scenarios. The primary risk driver was potassium borate via incidental ingestion. Potential risks to the dingo were acceptable for both exposure scenarios.

Similarly, potential impacts could occur if releases of flowback water were to occur to aquatic environments. Based on the use of low permeability materials (clay liners) and operational controls that limit the potential for turkey nest and dam overflows, the potential for these risks are also considered limited.

A combination of management and operational controls are being implemented to eliminate and control the potential for exposures. These include:

- Worker training and hazard identification
- Use of appropriate personal protective equipment (gloves, etc.)
- Flowback storage pond fencing to prevent entry of livestock and native fauna and minimise trespassing
- Use of low permeability materials or dam liners and routine dam inspections to prevent releases from flowback storage ponds
- Routine operational and security patrols to prevent trespassing.

C5.0 Conclusions

A weight-of-evidence evaluation of potential risks as described in **Section 5.0** was performed for the Schlumberger YF120Flex with J318 fluid system. Based on the qualitative and quantitative risk characterisations, the overall risk to human health and the environment is low. Existing operational control activities employed by Santos are in place that will limit the potential risks to human health and the environment. These measures include:

- Occupational health and safety procedures implemented during hydraulic fracturing operations to prevent workers from direct contact with chemicals during spills and when handling flowback water or sediments;
- Environmental authority conditions that preclude the construction of well pads within 100 metres of a watercourse of water body;
- Implementation of spill containment procedures during operations to prevent migration of and exposure to chemicals;
- Disposal or capping of sediments contained within drained mud pits and turkey nests , to prevent exposure to contaminates in windborne dust;
- Fencing of drill pads to prevent trespassers and installation of signs to indicate that the water in the turkeys nest and mud pit is not potable and may contain contaminants;
- Installation and maintenance of fences around the well pad to prevent access to the drill pad by livestock and large native fauna;
- Santos operational procedures to ensure well integrity and design of fracture to stay within the target seam; and
- Mud pits and turkeys nests with clay liners, or similar material, to prevent seepage of flowback water into underlying aquifers.

Regular monitoring of water supply bores and surface water for a representative suite of chemicals within 2 kilometre of wells that are fractured is required to confirm the conclusion of incomplete exposure pathways and low risk.

No additional risks, other than those previously discussed, were identified with the chemicals or systems employed by Schlumberger in hydraulic fracturing. Evaluation of other potential risks associated with hydraulic fracturing (i.e., noise and vibration) was conducted. Refer to **Section 9.0** for methodology specifics and results of this evaluation.

Tables

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Table 2. PBT Assessment of the YF120Flex with J318 Fluid System

Substance	P/vP criteria fulfilled?	B/vB criteria fulfilled?	T criteria fulfilled?	Overall Conclusion
Crystalline Silica (14808-60-7)	Yes (naturally-occurring inorganic mineral)	No (water-insoluble mineral; not bioavailable)	No (water-insoluble mineral; not bioavailable)	Not PBT (based on physico-chemical properties)
Guar Gum (9000-30-0)	No (screening data estimated)	No (screening data available)	No (screening data available)	Not PBT (based on screening and measured data)
Potassium borate (1332-77-0)	Yes (inorganic salt)	No (screening data available)	Yes (measured data; human health concerns)	Not PBT (based on screening and measured data)
Cholineium chloride (67-48-1)	No (screening data available)	No (screening data available)	No (screening data available)	Not PBT (based on screening data)
2,2′,2″-nitrilotriethanol (102-71-6)	No (screening data available)	No (experimental data available)	No (experimental data available)	Not PBT (based on screening and experimental data)
Diammonium peroxidisulphate (7727-54-0)	Not applicable (ionic species ubiquitous in environment)	No (essential ions to biological systems; actively regulated)	No (screening data available)	Not PBT (based on screening data and ubiquitous inorganic salt)
Potassium hydroxide (1310-58-3)	Not applicable (ionic species ubiquitous in environment)	No (essential ions to biological systems; actively regulated)	No (screening data available)	Not PBT (based on screening data and ubiquitous inorganic salt)
Glycerol (56-81-5)	No (screening data available)	No (screening data available)	No (screening data available)	Not PBT (based on screening data)
Hydrochloric acid (7647-01-0)	Not applicable (ionic species ubiquitous in environment)	No (essential ions to biological systems; actively regulated)	No (screening data available)	Not PBT (based on screening data and ubiquitous inorganic salt)

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Substance	P/vP criteria fulfilled?	B/vB criteria fulfilled?	T criteria fulfilled?	Overall Conclusion
Vinylidene chloride/methylacrylate copolymer (25038-72-6)	Yes (polymer not biodegradable)	No (polymer; not bioavailable)	No (polymer; not bioavailable)	Not PBT
Diatomaceous earth, calcined (91053-39-3)	Yes (naturally-occurring inorganic mineral)	No (water-insoluble mineral; not bioavailable)	No (water-insoluble mineral; not bioavailable)	Not PBT (based on physico-chemical properties)
Magnesium nitrate (10377-60-3)	Not applicable (ionic species ubiquitous in environment)	No (Mg is an essential ion to biological systems; nitrate ions are water-soluble)	No (screening data available)	Not PBT (based on screening data and ubiquitous inorganic salt)
Non-crystalline silica (7631-86-9)	Not applicable (inorganic substances ubiquitous in the environment)	Not applicable (inorganic substances ubiquitous in the environment)	No (screening data available)	Not PBT (based on screening data and ubiquitous inorganic substance)
5-chloro-2-methyl-2h-isothazolo-3-one/2-methyl-2h-isothiasol-3-one [3:1] (55965-84-9)	No (experimental data available)	No (experimental data available)	Yes (screening data available)	Not PBT (based on screening and experimental data)
Magnesium silicate hydrate [talc] (14807-96-6)	Yes (naturally-occurring inorganic mineral)	No (water-insoluble mineral; not bioavailable)	No (water-insoluble mineral; not bioavailable)	Not PBT (based on physico-chemical properties)
Magnesium chloride (7786-30-3)	Not applicable (ionic species ubiquitous in environment)	No (essential ions to biological systems; actively regulated)	No (screening data available)	Not PBT (based on screening data and ubiquitous inorganic salt)
Cristobalite (14464-46-1)	Yes (naturally-occurring inorganic mineral)	No (water-insoluble mineral; not bioavailable)	No (water-insoluble mineral; not bioavailable)	Not PBT (based on physico-chemical properties)
Crystalline Silica (14808-60-7)	Yes (naturally-occurring inorganic mineral)	No (water-insoluble mineral; not bioavailable)	No (water-insoluble mineral; not bioavailable)	Not PBT (based on physico-chemical properties)

Table 3 Exposure Assumptions - Trespasser

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/hr	0.05
	ET	Exposure time	hr/day	0.5
	EF	Exposure frequency	day/yr	20
	ED	Exposure duration	yr	10
	BW	Body weight	kg	47
	AT-NC	Averaging time - noncancer	days	3,650
	AT-C	Averaging time - cancer	days	25,550
Dermal	SA	Surface area for contact	cm^2/day	13,000
	DP	Dermal permeability factor	cm/h	chemical-specific
	ET	Exposure time	hr/day	1
	EF	Exposure frequency	day/yr	20
	ED	Exposure duration	yr	10
	BW	Body weight	kg	47
	AT-NC	Averaging time - noncancer	days	3,650
	AT-C	Averaging time - cancer	days	25,550
	CF	Conversion factor	l/cm^3	1.0E-03

Table 4 Oral Reference Doses and Drinking Water Guidelines Derived for Hydraulic Fracturing Chemicals

Chemical (CAS No.)	Study	Critical Effect/Target Organ(s)	NOAEL (mg/kg/day)	Uncertainty Factors	Oral Reference Dose (mg/kg/day)	Drinking Water Guideline (ppm)
Crystalline Silica (14808-60-7)	NDa	ND	ND	ND	ND	ND
Guar Gum (9000-30-0)	Rat 2-yr drinking water	General toxicity	1,250	100	12.5	44
Potassium borate (1332-77-0)	Rat developmental	Fetal body weight changes	10.3[b]	66	0.2[b]	0.7 [boron]
Cholinium chloride (67-48-1)	Human study	Hypotension	7500[b]	2	50 [as choline]	175 [as choline]
2,2',2''-nitrilotriethanol (102-71-6)	Rat 91-day dietary	-	1,000	1,000	1	3.5
Glycerol (56-81-5)	Rat 2-yr dietary	-	8,000	100	80	280
Vinylidene chloride/methylacrylate copolymer (25038-72-6)	ND	ND	ND	ND	ND	ND
Diatomaceous earth, calcined (91053-39-3)	ND	ND	ND	ND	ND	ND
Non-crystalline silica (7631-86-9)	Rat 2-yr dietary	-	2,500	100	2.5	0.09
5-chloro-2-methyl-2h-isothazolo-3-one/2-methyl-2h-isothiasol-3-one [3:1] (55965-84-9)	2-year rat drinking water	Gastric irritation of the stomach	2	100	0.0	0.07
Magnesium silicate hydrate [talc] (14807-96-6)	ND	ND	ND	ND	ND	ND
Cristobalite (14464-46-1)	ND	ND	ND	ND	ND	ND

[a] Not determined
[b] LOAEL

Table 5 Australian Drinking Water Screening Values for Hydraulic Fracturing Chemicals

Chemical (CAS No.)	Drinking Water Screening Guideline	Drinking Water Screening Value
Diammonium peroxidisulphate (7727-54-0)	sulfate	500 mg/L (health); 250 mg/L (aesthetic)
Potassium hydroxide (1310-58-3)	pH	6.5 to 8.5
Hydrochloric acid (7647-01-0)	pH, chloride	6.5 to 8.5; 250 mg/L (aesthetic)
Magnesium chloride (7786-30-3)	Chloride	250 mg/L (aesthetic)
Magnesium nitrate (10377-60-3)	Nitrate	50 mg/L (health)

Table 6 Environmental Fate Information

Crystalline Silica	Water-insoluble mineral; not biodegradable
Guar Gum	Readily biodegradable (half-life = 15 days)a
Potassium borate	Water-soluble inorganic; (borate): not biodegradable
Cholinium chloride	Readily biodegradable (half-life = 15 days)a
2,2′,2″-nitrilotriethanol	Readily biodegradable (half-life = 15 days)a
Diammonium peroxidisulphate	Dissociates completely in aqueous media
Potassium hydroxide	Dissociates completely in aqueous media
Glycerol	Readily biodegradable (half-life = 15 days)a
Hydrochloric acid	Dissociates completely in aqueous media
Vinylidene chloride/methacrylate copolymer	Polymer; not biodegradable
Diatomaceous earth, calcined	Water-insoluble mineral; not biodegradable
Magnesium nitrate	Dissociates completely in aqueous media
Non-crystalline silica	Water-insoluble mineral; not biodegradable
5-chloro-2-methyl-2h-isothazolo-3-one/2-methyl-2h-isothiasol-3-one [3:1]	Half-lives in river water-sediment system are 17.3 and 9.1 hours, respectively.
Magnesium silicate hydrate (talc)	Water-insoluble mineral; not biodegradable
Magnesium chloride	Dissociates completely in aqueous media
Cristobalite	Water-insoluble mineral; not biodegradable

Source: EU Guidance Document: Half-life estimates from in vitro biodegradation test results

Table 7 Risk Estimates for Trespasser Schlumberger YF120Flex with J318 Theoretical Exposure for Day 0

		Day 0		Toxicity	YF120Flex with J318			
							Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**PC (cm/hr)**	**RfDo**	**$CADD_{oral}$**	**$CADD_{derm}$**	**Incidental Ingestion**	**Dermal**
Crystalline silica	14808-60-7	1.5E+04	NA	-	-	-	-	-
Guar gum	9000-30-0	1.5E+03	NA	12.5	8.7E-02	-	7.0E-03	-
Potassium borate	1332-77-0	1.5E+03	5.1E-04	0.2	8.7E-02	5.8E-03	4.4E-01	2.9E-02
Cholinium chloride	67-48-1	1.5E+03	8.5E-07	50	8.7E-02	9.7E-06	1.7E-03	1.9E-07
2,2`,2"-nitrilotriethanol	102-71-6	1.5E+02	5.1E-05	1	8.7E-03	5.7E-05	8.7E-03	5.7E-05
Diammonium peroxidisulphate	7727-54-0	1.5E+02	NA	142.8	8.7E-03	-	6.1E-05	-
Diatomaceous earth, calcined	91053-39-3	1.5E+02	NA	-	-	-		-
Magnesium nitrate	10377-60-3	1.5E+02	9.3E-05	14.3	8.7E-03	1.1E-04	6.1E-04	7.4E-06
Potassium hydroxide	1310-58-3	1.5E+02	NA	-	-	-		-
Glycerol	56-81-5	1.5E+01	3.3E-05	80.0	8.7E-04	3.8E-06	1.1E-05	4.7E-08
Hydrochloric acid	7647-01-0	1.5E+01	NA	-	-	-	-	-
Cristobalite	14464-46-1	1.5E+00	NA	-	-	-	-	-
Non-crystalline silica	7631-86-9	1.5E+00	NA	2.5	8.7E-05	-	3.5E-05	-
5-chloro-2-methyl-2h-isothiazolol-3-one	26172-55-4	1.5E+00	1.4E-04	0.02	8.7E-05	1.6E-06	4.4E-03	7.8E-05

Table 8 Risk Estimates for Trespasser Schlumberger YF120Flex with J318 Theoretical Exposure for Day 150

		Day 150		Toxicity	YF120Flex with J318			
							Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**PC (cm/hr)**	**RfDo**	**$CADD_{oral}$**	**$CADD_{derm}$**	**Incidental Ingestion**	**Dermal**
Crystalline silica	14808-60-7	1.5E+04	NA	-	-	-	-	-
Guar gum	9000-30-0	1.5E+00	NA	12.5	8.5E-05	-	6.8E-06	-
Potassium borate	1332-77-0	1.5E+03	5.1E-04	0.2	8.7E-02	5.8E-03	4.4E-01	2.9E-02
Cholinium chloride	67-48-1	1.5E+00	8.5E-07	50	8.5E-05	9.4E-09	1.7E-06	1.9E-10
2,2`,2"-nitrilotriethanol	102-71-6	1.5E-01	5.1E-05	1	8.5E-06	5.6E-08	8.5E-06	5.6E-08
Diammonium peroxidisulphate	7727-54-0	1.5E+02	NA	142.8	8.7E-03	-	6.1E-05	-
Diatomaceous earth, calcined	91053-39-3	1.5E+02	NA	-	-	-		-
Magnesium nitrate	10377-60-3	1.5E+02	9.3E-05	14.3	8.7E-03	1.1E-04	6.1E-04	7.4E-06
Potassium hydroxide	1310-58-3	1.5E+02	NA	-	-	-		-
Glycerol	56-81-5	1.5E-02	3.3E-05	80.0	8.5E-07	3.7E-09	1.1E-08	4.6E-11
Hydrochloric acid	7647-01-0	1.5E+01	NA	-	-	-	-	-
Cristobalite	14464-46-1	1.5E+00	NA	-	-	-	-	-
Non-crystalline silica	7631-86-9	1.5E+00	NA	2.5	8.7E-05	-	3.5E-05	-
5-chloro-2-methyl-2h-isothiazolol-3-one	26172-55-4	1.0E-45	1.4E-04	0.02	6.1E-50	1.1E-51	3.1E-48	5.5E-50

Table 9 Exposure Assumptions - Cattle

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/day	86
	EF	Exposure frequency	day/yr	15
	ED	Exposure duration	yr	8
	BW	Body weight	kg	454
	AT-NC	Averaging time - noncancer	days	2,920

Table 10 Exposure Assumptions - Kangaroo

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/day	3
	EF	Exposure frequency	day/yr	10
	ED	Exposure duration	yr	15
	BW	Body weight	kg	25
	AT-NC	Averaging time - noncancer	days	5,475

Table 11 Exposure Assumptions - Dingo

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/day	0.75
	EF	Exposure frequency	day/yr	10
	ED	Exposure duration	yr	15
	BW	Body weight	kg	13
	AT-NC	Averaging time - noncancer	days	5,475

Table 12 Aquatic Toxicity Values (PNECs)

Chemical	Endpoint	NOEC (mg/L)	Assessment Factor	$PNEC_{aquatic}$ (mg/L)
Crystalline Silica (14808-60-7)	ND[a]	ND	ND	ND
Guar Gum (9000-30-0)	48-hr LC_{50} (Daphnia)	42	1,000	0.042
Potassium borate (1332-77-0)	Species Sensitivity Distribution	-	-	1.5[b,d];0.37[c,d]
Cholinium chloride (67-48-1)	Chronic Daphnia	30	50	0.6
2,2' ,2'' -nitrilotriethanol (102-71-6)	Chronic Daphnia	125	100	1.25
Diammonium peroxidisulphate (7727-54-0)	Acute fish	76	1,000	0.076
Potassium hydroxide (1310-58-3)	-	-	-	-
Glycerol (56-81-5)	Acute fish	5,000	1,000	5
Hydrochloric acid (7647-01-0)	-	-	-	-
Vinylidene chloride/methylacrylate copolymer (25038-72-6)	ND	ND	ND	ND
Diatomaceous earth, calcined (91053-39-3)	ND	ND	ND	ND
Magnesium nitrate (10377-60-3)	-	-	-	0.7[e]
Non-crystalline silica (7631-86-9)	-	-	-	-
5-chloro-2-methyl-2h-isothazolo-3-one/2-methyl-2h-isothiasol-3-one [3:1] (55965-84-9)	Acute Daphnia	0.027	1,000	0.000027
Magnesium silicate hydrate [talc] (14807-96-6)	ND	ND	ND	ND
Magnesium chloride (7786-30-3)	Acute algae	100	1,000	0.1
Cristobalite (14464-46-1)	ND	ND	ND	ND

aND = Not Determined.

bCanadian water quality guideline for the protection of aquatic life: boron (CCME, 2009).

cAustralia and New Zealand freshwater high reliability trigger value for boron (ANZECC, 2000).

dValue expressed as B equivalents. The conversion factor from mg disodium tetraborate decahydrate/L to mg B/L is 0.113.

eANZECC (2000) water quality “trigger value for nitrate.

Table 13 Risk Estimates for Cattle Schlumberger
YF120Flex with J318 Theoretical Exposure for Day 0

		Day 0	Toxicity	YF120Flex with J318	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**TI**	**Incidental Ingestion**
Crystalline silica	14808-60-7	1.5E+04			
Guar gum	9000-30-0	1.5E+03	2.1E+02	1.2E+01	5.6E-02
Potassium borate	1332-77-0	1.5E+03	1.7E+00	1.2E+01	6.8E+00
Cholinium chloride	67-48-1	1.5E+03	4.7E+03	1.2E+01	2.5E-03
2,2`,2"-nitrilotriethanol	102-71-6	1.5E+02	1.7E+02	1.2E+00	7.0E-03
Diammonium peroxidisulphate	7727-54-0	1.5E+02			
Diatomaceous earth, calcined	91053-39-3	1.5E+02			
Magnesium nitrate	10377-60-3	1.5E+02			
Potassium hydroxide	1310-58-3	1.5E+02			
Glycerol	56-81-5	1.5E+01	1.3E+03	1.2E-01	8.7E-05
Hydrochloric acid	7647-01-0	1.5E+01			
Cristobalite	14464-46-1	1.5E+00			
Non-crystalline silica	7631-86-9	1.5E+00	4.2E+02	1.2E-02	2.8E-05
5-chloro-2-methyl-2h-isothiazolol-3-one	26172-55-4	1.5E+00	3.3E-01	1.2E-02	3.5E-02
Magnesium chloride	7786-30-3	1.5E+00			
Magnesium silicate hydrate (talc)	14807-96-6	1.5E+00			
2-methyl-2h-isothiazol-3-one	2682-20-4	1.5E-01	3.3E-01	1.2E-03	3.5E-03
Vinylidene chloride/methylacrylate copolymer	25038-72-6	1.5E-01			

Hazard Index
6.9E+00

Table 14 Risk Estimates for Cattle Schlumberger
YF120Flex with J318 Theoretical Exposure for Day 150

		Day 150	Toxicity	YF120Flex with J318	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**TI**	**Incidental Ingestion**
Crystalline silica	14808-60-7	1.5E+04			
Guar gum	9000-30-0	1.5E+00	2.1E+02	1.1E-02	5.5E-05
Potassium borate	1332-77-0	1.5E+03	1.7E+00	1.2E+01	6.8E+00
Cholinium chloride	67-48-1	1.5E+00	4.7E+03	1.1E-02	2.4E-06
2,2`,2"-nitrilotriethanol	102-71-6	1.5E-01	1.7E+02	1.1E-03	6.8E-06
Diammonium peroxidisulphate	7727-54-0	1.5E+02			
Diatomaceous earth, calcined	91053-39-3	1.5E+02			
Magnesium nitrate	10377-60-3	1.5E+02			
Potassium hydroxide	1310-58-3	1.5E+02			
Glycerol	56-81-5	1.5E-02	1.3E+03	1.1E-04	8.5E-08
Hydrochloric acid	7647-01-0	1.5E+01			
Cristobalite	14464-46-1	1.5E+00			
Non-crystalline silica	7631-86-9	1.5E+00	4.2E+02	1.2E-02	2.8E-05
5-chloro-2-methyl-2h-isothiazolol-3-one	26172-55-4	1.0E-45	3.3E-01	8.2E-48	2.5E-47
Magnesium chloride	7786-30-3	1.5E+00			
Magnesium silicate hydrate (talc)	14807-96-6	1.5E+00			
2-methyl-2h-isothiazol-3-one	2682-20-4	1.0E-46	3.3E-01	8.1E-49	2.4E-48
Vinylidene chloride/methylacrylate copolymer	25038-72-6	1.5E-01			

Hazard Index
6.8E+00

Table 15 Risk Estimates for Kangaroo Schlumberger
YF120Flex with J318 Theoretical Exposure for Day 0

		Day 0	Toxicity	YF120Flex with J318	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**TI**	**Incidental Ingestion**
Crystalline silica	14808-60-7	1.5E+04			
Guar gum	9000-30-0	1.5E+03	4.3E+02	4.9E+00	1.1E-02
Potassium borate	1332-77-0	1.5E+03	3.5E+00	4.9E+00	1.4E+00
Cholinium chloride	67-48-1	1.5E+03	9.7E+03	4.9E+00	5.1E-04
2,2`,2"-nitrilotriethanol	102-71-6	1.5E+02	3.4E+02	4.9E-01	1.4E-03
Diammonium peroxidisulphate	7727-54-0	1.5E+02			
Diatomaceous earth, calcined	91053-39-3	1.5E+02			
Magnesium nitrate	10377-60-3	1.5E+02			
Potassium hydroxide	1310-58-3	1.5E+02			
Glycerol	56-81-5	1.5E+01	2.8E+03	4.9E-02	1.8E-05
Hydrochloric acid	7647-01-0	1.5E+01			
Cristobalite	14464-46-1	1.5E+00			
Non-crystalline silica	7631-86-9	1.5E+00	8.6E+02	4.9E-03	5.7E-06
5-chloro-2-methyl-2h-isothiazolol-3-one	26172-55-4	1.5E+00	-		
Magnesium chloride	7786-30-3	1.5E+00			
Magnesium silicate hydrate (talc)	14807-96-6	1.5E+00			
2-methyl-2h-isothiazol-3-one	2682-20-4	1.5E-01	6.9E-01	4.9E-04	7.1E-04
Vinylidene chloride/methylacrylate copolymer	25038-72-6	1.5E-01			

Hazard Index
1.4E+00

Table 16 Risk Estimates for Kangaroo Schlumberger
YF120Flex with J318 Theoretical Exposure for Day 150

		Day 150	Toxicity	YF120Flex with J318	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**TI**	**Incidental Ingestion**
Crystalline silica	14808-60-7	1.5E+04			
Guar gum	9000-30-0	1.5E+00	4.3E+02	4.8E-03	1.1E-05
Potassium borate	1332-77-0	1.5E+03	3.5E+00	4.9E+00	1.4E+00
Cholinium chloride	67-48-1	1.5E+00	9.7E+03	4.8E-03	5.0E-07
2,2`,2"-nitrilotriethanol	102-71-6	1.5E-01	3.4E+02	4.8E-04	1.4E-06
Diammonium peroxidisulphate	7727-54-0	1.5E+02			
Diatomaceous earth, calcined	91053-39-3	1.5E+02			
Magnesium nitrate	10377-60-3	1.5E+02			
Potassium hydroxide	1310-58-3	1.5E+02			
Glycerol	56-81-5	1.5E-02	2.8E+03	4.8E-05	1.7E-08
Hydrochloric acid	7647-01-0	1.5E+01			
Cristobalite	14464-46-1	1.5E+00			
Non-crystalline silica	7631-86-9	1.5E+00	8.6E+02	4.9E-03	5.7E-06
5-chloro-2-methyl-2h-isothiazolol-3-one	26172-55-4	1.0E-45	-		
Magnesium chloride	7786-30-3	1.5E+00			
Magnesium silicate hydrate (talc)	14807-96-6	1.5E+00			
2-methyl-2h-isothiazol-3-one	2682-20-4	1.0E-46	6.9E-01	3.4E-49	5.0E-49
Vinylidene chloride/methylacrylate copolymer	25038-72-6	1.5E-01			

Hazard Index
1.4E+00

Table 17 Risk Estimates for Dingo Halliburton CleanStimAUS Theoretical Exposure for Day 0

		Day 0	Toxicity	YF120Flex with J318	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**TI**	**Incidental Ingestion**
Crystalline silica	14808-60-7	1.5E+04			
Guar gum	9000-30-0	1.5E+03	5.1E+02	2.4E+00	4.7E-03
Potassium borate	1332-77-0	1.5E+03	4.2E+00	2.4E+00	5.7E-01
Cholinium chloride	67-48-1	1.5E+03	1.1E+04	2.4E+00	2.1E-04
2,2`,2"-nitrilotriethanol	102-71-6	1.5E+02	4.1E+02	2.4E-01	5.8E-04
Diammonium peroxidisulphate	7727-54-0	1.5E+02			
Diatomaceous earth, calcined	91053-39-3	1.5E+02			
Magnesium nitrate	10377-60-3	1.5E+02			
Potassium hydroxide	1310-58-3	1.5E+02			
Glycerol	56-81-5	1.5E+01	3.2E+03	2.4E-02	7.3E-06
Hydrochloric acid	7647-01-0	1.5E+01			
Cristobalite	14464-46-1	1.5E+00			
Non-crystalline silica	7631-86-9	1.5E+00	1.0E+03	2.4E-03	2.3E-06
5-chloro-2-methyl-2h-isothiazolol-3-one	26172-55-4	1.5E+00	8.1E-01	2.4E-03	2.9E-03
Magnesium chloride	7786-30-3	1.5E+00			
Magnesium silicate hydrate (talc)	14807-96-6	1.5E+00			
2-methyl-2h-isothiazol-3-one	2682-20-4	1.5E-01	8.1E-01	2.4E-04	2.9E-04
Vinylidene chloride/methylacrylate copolymer	25038-72-6	1.5E-01			

Hazard Index
5.8E-01

Table 18 Risk Estimates for Dingo Halliburton CleanStimAUS Theoretical Exposure for Day 150

		Day 150	Toxicity	YF120Flex with J318	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**TI**	**Incidental Ingestion**
Crystalline silica	14808-60-7	1.5E+04			
Guar gum	9000-30-0	1.5E+00	5.1E+02	2.3E-03	4.6E-06
Potassium borate	1332-77-0	1.5E+03	4.2E+00	2.4E+00	5.7E-01
Cholinium chloride	67-48-1	1.5E+00	1.1E+04	2.3E-03	2.0E-07
2,2`,2"-nitrilotriethanol	102-71-6	1.5E-01	4.1E+02	2.3E-04	5.7E-07
Diammonium peroxidisulphate	7727-54-0	1.5E+02			
Diatomaceous earth, calcined	91053-39-3	1.5E+02			
Magnesium nitrate	10377-60-3	1.5E+02			
Potassium hydroxide	1310-58-3	1.5E+02			
Glycerol	56-81-5	1.5E-02	3.2E+03	2.3E-05	7.1E-09
Hydrochloric acid	7647-01-0	1.5E+01			
Cristobalite	14464-46-1	1.5E+00			
Non-crystalline silica	7631-86-9	1.5E+00	1.0E+03	2.4E-03	2.3E-06
5-chloro-2-methyl-2h-isothiazolol-3-one	26172-55-4	1.0E-45	8.1E-01	1.7E-48	2.0E-48
Magnesium chloride	7786-30-3	1.5E+00			
Magnesium silicate hydrate (talc)	14807-96-6	1.5E+00			
2-methyl-2h-isothiazol-3-one	2682-20-4	1.0E-46	8.1E-01	1.7E-49	2.0E-49
Vinylidene chloride/methylacrylate copolymer	25038-72-6	1.5E-01			

Hazard Index
5.7E-01

Appendix C6-1

Table C6-1 Surface Water Quality Data for Theoretical Scenario in Initial Flowback for Schlumberger YF120Flex with J318 System

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Mud Pit Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Mud Pitcon = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)			
				Temporal Scenario (days)			
		YF120Flex with J318	Half-Life (days)	0	30	150	300
Crystalline silica	14808-60-7	112,287	NA	14971.57	14971.6	14971.6	14971.6
Guar gum	9000-30-0	11,228.7	15.0	1497.2	374.29	1.4621	0.0014278
Potassium borate	1332-77-0	11,229	NA	1497.2	1497.2	1497.2	1497.2
Cholinium chloride	67-48-1	11,229	15	1497.2	374.29	1.46	0.00143
2,2`,2"-nitrilotriethanol	102-71-6	1,123	15	149.7	37.43	0.15	0.00014
Diammonium peroxidisulphate	7727-54-0	1,123	NA	149.716	149.716	149.716	149.716
Diatomaceous earth, calcined	91053-39-3	1,123	NA	149.716	149.716	149.716	149.716
Magnesium nitrate	10377-60-3	1,123	NA	149.716	149.716	149.716	149.716
Potassium hydroxide	1310-58-3	1,123	NA	149.716	149.716	149.716	149.716
Glycerol	56-81-5	112	15	15.0	3.74	0.01	0.00001
Hydrochloric acid	7647-01-0	112.3	NA	15.0	15.0	15.0	15.0
Cristobalite	14464-46-1	11.2	NA	1.5	1.5	1.5	1.5
Non-crystalline silica	7631-86-9	11	NA	1.5	1.5	1.5	1.5
5-chloro-2-methyl-2h-isothiazolol-3-one	26172-55-4	11	1	1.5	0.00	0.00	0.00000
Magnesium chloride	7786-30-3	11	NA	1.5	1.5	1.5	1.5
Magnesium silicate hydrate (talc)	14807-96-6	11	NA	1.5	1.5	1.5	1.5
2-methyl-2h-isothiazol-3-one	2682-20-4	1	1	0.1	0.00	0.00	0.00000
Vinylidene chloride/methylacrylate copolymer	25038-72-6	1.1	NA	0.1	0.1	0.1	0.1

Appendix C6-2

Table C6-2 Comparison of Estimated Theoretical Schlumberger YF120Flex with J318 Concentrations to Human Health Drinking Water Guidelines

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Mud Pit Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Mud Pitcon = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)			
				Temporal Scenario (days)			
		YF120Flex with J318	Half-Life (days)	0	30	150	300
Crystalline silica	91053-39-3	112,287	NA	14971.57	14971.6	14971.6	14971.6
Guar gum	10377-60-3	11,228.7	15.0	1497.2	374.29	1.4621	0.0014278
Potassium borate	7647-01-0	11,229	NA	1497.2	1497.2	1497.2	1497.2
Cholinium chloride	25038-72-6	11,229	15	1497.2	374.29	1.46	0.00143
2,2`,2"-nitrilotriethanol	7631-86-9	1,123	15	149.7	37.43	0.15	0.00014
Diammonium peroxidisulphate	26172-55-4	1,123	NA	149.716	149.716	149.716	149.716
Diatomaceous earth, calcined	14808-60-7	1,123	NA	149.716	149.716	149.716	149.716
Magnesium nitrate	9000-30-0	1,123	NA	149.716	149.716	149.716	149.716
Potassium hydroxide	7786-30-3	1,123	NA	149.716	149.716	149.716	149.716
Glycerol	14807-96-6	112	15	15.0	3.74	0.01	0.00001
Hydrochloric acid	2682-20-4	112.3	NA	15.0	15.0	15.0	15.0
Cristobalite	14464-46-1	11.2	NA	1.5	1.5	1.5	1.5
Non-crystalline silica	102-71-6	11	NA	1.5	1.5	1.5	1.5
5-chloro-2-methyl-2h-isothiazolol-3-one	7727-54-0	11	1	1.5	0.00	0.00	0.00000
Magnesium chloride	1310-58-3	11	NA	1.5	1.5	1.5	1.5
Magnesium silicate hydrate (talc)	56-81-5	11	NA	1.5	1.5	1.5	1.5
2-methyl-2h-isothiazol-3-one	1332-77-0	1	1	0.1	0.00	0.00	0.00000
Vinylidene chloride/methylacrylate copolymer	67-48-1	1.1	NA	0.1	0.1	0.1	0.1

Appendix C6-3

Table C6-3 Comparison of Estimated Theoretical Schlumberger YF120Flex with J318 Concentrations to Aquatic Life Water Guidelines

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Mud Pit Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Mud Pitcon = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)				PNEC aquatic (mg/L)	Ratio of COPC Concentrations and Screening Criteria (Ratio greater than one = unacceptable potential risk)			
				Temporal Scenario (days)					Temporal Scenario (days)			
		YF120Flex with J318	Half-Life (days)	0	30	150	300		0	30	150	300
Crystalline silica	91053-39-3	112,287	NA	14971.57	14971.6	14971.6	14971.6	-				
Guar gum	10377-60-3	11,228.7	15.0	1497.2	374.29	1.4621	0.0014278	4.2E-02	3.6E+04	8.9E+03	3.5E+01	3.4E-02
Potassium borate	7647-01-0	11,229	NA	1497.2	1497.2	1497.2	1497.2	1.5E+00	1.0E+03	1.0E+03	1.0E+03	1.0E+03
Cholinium chloride	25038-72-6	11,229	15	1497.2	374.29	1.46	0.00143	6.0E-01	2495.26	623.815	2.436777	0.00238
2,2`,2"-nitrilotriethanol	7631-86-9	1,123	15	149.7	37.43	0.15	0.00014	1.3E+00	1.2E+02	3.0E+01	1.2E-01	1.1E-04
Diammonium peroxidisulphate	26172-55-4	1,123	NA	149.716	149.716	149.716	149.716	7.6E-02	2.0E+03	2.0E+03	2.0E+03	2.0E+03
Diatomaceous earth, calcined	14808-60-7	1,123	NA	149.716	149.716	149.716	149.716	-				
Magnesium nitrate	9000-30-0	1,123	NA	149.716	149.716	149.716	149.716	7.0E-01	2.1E+02	2.1E+02	2.1E+02	2.1E+02
Potassium hydroxide	7786-30-3	1,123	NA	149.716	149.716	149.716	149.716	-				
Glycerol	14807-96-6	112	15	15.0	3.74	0.01	0.00001	5.0E+00	3.0E+00	7.5E-01	2.9E-03	2.9E-06
Hydrochloric acid	2682-20-4	112.3	NA	15.0	15.0	15.0	15.0	-				
Cristobalite	14464-46-1	11.2	NA	1.5	1.5	1.5	1.5	-				
Non-crystalline silica	102-71-6	11	NA	1.5	1.5	1.5	1.5	-				
5-chloro-2-methyl-2h-isothiazolol-3-one	7727-54-0	11	1	1.5	0.00	0.00	0.00000	2.7E-05	5.5E+04	5.2E-05	3.9E-41	2.7E-86
Magnesium chloride	1310-58-3	11	NA	1.5	1.5	1.5	1.5	1.0E-01	1.5E+01	1.5E+01	1.5E+01	1.5E+01
Magnesium silicate hydrate (talc)	56-81-5	11	NA	1.5	1.5	1.5	1.5	-				
2-methyl-2h-isothiazol-3-one	1332-77-0	1	1	0.1	0.00	0.00	0.00000	2.7E-05	5.5E+03	5.2E-06	3.9E-42	2.7E-87
Vinylidene chloride/methylacrylate copolymer	67-48-1	1.1	NA	0.1	0.1	0.1	0.1	-				
								Cumulative Ratio	**102,449**	**12,763**	**3,234**	**3,197**

Santos

Appendix C7
Schlumberger Sapphire LF System

C1.0 Introduction

As presented in **Section 5.0** of the Hydraulic Fracturing Risk Assessment, Santos Ltd. (Santos) used a weight-of-evidence approach to evaluate the potential for human health and environmental (e.g., ecological) risks as a result of the hydraulic fracturing processes and the Schlumber Sapphire LF System.

Golder Associates Pty Ltd. (Golder), on behalf of Santos, completed a qualitative risk assessment (Golder, 2013c) that evaluated the nature of the geology in the areas undergoing stimulation, the potential for impacts on water resources, the process and chemicals used and the potential risks associated with chemicals and backflow water handled and stored above grade.

EHS Support, LLC (EHS Support) conducted a persistence, bioaccumulation and toxicity (PBT) assessment and and a Quantitative Risk Assessment (QRA) to meet Conditions 49e and 49f of the 2 October 2011 approval under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC 2008/4059) and the Environmental Amendment (EA) conditions to assess the toxicity of the mixtures.

The results and conclusions of the qualitative risk assessment components and the QRA are presented below. Refer to **Section 6.0** through **Section 8.0** for detailed discussions on the methodologies employed for the qualitative risk assessment and QRA components, which are referenced in the sections below.

C2.0 Qualitative Risk Assessment and Evaluation

C2.1 Chemicals Evaluated

The Schlumberger Sapphire LF 'fluid system' was assessed. The list of individual chemicals is presented in **Table 1** below. A mass balance of the chemicals is provided as **Appendix C7-1**.

Information regarding the chemical and physical properties of the individual chemicals listed below can be found on the Saftey Data Sheets in **Appendix E**.

While none of the fracturing fluid chemicals identified contain benzene, toluene, ethylbenzene, xylenes (BTEX) or polycyclic aromatic hydrocarbons (PAHs), PAHs occur naturally in coal and it is possible that certain PAHs may naturally be present in the coal seam groundwater used in the hydraulic fracturing process.

Table 1: Hydraulic fracturing chemicals

Chemical	CAS Number
Crystalline silica	14808-60-7
Sodium carboxymethylcellulose	9004-32-4
2-hydroxy-N,N,N-trimethylethanaminium chloride (Choline chloride)	67-48-1
2,2`,2"-nitrilotriethanol	102-71-6
Diammonium peroxidisulphate	7727-54-0
Diatomaceous earth, calcined	91053-39-3
Magnesium nitrate	10377-60-3
Cristobalite	14464-46-1
5-chloro-2-methyl-2h-isothiazolol-3-one	26172-55-4
Magnesium chloride	7786-30-3
Magnesium silicate hydrate (talc)	14807-96-6
2-methyl-2h-isothiazol-3-one	2682-20-4
Vinylidene chloride/methylacrylate copolymer	25038-72-6

C2.2 Risk Assessment Framework and Findings

As discussed in **Section 5.0**, a systematic weight of evidence approach was utilised to complete the risk assessment for the Schlumberger fluid systems. The work has involved the following evaluations:

Qualitative Assessment Methodologies

- PBT Assessment
- Exposure Assessment
- Mass Balance of Fluid System
- Fate and Transport Modeling.

Quantitative Risk Assessment Methodologies

- Quantitative Human Health Risk Assessment (HHRA)
- Quantitative Ecological Risk Assessment for Terrestrial and Aquatic Receptors.

C2.3 PBT Assessment

The PBT approach outlined in **Section 6.1** was undertaken to rank the hydraulic fracturing chemicals based on persistence (P), bioaccumulation (B) and toxic (T) potential. As a result of this assessment,

no chemical constituents identified in the Sapphire LF fluid system were classified as a PBT chemical and are therefore not considered to be inherently hazardous. The results of the PBT Assessment are presented in **Table 2**, attached.

C2.4 Exposure Assessment

As discussed in **Section 7.0**, the exposure assessment identified receptors potentially exposed to chemicals of potential concern (COPC) identified for the study and outlines the exposure pathways by which the receptors may come in to contact with the COPCs. A detailed exposure assessment was not conducted in the qualitative risk assessment.

C2.5 Mass Balance of Fluid System

A quantitative mass balance calculation was undertaken to identify the amount of each chemical additive of the hydraulic fracturing fluid system. The results of the mass balance calculations are presented in **Appendix C7-1**.

C2.6 Fate and Transport Modelling

As discussed in **Section 7.2**, fate and transport modelling was conducted on a range of key constituents of interest in typical hydraulic fracturing fluid systems. These results provided the framework for assessing potential mobility of all constituents used in hydraulic fracturing. The modelling demonstrated that despite the variability in chemical properties between fluid systems there is limited potential for chemicals to migrate within the coal seams. Refer to **Section 7.2** for further detail.

C3.0 Quantitative Risk Assessment

In accordance with the methodologies presented in **Section 8.0**, a QRA was conducted on theoretical datasets for those chemicals identified in the Sapphire LF fluid system. The QRA approach evaluates the toxicity of the individual substances and characterises the cumulative risks of the total effluent toxicity and ecotoxicity.

Generally, this methodology includes the identification of the hazards posed by constituents in the flowback water, compilation of the toxicity criteria for each constituent, development of exposure models to estimate the daily intake of the constituents, and calculations of individual constituent hazard quotients (daily intake divided by the toxicity criteria) and a cumulative constituent hazard index (HI) for each potentially complete exposure pathway for each human or terrestrial receptor.

Potential complete exposure pathways to the storage of flowback from hydraulically stimulated wells and potential risks to humans, terrestrial and aquatic receptors from the potential storage and accidental releases are evaluated in the QRA.

No further assessment of groundwater was determined to be necessary due to lack of potentially complete exposure pathways. Detailed operational procedures have been provided that are designed to contain the hydraulic fracturing fluids within the coal sequences, and no connection exists between groundwater in the coal seams and surface-water or springs (and therefore Matters of National Environmental Significance [MNES]). Further, the potential risks to workers involved with the hydraulic fracturing process were not considered as detailed Health and Safety (H&S) procedures are employed to manage exposures. The QRA considered the following specific exposure pathways:

1. Exposure of trespassers to flowback water contained within flowback storage ponds.
2. Exposure of terrestrial receptors (e.g., livestock and wildlife) to flowback water contained within the flowback storage ponds.
3. Exposure of aquatic receptors to flowback water in the situation of an accidental release, such as from piping or a release from the flowback storage pond. These potential releases could include a failure of containment systems, overtopping of the dam or in an extreme situation (considered highly unlikely) structural failure of the dam itself.

C3.1 Exposure Assessment

The purpose of the exposure assessment in the QRA was to predict the magnitude and frequency of potential human exposure to each COPC following the methodologies presented in **Section 8.1**. A conceptual site model (CSM) was developed which describes the potential receptors and exposure scenarios for the flowback water used in this exposure assessment. The potential exposures to receptors were evaluated based on the potential for a complete exposure pathway.

As discussed in **Section 8.3**, exposure point concentrations (EPCs) were derived for the theoretical assessment; empirical data were not available for evaluation. The EPCs for the theoretical assessment were calculated by estimating the mass and discharge flow of the COPCs in the flowback water.

C3.2 Human Health QRA

A human health hazard assessment was conducted according to the methodologies presented in **Section 8.4**. The purpose of the hazard assessment process was to summarise the environmental data, and to address the toxicological assessment of the COPCs that will be evaluated further in the risk assessment process.

Exposure assumptions for the human trespasser scenario were developed based on default or site-specific assumptions (**Section 8.4**). This receptor exposure pathway includes a small child to teenager that may come in contact with the above grade water exposure scenario for approximately 20 days/year for a 10-year period with potential incidental ingestion (of 50 millilitres [ML] of water) and dermal contact (e.g., swimming where the whole body gets wet) for one half hour. The exposure parameters used in the QRA are presented on **Table 3**, attached.

Calculation of intake of COPCs was performed using the equations presented below:

Ingestion of water:

$$Intake\ (mg/kg-day)\ =\ (CW\ x\ IR\ X\ EF\ X\ ED)\ /\ (BW\ x\ AT)$$

Dermal contact with water:

$$Absorbed\ dose\ (mg/kg-day)\ =\ (CW\ x\ SA\ x\ DP\ x\ ET\ x\ EF\ x\ ED\ x\ CF)\ /\ (BW\ x\ AT)$$

Where:

CW = concentration in water (mg/l)
ET = exposure time (hr/day or hours/hours)
EF = exposure frequency (day/year)
ED = exposure duration (years)
CF = correction factor (1 x 10^{-3} l/cm^3)
AT = averaging time (days)
IR = ingestion rate (l/hr)
BW = body weight (kg)
SA = skin surface area available for contact (cm^2/d)
DP = dermal permeability factor (Kp – cm/hr).

C3.3 Toxicity Assessment

A toxicity assessment was conducted to determine the relationship between the dose of a COPC taken into the body, and the probability that an adverse effect will result from that dose. Quantitative estimates of the potency of COPCs include two sets of toxicity values, one for genotoxic carcinogens and one for other non-genotoxic carcinogens and non-carcinogenic effects. As discussed in **Section 8.4,** detailed toxicological profiles were developed for the chemicals. The toxicological profiles are included as **Appendix F**.

The assessment of toxicity of the COPCs was used to develop initial screening criteria for human health exposure scenarios as discussed in **Section 8.4**. The derivation of Oral Reference Dose and Drinking Water Guideline Values are presented in **Table 4**, attached, and the Australian Drinking Water Screening Values are presented in **Table 5**, attached.

C3.4 Exposure Point Concentration

As presented above, the exposure scenarios are based on anticipated conditions, and the potential for exposure to the theoretical estimate of exposure. EPCs for the exposure assessment were calculated using the results of theoretical fate and transport modelling calculations and the existing environmental conditions within the fracturing fluids sump or mud pit, and the flowback storage ponds.

For the theoretical calculations, the mass and estimated chemical concentrations of the COPCs in the Sapphire LF fluids, as presented in **Appendix C7-1**, were used to estimate the potential concentrations in water within the fracturing fluids sump or flare pit, or flowback storage ponds. Based on stimulation flow back monitoring conducted by Santos and the QRA completed for the Schlumberger Fluid Systems

(**Appendix C**), 20 percent (%) of the total mass of constituents injected is assumed to be recovered in the flowback water. This mass is diluted within 150 % of the injected volume (the minimum volume that must be flowed back) to establish an "estimated" concentration (i.e., concentration expected due to full dilution of the back flow water) within the flowback storage ponds.

The flowback water will be contained within the flowback storage ponds for a projected maximum period of one year of operational activity before transfer or conveyance to the water treatment facilities. Therefore, the concentration of COPCs in the flowback storage pond water was adjusted, where applicable, to account for the biodegradation and photolytic degradation of constituents over time. The biodegradation information was obtained from the Organisation for Economic Cooperation and Development (OECD) ready tests (OECD, 1992) that were developed as a first-tier testing scheme to provide preliminary screening of organic chemicals. The ready tests are stringent screening tests that are conducted under aerobic conditions in which a high concentration of the test substance is used, and biodegradation is measured by non-specific parameters including dissolved organic carbon, biochemical oxygen demand and carbon dioxide production. **Table 6**, attached, presents the environmental fate information that was used to assess biodegradation of COPCs, and that was applied at the time periods of 0, 30, 150 and 300 days from initial flowback.

The water quality data derived using these assumptions for the theoretical COPCs are presented in **Appendix C7-1**.

The theoretical EPCs for the four exposure time periods (0, 30, 150 and 300 days) were compared to human health toxicity-based screening levels, and the results of this comparison, including the ratio of exceedance of screening levels, is presented in **Appendix C7-2**. There were no exceedance of the screening levels based either on an individual comparison, or on a cumulative comparison.

C3.5 Risk Estimation

Risk estimation was performed in accordance with the methodologies outlined in **Section 8.4**. The total target risk range for carcinogens was 1×10^{-4} to 1×10^{-6}; the target HI for non-threshold effects is less than or equal to 1.0.

No carcinogenic compounds are present in the stimulation fluids injected into the subsurface and as a result, only non-carcinogenic risks were calculated.

The results of the theoretical assessments for Sapphire LF fluid systems for the trespasser exposure scenarios (day 0 and day 150, Sapphire LF events) are summarized in **Tables 7** and **8**, attached. As discussed above, the theoretical assessment was only conducted at the well pad sites.

The exposure scenarios include the Sapphire LF fluid system event, as presented in **Appendix C7-1** for day 0 and day 150 from the flowback storage pond. The trespasser for day 0 did not have unacceptable risks for the Sapphire LF fluid system (HI=1.5×10^{-4}, **Table 7**, attached). The trespasser for day 150 did not have unacceptable risks for the Sapphire LF fluid system (HI=1.6×10^{-7}, **Table 8**, attached).

On this basis and using the theoretical concentrations, no adverse effects are predicted on trespassers.

C3.6 Ecological Risk Assessment

As discussed in **Section 8.5**, a screening level ecological risk assessment (ERA) was conducted to evaluate the potential for adverse ecological effects to terrestrial and aquatic ecological receptors that may be exposed to residual levels of hydraulic fracturing fluids in surface water used in the coal seam gas (CSG) fields.

C3.7 Exposure Assessment

Terrestrial receptors evaluated in the ERA include domesticated livestock, large mammalian wildlife and small mammalian wildlife. Beef cattle were used to evaluate domesticated livestock, kangaroos evaluated for large mammalian wildlife, and dingos for small mammalian wildlife. Aquatic receptors evaluated included invertebrates and fishes.

The estimate for dose-based or intake rates for the assessment endpoints for wildlife representing domestic livestock and native mammalian species used the following general equation:

$TI = C_{water} \times IR_{water} \times EF \times ED / BW \times ED \times 365$ days/year

Where:

TI = Total intake of COPC (mg/kg/day)
C_{water} = Concentration of COPC in water (mg/l)
IR_{water} = Ingestion rate (litres/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg).

The exposure assumptions are presented in **Tables 9** through **11**.

C3.8 Toxicity Assessment

To evaluate the potential for adverse ecological effects, toxicity reference values (TRVs) are selected as measurement endpoints for the ERA that will be used in the risk analysis. The TRVs are based on COPC levels that imply no adverse effects or levels that represent the lowest concentration at which adverse effects may occur. The ERA used two types of TRVs. The first TRV is a concentration-based TRV to evaluate the concentration of the selected COPC in the surface water and direct exposure by the aquatic ecological receptor. The determination of TRVs for freshwater was conducted according to the predicted no-effects concentration (PNEC) guidance in the Environmental Risk Assessment Guidance Manual for Industrial Chemicals prepared by the Australian Environmental Agency (AEA, 2009). As discussed in **Section 8.4**, detailed environmental profiles were developed for the chemicals. The environmental profiles are included in the risk dossiers in **Appendix G**. **Table 12**, attached, presents the COPC, the endpoint, NOEC [milligrams per litre (mg/L)], assessment factor and the aquatic PNEC (mg/L). The second TRV is a dose-based TRV to evaluate the intake dose of the selected COPC from exposure to surface water by ingestion. The calculated TRVs for each of the mammalian ecological receptors evaluated in the ERA are presented in the species-specific ecological risk models.

C3.9 Exposure Point Concentration

EPCs for the exposure assessment were calculated using the results of theoretical fate and transport modelling calculations. The potentially affected flowback water that represents complete exposure pathways for the ecological receptors includes the surface water systems (e.g., flowback storage ponds and mud pits) that were used to estimate the EPCs for the human health receptors. Similar to the EPCs for the human health receptors, the EPCs for the ecological receptors assumed 20 % of mass returned in the flowback water was diluted within 150 % of the injected volume of return water and was then adjusted based on biodegradation rates to calculate the theoretical EPCs for the four exposure time periods (0, 30, 150, and 300 days). **Appendix C7-1** presents the calculated EPCs for the ecological receptor exposure scenarios. The theoretical EPCs for the four exposure time periods (0, 30, 150, and 300 days) were compared to ecological based toxicity-based screening levels, and the results of this comparison, including the ratio of exceedance of screening levels, is presented in **Appenidix C7-3**.

Risks were characterised in accordance with the methodologies discussed in **Section 8.5.5**. The resulting ecological hazard quotient must be less than or equal to 1.0 for risks to be considered acceptable.

C3.10 Estimation of Risk

The HI calculated for flowback water for aquatic risk were elevated above the acceptable level for less than half of COPCs evaluated (**Appendix C7-3**). Where large discharges of flowback water occur to surface water and/or flux dilution within the surface-water was insufficient, potential impacts on aquatic receptors could occur. As noted in the toxicity assessment section above, the lack of a robust aquatic toxicological database resulted in highly conservative aquatic screening values for the theoretical exposure scenario COPCs to be conservatively very low.

The results of the theoretical assessments for Sapphire LF fluid systems for the livestock cattle, kangaroo and dingo are summarized in **Tables 13** through **18**, attached. The exposure scenarios include the Sapphire LF fluid systems EPCs presented in **Appendix C7-1** for day 0 and day 150 from the fracturing fluid well flowback. The modelled risks from Sapphire LF fluid system chemicals in the flowback water were acceptable for the livestock cattle (HI=4.6 x 10^{-4} to 8.9 x 10^{-8}), **Table 13** and **14**, attached), kangaroo (HI= HI=9.4 x 10^{-5} to 1.8 x 10^{-8}), **Table 15** and **16**, attached), and dingo (HI=3.9 x 10^{-5} to 7.4 x 10^{-9}) for both exposure scenarios (**Tables 17** and **18**, attached).

C4.0 Summary of QRA Findings

The QRA was completed as discussed in **Section 8.0**. An assessment was conducted using highly conservative theoretical calculations based on the chemicals utilised by Schlumberger in hydraulic fracturing. This assessment assumed that a range of theoretical concentrations of injected chemicals would be present in the flowback water based on biodegradation rates, where applicable.

Consistent with the risk assessment and groundwater fate and transport modelling conducted by Golder, no potentially complete exposure pathways were identified for groundwater. Potential exposures are limited to the aboveground storage and handling of flowback water as part of the CSG Water Management Plan (WMP). Management of CSG water involves the temporary storage of flowback water in flowback storage ponds.

The results of the qualitative PBT Assessment indicated that no chemical constituents identified in the Sapphire LF fluid system was classified as a PBT chemical and therefore fluids containing these chemicals are not considered inherently hazardous.

The two exposure scenarios modelled for the QRA were 20 % flowback return, and either 0 or 150-day retention with EPC based on applicable degradation rates. Based on quantitative risk calculations, the potential risks to the trespasser associated with the flowback water are acceptable. There were no carcinogenic risks identified.

The modelled risks from Sapphire LF fluid system chemicals in the flowback water were acceptable for the livestock cattle, kangaroo, and dingo for both exposure scenarios.

Similarly, potential impacts could occur if releases of flowback water were to occur to aquatic environments. Based on the use of low permeability materials (clay liners) and operational controls that limit the potential for turkey nest and dam overflows, the potential for these risks are also considered limited.

A combination of management and operational controls are being implemented to eliminate and control the potential for exposures. These include:

- Worker training and hazard identification
- Use of appropriate personal protective equipment (gloves, etc.)
- Flowback storage pond fencing to prevent entry of livestock and native fauna and minimise trespassing
- Use of low permeability materials or dam liners and routine dam inspections to prevent releases from flowback storage ponds
- Routine operational and security patrols to prevent trespassing.

C5.0 Conclusions

A weight-of-evidence evaluation of potential risks as described in **Section 5.0** was performed for the Schlumberger Sapphire LF fluid system. Based on the qualitative and quantitative risk characterisations, the overall risk to human health and the environment is low. Existing operational control activities employed by Santos are in place that will limit the potential risks to human health and the environment. These measures include:

- Occupational health and safety procedures implemented during hydraulic fracturing operations to prevent workers from direct contact with chemicals during spills and when handling flowback water or sediments;
- Environmental authority conditions that preclude the construction of well pads within 100 metres of a watercourse of water body;
- Implementation of spill containment procedures during operations to prevent migration of and exposure to chemicals;
- Disposal or capping of sediments contained within drained mud pits and turkey nests, to prevent exposure to contaminates in windborne dust;
- Fencing of drill pads to prevent trespassers and installation of signs to indicate that the water in the turkeys nest and mud pit is not potable and may contain contaminants;
- Installation and maintenance of fences around the well pad to prevent access to the drill pad by livestock and large native fauna;
- Santos operational procedures to ensure well integrity and design of fracture to stay within the target seam; and
- Mud pits and turkeys nests with clay liners, or similar material, to prevent seepage of flowback water into underlying aquifers.

Regular monitoring of water supply bores and surface water for a representative suite of chemicals within 2 kilometre of wells (and 200 m vertical separation) that are fractured is required to confirm the conclusion of incomplete exposure pathways and low risk.

No additional risks, other than those previously discussed, were identified with the chemicals or systems employed by Schlumberger in hydraulic fracturing. Evaluation of other potential risks associated with hydraulic fracturing (i.e., noise and vibration) was conducted. Refer to **Section 9.0** for methodology specifics and results of this evaluation.

Tables

Table 2. PBT Assessment of the Sapphire LF Fluid System

Substance	P/vP criteria fulfilled?	B/vB criteria fulfilled?	T criteria fulfilled?	Overall Conclusion
Sodium carboxymethylcellulose (9004-32-4)	Yes (water-soluble polymer)	No (polymer; not bioavailable)	No (polymer; not bioavailable)	Not PBT (based on physico-chemical properties)
2-hydroxy-N,N,N-trimethylethanaminium chloride (Choline chloride) (67-48-1)	No (screening data available)	No (screening data available)	No (screening data available)	Not PBT (based on screening data)
2,2′,2″-nitrilotriethanol (102-71-6)	No (screening data available)	No (experimental data available)	No (experimental data available)	Not PBT (based on screening and experimental data)
Diammonium peroxidisulphate (7727-54-0)	Not applicable (ionic species ubiquitous in environment)	No (essential ions to biological systems; actively regulated)	No (screening data available)	Not PBT (based on screening data and ubiquitous inorganic salt)
Vinylidene chloride/methylacrylate copolymer (25038-72-6)	Yes (polymer not biodegradable)	No (polymer; not bioavailable)	No (polymer; not bioavailable)	Not PBT
Diatomaceous earth, calcined (91053-39-3)	Yes (naturally-occurring inorganic mineral)	No (water-insoluble mineral; not bioavailable)	No (water-insoluble mineral; not bioavailable)	Not PBT (based on physico-chemical properties)
Magnesium nitrate (10377-60-3)	Not applicable (ionic species ubiquitous in environment)	No (Mg is an essential ion to biological systems; nitrate ions are water-soluble)	No (screening data available)	Not PBT (based on screening data and ubiquitous inorganic salt)
5-chloro-2-methyl-2h-isothazolo-3-one/2-methyl-2h-isothiasol-3-one [3:1] (55965-84-9)	No (experimental data available)	No (experimental data available)	Yes (screening data available)	Not PBT (based on screening and experimental data)

Table 2. PBT Assessment of the Sapphire LF Fluid System

Substance	P/vP criteria fulfilled?	B/vB criteria fulfilled?	T criteria fulfilled?	Overall Conclusion
Magnesium silicate hydrate [talc] (14807-96-6)	Yes (naturally-occurring inorganic mineral)	No (water-insoluble mineral; not bioavailable)	No (water-insoluble mineral; not bioavailable)	Not PBT (based on physico-chemical properties)
Magnesium chloride (7786-30-3)	Not applicable (ionic species ubiquitous in environment)	No (essential ions to biological systems; actively regulated)	No (screening data available)	Not PBT (based on screening data and ubiquitous inorganic salt)
Cristobalite (14464-46-1)	Yes (naturally-occurring inorganic mineral)	No (water-insoluble mineral; not bioavailable)	No (water-insoluble mineral; not bioavailable)	Not PBT (based on physico-chemical properties)
Crystalline Silica (14808-60-7)	Yes (naturally-occurring inorganic mineral)	No (water-insoluble mineral; not bioavailable)	No (water-insoluble mineral; not bioavailable)	Not PBT (based on physico-chemical properties)

Table 3 Exposure Assumptions - Trespasser

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/hr	0.05
	ET	Exposure time	hr/day	0.5
	EF	Exposure frequency	day/yr	20
	ED	Exposure duration	yr	10
	BW	Body weight	kg	47
	AT-NC	Averaging time - noncancer	days	3,650
	AT-C	Averaging time - cancer	days	25,550
Dermal	SA	Surface area for contact	cm^2/day	13,000
	DP	Dermal permeability factor	cm/h	chemical-specific
	ET	Exposure time	hr/day	1
	EF	Exposure frequency	day/yr	20
	ED	Exposure duration	yr	10
	BW	Body weight	kg	47
	AT-NC	Averaging time - noncancer	days	3,650
	AT-C	Averaging time - cancer	days	25,550
	CF	Conversion factor	l/cm^3	1.0E-03

Table 4 Oral Reference Doses and Drinking Water Guidelines Derived for Hydraulic Fracturing Chemicals

Chemical (CAS No.)	Study	Critical Effect/Target Organ(s)	NOAEL (mg/kg/day)	Uncertainty Factors	Oral Reference Dose (mg/kg/day)	Drinking Water Guideline (ppm)
Sodium carboxymethylcellulose (9004-32-4)	NDa	ND	ND	ND	ND	ND
Crystalline silica (14808-60-7)	ND	ND	ND	ND	ND	ND
2-hydroxy-N,N,N-trimethylethanaminium chloride (Choline chloride) (67-48-1)	Human study	Hypotension	7500[b]	2	50 [as choline]	175 [as choline]
2,2',2''-nitrilotriethanol (102-71-6)	Rat 91-day dietary	-	1,000	1,000	1	3.5
Vinylidene chloride/methylacrylate copolymer (25038-72-6)	ND	ND	ND	ND	ND	ND
Diatomaceous earth, calcined (91053-39-3)	ND	ND	ND	ND	ND	ND
5-chloro-2-methyl-2h-isothazolo-3-one/2-methyl-2h-isothiasol-3-one [3:1] (55965-84-9)	2-year rat drinking water	Gastric irritation of the stomach	2	100	0.0	0.07
Magnesium silicate hydrate [talc] (14807-96-6)	ND	ND	ND	ND	ND	ND
Cristobalite (14464-46-1)	ND	ND	ND	ND	ND	ND

[a] Not determined
[b] LOAEL

Table 5 Australian Drinking Water Screening Values for Hydraulic Fracturing Chemicals

Chemical (CAS No.)	Drinking Water Screening Guideline	Drinking Water Screening Value
Diammonium peroxidisulphate (7727-54-0)	sulfate	500 mg/L (health); 250 mg/L (aesthetic)
Magnesium chloride (7786-30-3)	Chloride	250 mg/L (aesthetic)
Magnesium nitrate (10377-60-3)	Nitrate	50 mg/L (health)

Table 6 Environmental Fate Information

Crystalline Silica	Water-insoluble mineral; not biodegradable
Sodium carboxymethylcellulose	Not biodegradable[a]
2-hydroxy-N,N,N-trimethylethanaminium chloride (Choline chloride)	Readily biodegradable (half-life = 15 days)[a]
2,2′,2″-nitrilotriethanol	Readily biodegradable (half-life = 15 days)[a]
Diammonium peroxidisulphate	Dissociates completely in aqueous media
Vinylidene chloride/methacrylate copolymer	Polymer; not biodegradable
Diatomaceous earth, calcined	Water-insoluble mineral; not biodegradable
Magnesium nitrate	Dissociates completely in aqueous media
Crystalline silica	Water-insoluble mineral; not biodegradable
5-chloro-2-methyl-2h-isothazolo-3-one/2-methyl-2h-isothiasol-3-one [3:1]	Half-lives in river water-sediment system are 17.3 and 9.1 hours, respectively.
Magnesium silicate hydrate (talc)	Water-insoluble mineral; not biodegradable
Magnesium chloride	Dissociates completely in aqueous media
Cristobalite	Water-insoluble mineral; not biodegradable

Source: EU Guidance Document: Half-life estimates from in vitro biodegradation test results

Table 7 Risk Estimates for Trespasser Schlumberger Sapphire LF Theoretical Exposure for Day 0

		Day 0		Toxicity	Sapphire LF			
							Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**PC (cm/hr)**	**RfDo**	**$CADD_{oral}$**	**$CADD_{derm}$**	**Incidental Ingestion**	**Dermal**
Crystalline silica	14808-60-7	1.2E+02	NA	-	-	-	-	-
Sodium carboxymethylcellulose	9004-32-4	1.4E+01	NA	-	-	-	-	-
2-hydroxy-N,N,N-trimethylethanaminium chloride (Choline chloride)	67-48-1	1.4E+01	8.5E-07	50	8.4E-04	9.3E-08	1.7E-05	1.9E-09
Diammonium peroxidisulphate	7727-54-0	1.4E+00	NA	-	-	-	-	-
2,2`,2"-nitrilotriethanol	102-71-6	1.4E+00	5.1E-05	1.0	8.4E-05	5.5E-07	8.4E-05	5.5E-07
Diatomaceous earth, calcined	91053-39-3	1.4E-01	NA	-	-	-	-	-
Vinylidene chloride/methylacrylate copolymer	25038-72-6	1.4E-01	NA	-	-	-		-
Magnesium nitrate	10377-60-3	1.4E-02	9.3E-05	14.3	8.4E-07	1.0E-08	5.9E-08	7.1E-10
5-chloro-2-methyl-2h-isothiazolol-3-one	26172-55-4	1.4E-02	1.4E-04	0.02	8.4E-07	1.5E-08	4.2E-05	7.5E-07
Magnesium chloride	7786-30-3	1.4E-02	NA	-	-	-	-	-
2-methyl-2h-isothiazol-3-one	2682-20-4	1.4E-03	1.4E-04	0.02	8.4E-08	1.5E-09	4.2E-06	7.5E-08
Cristobalite	14464-46-1	1.4E-03	NA	-	-	-	-	-
Magnesium silicate hydrate (talc)	14807-96-6	1.4E-03	NA	-	-	-	-	-
							Hazard Index	1.5E-04

Table 8 Risk Estimates for Trespasser Schlumberger Sapphire LF Theoretical Exposure for Day 150

		Day 150		Toxicity	Sapphire LF			
							Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**PC (cm/hr)**	**RfDo**	**$CADD_{oral}$**	**$CADD_{derm}$**	**Incidental Ingestion**	**Dermal**
Crystalline silica	14808-60-7	115.2	NA	-	-	-	-	-
Sodium carboxymethylcellulose	9004-32-4	14.4	NA	-	-	-	-	-
2-hydroxy-N,N,N-trimethylethanaminium chloride (Choline chloride)	67-48-1	0.01	8.5E-07	50	8.2E-07	9.1E-11	1.6E-08	1.8E-12
Diammonium peroxidisulphate	7727-54-0	1.4	NA	-	-	-	-	-
2,2`,2"-nitrilotriethanol	102-71-6	0.001	5.1E-05	1.0	8.2E-08	5.4E-10	8.2E-08	5.4E-10
Diatomaceous earth, calcined	91053-39-3	0.1	NA	-	-	-	-	-
Vinylidene chloride/methylacrylate copolymer	25038-72-6	0.1	NA	-	-	-		-
Magnesium nitrate	10377-60-3	0.01	9.3E-05	14.3	8.4E-07	1.0E-08	5.9E-08	7.1E-10
5-chloro-2-methyl-2h-isothiazolol-3-one	26172-55-4	1.0E-47	1.4E-04	0.02	5.9E-52	1.1E-53	2.9E-50	5.3E-52
Magnesium chloride	7786-30-3	0.01	NA	-	-	-	-	-
2-methyl-2h-isothiazol-3-one	2682-20-4	1.0E-48	1.4E-04	0.02	5.9E-53	1.1E-54	2.9E-51	5.3E-53
Cristobalite	14464-46-1	0.001	NA	-	-	-	-	-
Magnesium silicate hydrate (talc)	14807-96-6	0.001	NA	-	-	-	-	-
							Hazard Index	1.6E-07

Table 9 Exposure Assumptions - Cattle

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/day	86
	EF	Exposure frequency	day/yr	15
	ED	Exposure duration	yr	8
	BW	Body weight	kg	454
	AT-NC	Averaging time - noncancer	days	2,920

Table 10 Exposure Assumptions - Kangaroo

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/day	3
	EF	Exposure frequency	day/yr	10
	ED	Exposure duration	yr	15
	BW	Body weight	kg	25
	AT-NC	Averaging time - noncancer	days	5,475

Table 11 Exposure Assumptions - Dingo

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/day	0.75
	EF	Exposure frequency	day/yr	10
	ED	Exposure duration	yr	15
	BW	Body weight	kg	13
	AT-NC	Averaging time - noncancer	days	5,475

Table 12 Aquatic Toxicity Values (PNECs)

Chemical	Endpoint	NOEC (mg/L)	Assessment Factor	$PNEC_{aquatic}$ (mg/L)
Crystalline Silica (14808-60-7)	ND[a]	ND	ND	ND
Cholinium chloride (67-48-1)	Chronic Daphnia	30	50	0.6
2,2' ,2'' -nitrilotriethanol (102-71-6)	Chronic Daphnia	125	100	1.25
Diammonium peroxidisulphate (7727-54-0)	Acute fish	76	1,000	0.076
Vinylidene chloride/methylacrylate copolymer (25038-72-6)	ND	ND	ND	ND
Diatomaceous earth, calcined (91053-39-3)	ND	ND	ND	ND
Magnesium nitrate (10377-60-3)	-	-	-	0.7[b]
Sodium carboxymethylcellulose (9004-32-4)	Acute Algae	500	1,000	0.5
5-chloro-2-methyl-2h-isothazolo-3-one/2-methyl-2h-isothiasol-3-one [3:1] (55965-84-9)	Acute Daphnia	0.027	1,000	0.000027
Magnesium silicate hydrate [talc] (14807-96-6)	ND	ND	ND	ND
Magnesium chloride (7786-30-3)	Acute algae	100	1,000	0.1
Cristobalite (14464-46-1)	ND	ND	ND	ND

aND = Not Determined.

bANZECC (2000) water quality “trigger value for nitrate.

Table 13 Risk Estimates for Cattle Schlumberger
Sapphire LF Theoretical Exposure for Day 0

		Day 0	Toxicity	Sapphire LF	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**TI**	**Incidental Ingestion**
Crystalline silica	14808-60-7	1.2E+02			
Sodium carboxymethylcellulose	9004-32-4	1.4E+01			
2-hydroxy-N,N,N-trimethylethanaminium chloride (Choline chloride)	67-48-1	1.4E+01	4.7E+03	1.1E-01	2.4E-05
Diammonium peroxidisulphate	7727-54-0	1.4E+00			
2,2`,2"-nitrilotriethanol	102-71-6	1.4E+00	1.7E+02	1.1E-02	6.7E-05
Diatomaceous earth, calcined	91053-39-3	1.4E-01			
Vinylidene chloride/methylacrylate copolymer	25038-72-6	1.4E-01			
Magnesium nitrate	10377-60-3	1.4E-02			
5-chloro-2-methyl-2h-isothiazolol-3-one	26172-55-4	1.4E-02	3.3E-01	1.1E-04	3.4E-04
Magnesium chloride	7786-30-3	1.4E-02			
2-methyl-2h-isothiazol-3-one	2682-20-4	1.4E-03	3.3E-01	1.1E-05	3.4E-05
Cristobalite	14464-46-1	1.4E-03			
Magnesium silicate hydrate (talc)	14807-96-6	1.4E-03			

Hazard Index
4.6E-04

Table 14 Risk Estimates for Cattle Schlumberger
Sapphire LF Theoretical Exposure for Day 150

		Day 150	Toxicity	Sapphire LF	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**TI**	**Incidental Ingestion**
Crystalline silica	14808-60-7	1.2E+02			
Sodium carboxymethylcellulose	9004-32-4	1.4E+01			
2-hydroxy-N,N,N-trimethylethanaminium chloride (Choline chloride)	67-48-1	1.4E-02	4.7E+03	1.1E-04	2.3E-08
Diammonium peroxidisulphate	7727-54-0	1.4E+00			
2,2`,2"-nitrilotriethanol	102-71-6	1.4E-03	1.7E+02	1.1E-05	6.6E-08
Diatomaceous earth, calcined	91053-39-3	1.4E-01			
Vinylidene chloride/methylacrylate copolymer	25038-72-6	1.4E-01			
Magnesium nitrate	10377-60-3	1.4E-02			
5-chloro-2-methyl-2h-isothiazolol-3-one	26172-55-4	1.0E-47	3.3E-01	7.9E-50	2.4E-49
Magnesium chloride	7786-30-3	1.4E-02			
2-methyl-2h-isothiazol-3-one	2682-20-4	1.0E-48	3.3E-01	7.9E-51	2.4E-50
Cristobalite	14464-46-1	1.4E-03			
Magnesium silicate hydrate (talc)	14807-96-6	1.4E-03			

Hazard Index
8.9E-08

Table 15 Risk Estimates for Kangaroo Schlumberger
Sapphire LF Theoretical Exposure for Day 0

		Day 0	Toxicity	Sapphire LF	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**TI**	**Incidental Ingestion**
Crystalline silica	14808-60-7	1.2E+02			
Sodium carboxymethylcellulose	9004-32-4	1.4E+01			
2-hydroxy-N,N,N-trimethylethanaminium chloride (Choline chloride)	67-48-1	1.4E+01	9.7E+03	4.7E-02	4.9E-06
Diammonium peroxidisulphate	7727-54-0	1.4E+00			
2,2`,2"-nitrilotriethanol	102-71-6	1.4E+00	3.4E+02	4.7E-03	1.4E-05
Diatomaceous earth, calcined	91053-39-3	1.4E-01			
Vinylidene chloride/methylacrylate copolymer	10377-60-3	1.4E-01			
Magnesium nitrate	14464-46-1	1.4E-02			
5-chloro-2-methyl-2h-isothiazolol-3-one	26172-55-4	1.4E-02	6.9E-01	4.7E-05	6.9E-05
Magnesium chloride	7786-30-3	1.4E-02			
2-methyl-2h-isothiazol-3-one	14807-96-6	1.4E-03	6.9E-01	4.7E-06	6.9E-06
Cristobalite	2682-20-4	1.4E-03			
Magnesium silicate hydrate (talc)	25038-72-6	1.4E-03			

Hazard Index
9.4E-05

Table 16 Risk Estimates for Kangaroo Schlumberger
Sapphire LF Theoretical Exposure for Day 150

		Day 150	Toxicity	Sapphire LF	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**TI**	**Incidental Ingestion**
Crystalline silica	14808-60-7	1.2E+02			
Sodium carboxymethylcellulose	9004-32-4	1.4E+01			
2-hydroxy-N,N,N-trimethylethanaminium chloride (Choline chloride)	67-48-1	1.4E-02	9.7E+03	4.6E-05	4.8E-09
Diammonium peroxidisulphate	7727-54-0	1.4E+00			
2,2`,2"-nitrilotriethanol	102-71-6	1.4E-03	3.4E+02	4.6E-06	1.3E-08
Diatomaceous earth, calcined	91053-39-3	1.4E-01			
Vinylidene chloride/methylacrylate copolymer	10377-60-3	1.4E-01			
Magnesium nitrate	14464-46-1	1.4E-02			
5-chloro-2-methyl-2h-isothiazolol-3-one	26172-55-4	1.0E-47	6.9E-01	3.3E-50	4.8E-50
Magnesium chloride	7786-30-3	1.4E-02			
2-methyl-2h-isothiazol-3-one	14807-96-6	1.0E-48	6.9E-01	3.3E-51	4.8E-51
Cristobalite	2682-20-4	1.4E-03			
Magnesium silicate hydrate (talc)	25038-72-6	1.4E-03			

Hazard Index
1.8E-08

Table 17 Risk Estimates for Dingo Schlumberger Sapphire LF Theoretical Exposure for Day 0

		Day 0	Toxicity	Sapphire LF	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**TI**	**Incidental Ingestion**
Crystalline silica	14808-60-7	1.2E+02			
Sodium carboxymethylcellulose	9004-32-4	1.4E+01			
2-hydroxy-N,N,N-trimethylethanaminium chloride (Choline chloride)	67-48-1	1.4E+01	1.1E+04	2.3E-02	2.0E-06
Diammonium peroxidisulphate	7727-54-0	1.4E+00			
2,2`,2"-nitrilotriethanol	102-71-6	1.4E+00	4.1E+02	2.3E-03	5.6E-06
Diatomaceous earth, calcined	91053-39-3	1.4E-01			
Vinylidene chloride/methylacrylate copolymer	10377-60-3	1.4E-01			
Magnesium nitrate	14464-46-1	1.4E-02			
5-chloro-2-methyl-2h-isothiazolol-3-one	26172-55-4	1.4E-02	8.1E-01	2.3E-05	2.8E-05
Magnesium chloride	7786-30-3	1.4E-02			
2-methyl-2h-isothiazol-3-one	14807-96-6	1.4E-03	8.1E-01	2.3E-06	2.8E-06
Cristobalite	2682-20-4	1.4E-03			
Magnesium silicate hydrate (talc)	25038-72-6	1.4E-03			

Hazard Index
3.9E-05

Table 18 Risk Estimates for Dingo Schlumberger Sapphire LF Theoretical Exposure for Day 150

		Day 150	Toxicity	Sapphire LF	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**TI**	**Incidental Ingestion**
Crystalline silica	14808-60-7	1.2E+02			
Sodium carboxymethylcellulose	9004-32-4	1.4E+01			
2-hydroxy-N,N,N-trimethylethanaminium chloride (Choline chloride)	67-48-1	1.4E-02	1.1E+04	2.2E-05	1.9E-09
Diammonium peroxidisulphate	7727-54-0	1.4E+00			
2,2`,2"-nitrilotriethanol	102-71-6	1.4E-03	4.1E+02	2.2E-06	5.5E-09
Diatomaceous earth, calcined	91053-39-3	1.4E-01			
Vinylidene chloride/methylacrylate copolymer	10377-60-3	1.4E-01			
Magnesium nitrate	14464-46-1	1.4E-02			
5-chloro-2-methyl-2h-isothiazolol-3-one	26172-55-4	1.0E-47	8.1E-01	1.6E-50	2.0E-50
Magnesium chloride	7786-30-3	1.4E-02			
2-methyl-2h-isothiazol-3-one	14807-96-6	1.0E-48	8.1E-01	1.6E-51	2.0E-51
Cristobalite	2682-20-4	1.4E-03			
Magnesium silicate hydrate (talc)	25038-72-6	1.4E-03			

Hazard Index
7.4E-09

Appendix C7-1

Table C7-1 Surface Water Quality Data for Theoretical Scenario in Initial Flowback for Schlumberger Sapphire LF System

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Mud Pit Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Mud Pitcon = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)			
				Temporal Scenario (days)			
		Sapphire LF	Half-Life (days)	0	30	150	300
Crystalline silica	14808-60-7	864.0	NA	115.20	115.2	115.2	115.2
Sodium carboxymethylcellulose	9004-32-4	108.0	NA	14.4	14.4	14.4	14.4
2-hydroxy-N,N,N-trimethylethanaminium chloride (Choline chloride)	67-48-1	108.0	15	14.4	3.6	0.01	0.00001
Diammonium peroxidisulphate	7727-54-0	10.8	NA	1.4	1.4	1.4	1.4
2,2`,2"-nitrilotriethanol	102-71-6	10.8	15	1.4	0.4	0.001	0.000001
Diatomaceous earth, calcined	91053-39-3	1.1	NA	0.1	0.1	0.1	0.1
Vinylidene chloride/methylacrylate copolymer	25038-72-6	1.1	NA	0.1	0.1	0.1	0.1
Magnesium nitrate	10377-60-3	0.1	NA	0.01	0.01	0.01	0.01
5-chloro-2-methyl-2h-isothiazolol-3-one	26172-55-4	0.1	1	0.01	1.3E-11	1.0E-47	7.1E-93
Magnesium chloride	7786-30-3	0.1	NA	0.01	0.01	0.01	0.01
2-methyl-2h-isothiazol-3-one	2682-20-4	0.01	1	0.001	1.3E-12	1.0E-48	7.1E-94
Cristobalite	14464-46-1	0.01	NA	0.001	0.001	0.001	0.001
Magnesium silicate hydrate (talc)	14807-96-6	0.01	NA	0.001	0.001	0.001	0.001

Appendix C7-2

Table C7-2 Comparison of Estimated Theoretical Schlumberger Sapphire LF Concentrations to Human Health Drinking Water Guidelines

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Mud Pit Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Mud Pitcon = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)			
				Temporal Scenario (days)			
		Sapphire LF	Half-Life (days)	0	30	150	300
Crystalline silica	14808-60-7	864.0	NA	115.20	115.2	115.2	115.2
Sodium carboxymethylcellulose	9004-32-4	108.0	NA	14.4	14.4	14.4	14.4
2-hydroxy-N,N,N-trimethylethanaminium chloride (Choline chloride)	67-48-1	108.0	15	14.4	3.6	0.01	0.00001
Diammonium peroxidisulphate	7727-54-0	10.8	NA	1.4	1.4	1.4	1.4
2,2`,2"-nitrilotriethanol	102-71-6	10.8	15	1.4	0.4	0.001	0.000001
Diatomaceous earth, calcined	91053-39-3	1.1	NA	0.1	0.1	0.1	0.1
Vinylidene chloride/methylacrylate copolymer	25038-72-6	1.1	NA	0.1	0.1	0.1	0.1
Magnesium nitrate	10377-60-3	0.1	NA	0.01	0.01	0.01	0.01
5-chloro-2-methyl-2h-isothiazolol-3-one	26172-55-4	0.1	1	0.01	1.3E-11	1.0E-47	7.1E-93
Magnesium chloride	7786-30-3	0.1	NA	0.01	0.01	0.01	0.01
2-methyl-2h-isothiazol-3-one	2682-20-4	0.01	1	0.001	1.3E-12	1.0E-48	7.1E-94
Cristobalite	14464-46-1	0.01	NA	0.001	0.001	0.001	0.001
Magnesium silicate hydrate (talc)	14807-96-6	0.01	NA	0.001	0.001	0.001	0.001

Appendix C7-3

Table C7-3 Comparison of Estimated Theoretical Schlumberger Sapphire LF Concentrations to Aquatic Life Water Guidelines

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Mud Pit Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Mud Pitcon = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)				PNEC aquatic (mg/L)	Ratio of COPC Concentrations and Screening Criteria (Ratio greater than one = unacceptable potential risk)			
				Temporal Scenario (days)					Temporal Scenario (days)			
		Sapphire LF	Half-Life (days)	0	30	150	300		0	30	150	300
Crystalline silica	14808-60-7	864.0	NA	115.20	115.2	115.2	115.2	-				
Sodium carboxymethylcellulose	9004-32-4	108.0	NA	14.4	14.4	14.4	14.4	5.0E-01	2.9E+01	2.9E+01	2.9E+01	2.9E+01
2-hydroxy-N,N,N-trimethylethanaminium chloride (Choline chloride)	67-48-1	108.0	15	14.4	3.6	0.01	0.00001	6.0E-01	2.4E+01	6.0E+00	2.3E-02	2.3E-05
Diammonium peroxidisulphate	7727-54-0	10.8	NA	1.4	1.4	1.4	1.4	7.6E-02	1.9E+01	1.9E+01	1.9E+01	1.9E+01
2,2`,2"-nitrilotriethanol	102-71-6	10.8	15	1.4	0.4	0.001	0.000001	1.3E+00	1.2E+00	2.9E-01	1.1E-03	1.1E-06
Diatomaceous earth, calcined	91053-39-3	1.1	NA	0.1	0.1	0.1	0.1	-				
Vinylidene chloride/methylacrylate copolymer	25038-72-6	1.1	NA	0.1	0.1	0.1	0.1	-				
Magnesium nitrate	10377-60-3	0.1	NA	0.01	0.01	0.01	0.01	7.0E-01	2.1E-02	2.1E-02	2.1E-02	2.1E-02
5-chloro-2-methyl-2h-isothiazolol-3-one	26172-55-4	0.1	1	0.01	1.3E-11	1.0E-47	7.1E-93	2.7E-05	5.3E+02	5.0E-07	3.7E-43	2.6E-88
Magnesium chloride	7786-30-3	0.1	NA	0.01	0.01	0.01	0.01	1.0E-01	1.4E-01	1.4E-01	1.4E-01	1.4E-01
2-methyl-2h-isothiazol-3-one	2682-20-4	0.01	1	0.001	1.3E-12	1.0E-48	7.1E-94	2.7E-05	5.3E+01	5.0E-08	3.7E-44	2.6E-89
Cristobalite	14464-46-1	0.01	NA	0.001	0.001	0.001	0.001	-				
Magnesium silicate hydrate (talc)	14807-96-6	0.01	NA	0.001	0.001	0.001	0.001	-				
								Cumulative Ratio	**660**	**54**	**48**	**48**

Santos

Appendix C8
Halliburton Hydraulic Fracturing Fluid System – Well RM 08-14-3

C1.0 Introduction

Santos Ltd. (Santos) is looking to use a borate, guar-based crosslinked Halliburton hydraulic fracturing fluid system (the fluid system) for development of coal seam gas (CSG) resources in the Surat and Bowen Basins of Queensland, specifically in the Roma Shallow Gas Project Area (RSGPA). The disclosure for well RM08-14-3, including a listing of the chemical constituents and percent (%) of total volume in the fluid system, is provided in **Appendix C8-1**. The fluid system components provided in **Appendix C8-1** were addressed previously as part of the Hydraulic Fracturing Risk Assessment by Santos (2021), with the exception of the following:

- Hydoxylpropyl guar
- Ulexite
- Disodium octaborate tetrahydrate.

Specifically, the assessed fluid system components were addressed either in the Delta 140 fluid system (Appendix C2 and C5), the Clean Stim fluid system (Appendix C3), or the Y120 Flex fluid system (Appendix C6).

As presented in **Section 5.0**, Santos used a weight-of-evidence approach to evaluate the potential for human health and environmental (e.g., ecological) risks as a result of the hydraulic fracturing processes and the use of the Halliburton Hydraulic Fracturing Fluid System in Well RM 08-14-3.

EHS Support, LLC (EHS Support) conducted a Quantitative Risk Assessment (QRA) to meet Conditions 49e and 49f of the 2 October 2011 approval under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC 2008/4059) and the Environmental Amendment (EA) conditions to assess the toxicity of the mixtures.

The results and conclusions of the qualitative risk assessment components and the QRA are presented below. Refer to **Section 6.0** through **Section 8.0** for detailed discussions on the methodologies employed for the qualitative risk assessment and QRA components, which are referenced in the sections below.

C2.0 Qualitative Risk Assessment and Evaluation

C2.1 Chemicals Evaluated

The Halliburton Hydraulic Fracturing Fluid System – Well RM 08-14-3 was assessed. The list of individual chemicals is presented in **Table 1** below. A mass balance of the chemicals is provided as **Table C8-1**.

Information regarding the chemical and physical properties of the individual chemicals listed can be found on the Safety Data Sheets in **Appendix E**.

The fluid system does not contain BTEX (benzene, toluene, ethylbenzene, xylenes) or polycyclic aromatic hydrocarbons (PAHs) based on EHS Support's understanding that Halliburton has tested all of their products. Field monitoring will also be conducted in accordance with regulatory requirements. While none of the fracturing fluid chemicals identified contain BTEX or PAHs, PAHs occur naturally in coal and it is possible that certain PAHs may naturally be present in the coal seam groundwater used in the hydraulic fracturing process.

Table 1: Hydraulic fracturing chemicals

Chemical	CAS Number
Hydroxypropyl guar	39421-75-5
Triethanolamine	107-71-6
Monoethanolamine borate	26038-87-9
Ulexite	1319-33-1
Ethylene glycol	107-21-1
Diethanolamine	111-42-2
Acetic acid	64-19-2
Sodium hydroxide	1310-73-2
Lactose	63-42-3
Disodium octaborate tetrahydrate	12280-03-4
Crystalline Silica	14808-60-7
Tributyl tetradecyl phosphonium chloride	81741-28-8
Silica dioxide	7631-86-9
Sodium carbonate	497-19-8
Hemicellulase enzyme	9012-54-8

C2.2 Risk Assessment Framework and Findings

As discussed in **Section 5.0**, a systematic weight of evidence approach was utilised to complete the risk assessment for the Halliburton Hydraulic Fracturing Fluid System – Well RM 08-14-3. The work has involved the following evaluations:

Qualitative Assessment Methodologies

- PBT Assessment
- Exposure Assessment
- Mass Balance of Fluid System
- Fate and Transport Modeling.

Quantitative Risk Assessment Methodologies

- Quantitative Human Health Risk Assessment (HHRA)
- Quantitative Ecological Risk Assessment for Terrestrial and Aquatic Receptors.

C2.3 PBT Assessment

For the environmental hazard assessment, a PBT (persistence, bioaccumulative, toxicity) assessment was conducted in accordance with the guidance developed by DEWHA (2009), as presented in **Section 6.1**. The PBT assessment is conducted because of specific concerns for substances that can be shown to persist for long periods in the environment, to bioaccumulate in food chains, and can give rise to toxic effects after a longer time and over a greater spatial scale than chemicals without these properties. These effects may be difficult to detect at an early stage because of long-term exposures at normally low concentration levels and long life-cycles of species at the top of the food chain.

The PBT approach outlined in **Section 6.1** was undertaken to rank the hydraulic fracturing chemicals based on PBT potential. As a result of this assessment, no chemical constituents identified in the Halliburton Hydraulic Fracturing Fluid System – Well RM 08-14-3 were classified as a PBT chemical and are therefore not considered to be inherently hazardous (**Appendix G**). The results of the PBT Assessment are presented in **Table 2**, attached.

C2.3 Exposure Assessment

As discussed in **Section 7.0**, the exposure assessment identified receptors potentially exposed to chemicals of potential concern (COPC) identified for the study and outlines the exposure pathways by which the receptors may come in to contact with the COPCs. A detailed exposure assessment was not conducted in the qualitative risk assessment.

C2.4 Mass Balance of Fluid System

A quantitative mass balance calculation was undertaken to identify the amount of each chemical additive of the hydraulic fracturing fluid system. The results of the mass balance calculations are presented in **Table C8-1**.

C2.5 Fate and Transport Modelling

As discussed in **Section 7.2**, fate and transport modelling was conducted on a range of key constituents of interest in typical hydraulic fracturing fluid systems. These results provided the framework for assessing potential mobility of all constituents used in hydraulic fracturing. The modelling demonstrated that despite the variability in chemical properties between fluid systems there is limited potential for chemicals to migrate within the coal seams. Refer to **Section 7.2** for further detail.

C3.0 Quantitative Risk Assessment

In accordance with the methodologies presented in **Section 8.0**, a QRA was conducted on theoretical datasets for those chemicals identified in the Halliburton Hydraulic Fracturing Fluid System – Well RM 08-14-3. The QRA approach evaluates the toxicity of the individual substances and characterises the cumulative risks of the total effluent toxicity and ecotoxicity.

Generally, this methodology includes the identification of the hazards posed by constituents in the flowback water, compilation of the toxicity criteria for each constituent, development of exposure models to estimate the daily intake of the constituents, and calculations of individual constituent hazard quotients (daily intake divided by the toxicity criteria) and a cumulative constituent hazard index (HI) for each potentially complete exposure pathway for each human or terrestrial receptor.

Potential complete exposure pathways to the storage of flowback from hydraulically stimulated wells, and potential risks to humans, terrestrial and aquatic receptors from the potential storage and accidental releases are evaluated in the QRA.

No further assessment of groundwater was determined to be necessary due to lack of potentially complete exposure pathways. Detailed operational procedures have been provided that are designed to contain the hydraulic fracturing fluids within the coal sequences, and no connection exists between groundwater in the coal seams and surface-water or springs (and therefore Matters of National Environmental Significance [MNES]). Further, the potential risks to workers involved with the hydraulic fracturing process were not considered as detailed Health and Safety (H&S) procedures are employed to manage exposures. The QRA considered the following specific exposure pathways:

1. Exposure of trespassers to flowback water contained within flowback storage ponds.
2. Exposure of terrestrial receptors (e.g., livestock and wildlife) to flowback water contained within the flowback storage tank.
3. Exposure of aquatic receptors to flowback water in the situation of an accidental release, such as from piping or a release from the flowback storage tank. These potential releases could include a failure of containment systems, overtopping of the dam or in an extreme situation (considered highly unlikely) structural failure of the dam itself.

C3.1 Exposure Assessment

The purpose of the exposure assessment in the QRA was to predict the magnitude and frequency of potential human exposure to each COPC following the methodologies presented in **Section 8.1**. A conceptual site model (CSM) was developed which describes the potential receptors and exposure scenarios for the flowback water used in this exposure assessment. The potential exposures to receptors were evaluated based on the potential for a complete exposure pathway.

As discussed in **Section 8.3**, exposure point concentrations (EPCs) were derived for the theoretical assessment; empirical data were not available for evaluation. The EPCs for the theoretical assessment were calculated by estimating the mass and discharge flow of the COPCs in the flowback water.

C3.2 Human Health QRA

A human health hazard assessment was conducted according to the methodologies presented in **Section 8.4**. The purpose of the hazard assessment process was to summarise the environmental data, and to address the toxicological assessment of the COPCs that will be evaluated further in the risk assessment process.

Exposure assumptions for the human trespasser scenario were developed based on default or site-specific assumptions (**Section 8.4**). This receptor exposure pathway includes a small child to teenager

that may come in contact with the above grade water exposure scenario for approximately 20 days/year for a 10-year period with potential incidental ingestion [of 50 millilitres (ML) of water] and dermal contact (e.g., swimming where the whole body gets wet) for one half hour. The exposure parameters used in the QRA are presented on **Table 3**, attached.

Calculation of intake of COPCs was performed using the equations presented below:

Ingestion of water:

$$Intake\ (mg/kg-day)\ =\ (CW\ x\ IR\ X\ EF\ X\ ED)\ /\ (BW\ x\ AT)$$

Dermal contact with water:

$$Absorbed\ dose\ (mg/kg-day)\ =\ (CW\ x\ SA\ x\ DP\ x\ ET\ x\ EF\ x\ ED\ x\ CF)\ /\ (BW\ x\ AT)$$

Where:

CW = concentration in water (mg/l)
ET = exposure time (hr/day or hours/hours)
EF = exposure frequency (day/year)
ED = exposure duration (years)
CF = correction factor (1 x 10-3 l/cm3)
AT = averaging time (days)
IR = ingestion rate (l/hr)
BW = body weight (kg)
SA = skin surface area available for contact (cm2/d)
DP = dermal permeability factor (Kp – cm/hr).

C3.3 Toxicity Assessment

A toxicity assessment was conducted to determine the relationship between the dose of a COPC taken into the body, and the probability that an adverse effect will result from that dose. Quantitative estimates of the potency of COPCs include two sets of toxicity values, one for genotoxic carcinogens and one for other non-genotoxic carcinogens and non-carcinogenic effects. As discussed in **Section 8.4**, detailed toxicological profiles were developed for the chemicals. The toxicological profiles are included as **Appendix F8**.

The assessment of toxicity of the COPCs was used to develop initial screening criteria for human health exposure scenarios as discussed in **Section 8.4**. The derivation of Oral Reference Dose and Drinking Water Guideline Values are presented in **Table 4**, attached.

C3.4 Exposure Point Concentration

As presented above, the exposure scenarios are based on anticipated conditions, and the potential for exposure to the theoretical estimate of exposure. EPCs for the exposure assessment were calculated using the results of theoretical fate and transport modelling calculations and the existing environmental conditions within the fracturing fluids flowback storage ponds, and the flowback used in the irrigation fields.

To assess the potential flux of hydraulic fracturing chemicals to the environment, vendor disclosures for the hydraulic fracturing fluid systems were reviewed, and the chemical concentrations of key inputs were determined. It should also be noted that diethanolamine is a new chemical, and is only included as a contingency; at this time it is unlikely to be used.

For the theoretical calculations, the mass and estimated chemical concentrations of the COPCs in the Halliburton Hydraulic Fracturing Fluid System – Well RM 08-14-3, as presented in **Table C8-1**, were used to estimate the potential concentrations in water within the fracturing fluids sump or flare pit, or

flowback storage ponds. Based on stimulation flow back monitoring conducted by Santos and the QRA completed for the Schlumberger Fluid Systems (**Appendix C**), 20 % of the total mass of constituents injected is assumed to be recovered in the flowback water. This mass is diluted within 150 % of the injected volume (the minimum volume that must be flowed back) to establish an "estimated" concentration (i.e., concentration expected due to full dilution of the back flow water) within the flowback storage ponds.

The flowback water will be contained within the flowback storage ponds for a projected maximum period of one year of operational activity before transfer or conveyance to the water treatment facilities and or transferred into Santos water convenyance systems (for treatment) and thereby blended with other coal seam gas (CSG) water not containing these constituents. To be conservative it has been assumed that the fluids are stored with ponds with theconcentration of COPCs in the flowback storage pond water adjusted, where applicable, to account for the biodegradation and photolytic degradation of constituents over time. The biodegradation information was obtained from the Organisation for Economic Cooperation and Development (OECD) ready tests (OECD, 1992) that were developed as a first-tier testing scheme to provide preliminary screening of organic chemicals. The ready tests are stringent screening tests that are conducted under aerobic conditions in which a high concentration of the test substance is used, and biodegradation is measured by non-specific parameters including dissolved organic carbon, biochemical oxygen demand and carbon dioxide production. **Table 6**, attached, presents the environmental fate information that was used to assess biodegradation of COPCs, and that was applied at the time periods of 0, 30, 150 and 300 days from initial flowback.

The water quality data derived using these assumptions for the theoretical COPCs are presented in **Table C8-1**.

The theoretical EPCs for the four exposure time periods (0, 30, 150 and 300 days) were compared to human health toxicity-based screening levels, and the results of this comparison, including the ratio of exceedance of screening levels, is presented in **Table C8-2**.

C3.5 Risk Estimation

Risk estimation was performed in accordance with the methodologies outlined in **Section 8.4**. The total target risk range for carcinogens was 1×10^{-4} to 1×10^{-6}; the target HI for non-threshold effects is less than or equal to 1.0.

Diethanolamine is the only carcinogenic compound present in the stimulation fluids injected into the subsurface. The toxicity criteria corresponding to an oral reference dose (**Table 4**, attached) was derived based on a cancer slope factor based on the NOAEL (See diethanolamine in **Appendix F8**).

The results of the theoretical assessments for Halliburton Hydraulic Fracturing Fluid System – Well RM 08-14-3 for the trespasser exposure scenarios (day 0 and day 150, Halliburton Hydraulic Fracturing Fluid System – Well RM 08-14-3 events) are summarized in **Tables 7** and **8**, attached. As discussed above, the theoretical assessment was only conducted at the well pad sites.

The exposure scenarios include the Halliburton Hydraulic Fracturing Fluid System – Well RM 08-14-3 event, as presented in **Table C8-1**for day 0 and day 150 from the flowback storage tank. The trespasser for day 0 had no unacceptable risks for the Halliburton Hydraulic Fracturing Fluid System – Well RM 08-14-3 (HI=0.088, **Table 7**, attached), and for day 150 (HI=0.065, **Table 8**, attached). There were no unacceptable risks for either day scenario.

On this basis and using the theoretical concentrations, on this basis and using the theoretical concentrations, no adverse effects are predicted on trespassers.

C3.6 Ecological Risk Assessment

As discussed in Section 8.5, a screening level ecological risk assessment (ERA) was conducted to evaluate the potential for adverse ecological effects to terrestrial and aquatic ecological receptors that may be exposed to residual levels of hydraulic fracturing fluids in surface water used in the CSG fields.

C3.7 Exposure Assessment

Terrestrial receptors evaluated in the ERA include domesticated livestock, large mammalian wildlife and small mammalian wildlife. Beef cattle were used to evaluate domesticated livestock, kangaroos evaluated for large mammalian wildlife, and dingos for small mammalian wildlife. Aquatic receptors evaluated included invertebrates and fishes.

The estimate for dose-based or intake rates for the assessment endpoints for wildlife representing domestic livestock and native mammalian species used the following general equation:

TI = Cwater x IRwater x EF x ED / BW x ED x 365 days/year

Where:

TI = Total intake of COPC (mg/kg/day)
Cwater = Concentration of COPC in water (mg/l)
IRwater = Ingestion rate (litres/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg).

The exposure assumptions are presented in **Tables 9** through **11**.

C3.8 Toxicity Assessment

To evaluate the potential for adverse ecological effects, toxicity reference values (TRVs) are selected as measurement endpoints for the ERA that will be used in the risk analysis. The TRVs are based on COPC levels that imply no adverse effects or levels that represent the lowest concentration at which adverse effects may occur. The ERA used two types of TRVs (**Section 8.5.3**). The first TRV is a concentration-based TRV to evaluate the concentration of the selected COPC in the surface water and direct exposure by the aquatic ecological receptor. The determination of TRVs for freshwater was conducted according to the predicted no-effects concentration (PNEC) guidance in the Environmental Risk Assessment Guidance Manual for Industrial Chemicals prepared by the Australian Environmental Agency (AEA, 2009). As discussed in **Section 8.4**, detailed environmental profiles were developed for the chemicals. The environmental profiles are included in the risk dossiers in **Appendix G**. **Table 12**, attached, presents the COPC, the endpoint, NOEC [milligrams per litre (mg/L)], assessment factor, and the aquatic PNEC (mg/L). The second TRV is a dose-based TRV to evaluate the intake dose of the selected COPC from exposure to surface water by ingestion. The calculated TRVs for each of the mammalian ecological receptors evaluated in the ERA are presented in the species-specific ecological risk models.

C3.9 Exposure Point Concentration

EPCs for the exposure assessment were calculated using the results of theoretical fate and transport modelling calculations. The potentially affected flowback water that represents complete exposure pathways for the ecological receptors includes the surface water systems (e.g., flowback storage ponds and mud pits) that were used to estimate the EPCs for the human health receptors. The EPCs for the ecological receptors were estimated assuming the same Scenarios, with exposure occurring in the

irrigation area where irrigation water may pool and wildlife may drink from the standing water. **Table C8-1**presents the calculated EPCs for the ecological receptor exposure scenarios. The theoretical EPCs for the four exposure time periods (0, 30, 150, and 300 days) were compared to ecological based toxicity-based screening levels, and the results of this comparison, including the ratio of exceedance of screening levels, is presented in **Table C8-3**.

Risks were characterised in accordance with the methodologies discussed in **Section 8.5.6**. The resulting ecological hazard quotient must be less than or equal to 1.0 for risks to be considered acceptable.

C3.10 Estimation of Risk

The HI calculated for flowback water for aquatic risk were elevated above the acceptable level for the majority of COPCs evaluated (**Table C8-3**). Where large discharges of flowback water occur to surface water and/or flux dilution within the surface-water was insufficient, potential impacts on aquatic receptors could occur. As noted in the toxicity assessment section above, the lack of a robust aquatic toxicological database resulted in highly conservative aquatic screening values for the theoretical exposure scenario COPCs to be conservatively very low.

The results of the theoretical assessments for Halliburton Hydraulic Fracturing Fluid System – Well RM 08-14-3 for the livestock cattle, kangaroo and dingo are summarized in **Tables 13** through **18**, attached. The exposure scenarios include the Halliburton Hydraulic Fracturing Fluid System – Well RM 08-14-3 EPCs presented in **Table C8-1** for day 0 and day 150 from the fracturing fluid well flowback. The modelled risks from Halliburton Hydraulic Fracturing Fluid System – Well RM 08-14-3 chemicals in the flowback water were acceptable for the livestock (HI=0.9 to 0.65, **Table 13** and **14**, attached), kangaroo (HI=0.18 0.13, **Table 15** and **16**, attached), and dingo (HI=0.075 to 0.054, **Table 17** and **18**, attached), for all exposure scenarios.

C4.0 Summary of QRA Findings

The QRA was completed as discussed in **Section 8.0**. An assessment was conducted using highly conservative theoretical calculations based on the chemicals utilised by Schlumberger in hydraulic fracturing. This assessment assumed that a range of theoretical concentrations of injected chemicals would be present in the flowback water based on biodegradation rates, where applicable.

Consistent with the risk assessment and groundwater fate and transport modelling conducted by Golder, no potentially complete exposure pathways were identified for groundwater. Potential exposures are limited to the aboveground storage and handling of flowback water as part of the CSG Water Management Plan (WMP). Management of CSG water involves the temporary storage of flowback water in flowback storage ponds.

The exposure scenario modelled for the QRA was a trespasser being exposed to flowback water under various EPC scenarios. Based on quantitative risk calculations, the potential risks for the trespasser were acceptable for the EPC scenarios. There were no carcinogenic risks identified.

The modelled risks from Halliburton Hydraulic Fracturing Fluid System – Well RM 08-14-3 chemicals in the flowback water were acceptable for the livestock cattle, kangaroo, and dingo for all EPC exposure scenarios.

Similarly, potential impacts could occur if releases of flowback water were to occur to aquatic environments. Based on the use of low permeability materials (clay liners) and operational controls that limit the potential for turkey nest and dam overflows, the potential for these risks are also considered limited.

A combination of management and operational controls are being implemented to eliminate and control the potential for exposures. These include:

- Worker training and hazard identification
- Use of appropriate personal protective equipment (gloves, etc.)
- Flowback storage pond fencing to prevent entry of livestock and native fauna and minimise trespassing
- Use of low permeability materials or dam liners and routine dam inspections to prevent releases from flowback storage ponds
- Routine operational and security patrols to prevent trespassing.

C5.0 Conclusions

A weight-of-evidence evaluation of potential risks as described in Section 5.0 of the RA Compendium was performed for the Halliburton Hydraulic Fracturing Fluid System – Well RM 08-14-3. Based on the qualitative and quantitative risk characterisations, the overall risk to human health and the environment is acceptable. Existing operational control activities employed by Santos are in place that will limit the potential risks to human health and the environment. These measures include:

- Occupational health and safety procedures implemented during hydraulic fracturing operations to prevent workers from direct contact with chemicals during spills and when handling flowback water or sediments;
- Environmental authority conditions that preclude the construction of well pads within 100 metres of a watercourse of water body;
- Implementation of spill containment procedures during operations to prevent migration of and exposure to chemicals;
- Disposal or capping of sediments contained within drained mud pits and turkey nests , to prevent exposure to contaminates in windborne dust;
- Fencing of drill pads to prevent trespassers and installation of signs to indicate that the water in the turkeys nest and mud pit is not potable and may contain contaminants;
- Installation and maintenance of fences around the well pad to prevent access to the drill pad by livestock and large native fauna;
- Santos operational procedures to ensure well integrity and design of fracture to stay within the target seam; and
- Mud pits and turkeys nests with clay liners, or similar material, to prevent seepage of flowback water into underlying aquifers.

Monitoring of water supply bores and surface water for a representative suite of chemicals within 2 kilometre of wells (and 200 m vertical separation) that are fractured will be conducted (as needed) to confirm the conclusion of incomplete exposure pathways and low risk.

No additional risks, other than those previously discussed, were identified with the chemicals or systems employed in hydraulic fracturing. Evaluation of other potential risks associated with hydraulic fracturing (i.e., noise and vibration) was conducted. Refer to **Section 9.0** for methodology specifics and results of this evaluation.

Tables

Table 2: PBT Assessment of the Halliburton RM08-14-3 Fluid System

Substance	P/vP criteria fulfilled?	B/vB criteria fulfilled?	T criteria fulfilled?	Overall conclusion
Hydroxypropyl guar (39421-75-5)	No (screening data estimated)	No (screening data available)	No (screening data available)	Not PBT (based on screening data)
Triethanolamine (107-71-6)	No (screening data available)	No (experimental data available)	No (experimental data available)	Not PBT (based on screening and experimental data)
Monoethanolamine borate (26038-87-9)	No (screening data available)	No (screening data available)	No (screening data available)	Not PBT (based on screening data)
Ulexite (1319-33-1)	Yes (inorganic salt)	No (screening data available)	Yes (measured data; human health concerns)	Not PBT (based on screening and measured data)
Ethylene glycol (107-21-1)	No (screening data available)	No (measured data available)	No (measured data available)	Not PBT (based on screening and measured data)
Diethanolamine (111-42-2)	No (screening data available)	No (screening data available)	Human health concerns	Not PBT (based on screening and measured data)
Acetic acid (64-19-2)	No (screening data available)	No (screening data available)	No (measured data available)	Not PBT (based on screening and measured data)
Sodium hydroxide (1310-73-2)	Not applicable (ionic species ubiquitous in environment)	No (essential ions to biological systems; actively regulated)	No (screening data available)	Not PBT (based screening data and ubiquitous inorganic salt)
Lactose (63-42-3)	No (screening data available)	No (screening data available)	No (screening data available)	Not PBT (based on screening data)
Disodium octaborate tetrahydrate (12280-03-4)	Yes (inorganic salt)	No (screening data available)	Yes (measured data; human health concerns)	Not PBT (based on screening and measured data)
Crystalline Silica (14808-60-7)	Yes (naturally-occurring inorganic mineral)	No (water-insoluble mineral; not bioavailable)	No (water-insoluble mineral; not bioavailable)	Not PBT (based on physico-chemical properties)
Tributyl tetradecyl phosphonium chloride (81741-28-8)	Yes (measured data available)	No (screening data available)	Yes (screening data available)	Not PBT (based on measured and screening data)
Silica dioxide	Yes (naturally-occurring inorganic mineral)	No (water-insoluble mineral; not bioavailable)	No (screening data available)	Not PBT (based on screening data and physic-chemical properties)
Sodium carbonate (497-19-8)	Not applicable (ionic species ubiquitous in environment)	No (essential ions to biological systems; actively regulated)	No (screening data available)	Not PBT (based screening data and ubiquitous inorganic salt)
Hemicellulase enzyme (9012-54-8)	No (screening data available)	No (screening data available)	No (screening data available)	Not PBT (based on screening data)

Table 3 Exposure Assumptions - Trespasser

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/hr	0.05
	ET	Exposure time	hr/day	0.5
	EF	Exposure frequency	day/yr	20
	ED	Exposure duration	yr	10
	BW	Body weight	kg	47
	AT-NC	Averaging time - noncancer	days	3,650
	AT-C	Averaging time - cancer	days	25,550
Dermal	SA	Surface area for contact	cm^2/day	13,000
	DP	Dermal permeability factor	cm/h	chemical-specific
	ET	Exposure time	hr/day	1
	EF	Exposure frequency	day/yr	20
	ED	Exposure duration	yr	10
	BW	Body weight	kg	47
	AT-NC	Averaging time - noncancer	days	3,650
	AT-C	Averaging time - cancer	days	25,550
	CF	Conversion factor	l/cm^3	1.0E-03

Table 4: Oral Reference Doses and Drinking Water Guidelines Derived for Hydraulic Fracturing Chemicals

Constituent (CAS No.)	Study	Critical Effect/Target Organ(s)	NOAEL (mg/kg-day)	Uncertainty Factors	Oral Reference Dose (mg/kg-day)	Drinking Water Guideline (ppm)
Hydroxypropyl guar	Rat 2-yr drinking water	General toxicity	1,250	100	12.5	44
Triethanolamine	Rat 91-day dietary	-	1,000	1,000	1.0	3.5
Monoethanolamine borate	28-day rat oral gavage	None	1,000	1,000	1.0	3.5
Ulexite	Rat developmental	Fetal body weight changes	10.3[a]	66	0.2 [boron]	0.7 [boron]
Ethylene glycol	1-year rat (dietary)	Kidney toxicity	150	100	1.5	5.3
Diethanolamine	2-yr mouse	Choline deficiency	10	-	-	-
Diethanolamine	2-yr mouse dermal	Kidney tumors (male mice)	0.015114 $(mg/kg\text{-}day)^{-1}$*	Not applicable	0.66 µg/kg-day**	0.0023
Lactose	2-year rat dietary	Multiple effects in colon/cecum (poor intestinal absorption)	1,000[b]	1,000	1.0	3.5
Disodium octaborate tetrahydrate	Rat developmental	Fetal body weight changes	10.3[a]	66	0.2 [boron]	0.7 [boron]
Crystalline Silica	ND[b]	ND	ND	ND	ND	ND
Tributyl tetradecyl phosphonium chloride	Rat 90-day drinking water	General toxicity	8.66	1,000	0.009	0.03
Silica dioxide	Rat 2-yr dietary	None	2,500	100	2.5	0.09
Hemicellulase enzyme	13-week rat (dietary)	Reduced body weight gain	600	1,000	0.6	2

[a]LOAEL.
[b]Not determined.
*Cancer slope factor.
**Chronic toxicity value (10^{-5} cancer risk).

Table 5: Australian Drinking Water Screening Values for Hydraulic Fracturing Chemicals

Constituent (CAS No.)	Drinking Water Screening Guideline	Drinking Water Screening Value
Acetic acid	pH	6.5 to 8.5
Sodium carbonate	Sodium; pH	180 ppm (aesthetic); 6.5 to 8.5
Sodium hydroxide	pH	6.5 to 8.5

Table 6 Environmental Fate Information

Hydroxypropyl guar	Readily biodegradable (half-life = 15 days)[a]
Triethanolamine	Readily biodegradable (half-life = 15 days)[a]
Monoethanolamine borate	Readily biodegradable (half-life = 15 days)[a]
Ulexite	Slightly water-soluble inorganic; (borate): not biodegradable
Ethylene glycol	Readily biodegradable (half-life = 15 days)[a]
Diethanolamine	Readily biodegradable (half-life = 15 days)[a]
Acetic acid	Readily biodegradable (half-life = 15 days)[a]
Sodium hydroxide	Dissociates completely in aqueous media
Lactose	Estimated: readily biodegradable (half-life = 15 days)[a]
Disodium octaborate tetrahydrate	Water-soluble inorganic; (borate): not biodegradable
Crystalline Silica	Water-insoluble mineral; not biodegradable
Non-crystalline silica	Water-insoluble mineral; not biodegradable
Tributyl tetradecyl phosphonium chloride	Inherently biodegradable (half-life = 150 days)[a]
Sodium carbonate	Dissociates completely in aqueous media
Hemicellulase enzyme	Readily biodegradable (half-life = 15 days)[a]

a Source: EU Guidance Document: Half-life estimates from in vitro biodegradation test results

Table 7 Risk Estimates for Trespasser Halliburton Hydraulic Fracturing Fluid System in Well RM 08-14-3 Theoretical Exposure for Day 0

		Day 0		Toxicity	Halliburton Fluid System - Well RM 08-14-3			
							Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**PC (cm/hr)**	**RfDo**	**$CADD_{oral}$**	**$CADD_{derm}$**	**Incidental Ingestion**	**Dermal**
Hydroxypropyl guar	39421-75-5	2.8E+02	NA	12.500	1.6E-02	-	1.3E-03	-
Triethanolamine	107-71-6	1.4E+02	5.1E-05	1.0	8.4E-03	5.50482E-05	8.4E-03	5.5E-05
Monoethanolamine borate	26038-87-9	1.0E+02	NA	1	6.1E-03	-	6.1E-03	-
Ulexite	1319-33-1	1.4E+02	NA	0.2	8.1E-03	-	4.0E-02	-
Ethylene glycol	107-21-1	6.9E+01	9.0E-05	1.5	4.0E-03	4.7E-05	2.7E-03	3.1E-05
Diethanolamine	111-42-2	4.3E+01	4.6E-05	0.66	2.5E-03	1.50038E-05	3.8E-03	2.3E-05
Acetic acid	64-19-2	2.4E+01	5.6E-04	-	-	-		-
Sodium hydroxide	1310-73-2	2.8E+01	NA	-	-	-		-
Lactose	63-42-3	7.8E+00	9.2E-09	1	4.5E-04	5.4E-10	4.5E-04	5.4E-10
Disodium octaborate tetrahydrate	12280-03-4	2.2E+00	NA	0.2	1.3E-04	-	6.3E-04	-
Crystalline Silica	14808-60-7	1.2E+01	NA	-	-	-		-
Tributyl tetradecyl phosphonium chloride	81741-28-8	3.6E+00	NA	0.009	2.1E-04	-	6.1E-03	-
Silica dioxide	7631-86-9	2.8E+00	NA	2.5	1.7E-04	-	6.1E-03	-
Sodium carbonate	497-19-8	3.1E+00	NA	51.4	1.8E-04	-	6.1E-03	
Hemicellulase enzyme	9012-54-8	7.6E-01	NA	0.6	4.4E-05	-	6.1E-03	
							Hazard Index	8.8E-02

Table 8 Risk Estimates for Trespasser Halliburton Hydraulic Fracturing Fluid System in Well RM 08-14-3 Theoretical Exposure for Day 150

		Day 150		Toxicity	Halliburton Fluid System - Well RM 08-14-3			
							Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**PC (cm/hr)**	**RfDo**	**$CADD_{oral}$**	**$CADD_{derm}$**	**Incidental Ingestion**	**Dermal**
Hydroxypropyl guar	39421-75-5	2.7E-01	NA	12.500	1.6E-05	-	1.3E-06	-
Triethanolamine	107-71-6	1.4E-01	5.1E-05	1.0	8.2E-06	5.3758E-08	8.2E-06	5.4E-08
Monoethanolamine borate	26038-87-9	1.0E-01	NA	1	5.9E-06	-	5.9E-06	-
Ulexite	1319-33-1	1.4E+02	NA	0.2	8.1E-03	-	4.0E-02	-
Ethylene glycol	107-21-1	6.7E-02	9.0E-05	1.5	3.9E-06	4.6E-08	2.6E-06	3.1E-08
Diethanolamine	111-42-2	4.2E-02	4.6E-05	0.66	2.4E-06	1.46522E-08	3.7E-06	2.2E-08
Acetic acid	64-19-2	2.3E-02	5.6E-04	-	-	-		-
Sodium hydroxide	1310-73-2	2.8E+01	NA	-	-	-		-
Lactose	63-42-3	7.6E-03	9.2E-09	1	4.4E-07	5.3E-13	4.4E-07	5.3E-13
Disodium octaborate tetrahydrate	12280-03-4	2.2E+00	NA	0.2	1.3E-04	-	6.3E-04	-
Crystalline Silica	14808-60-7	1.2E+01	NA	-	-	-		-
Tributyl tetradecyl phosphonium chloride	81741-28-8	1.8E+00	NA	0.009	1.1E-04	-	6.1E-03	-
Silica dioxide	7631-86-9	2.8E+00	NA	2.5	1.7E-04	-	6.1E-03	-
Sodium carbonate	497-19-8	3.1E+00	NA	51.4	1.8E-04	-	6.1E-03	
Hemicellulase enzyme	9012-54-8	7.4E-04	NA	0.6	4.3E-08	-	6.1E-03	
							Hazard Index	6.5E-02

Table 9 Exposure Assumptions - Cattle

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/day	86
	EF	Exposure frequency	day/yr	15
	ED	Exposure duration	yr	8
	BW	Body weight	kg	454
	AT-NC	Averaging time - noncancer	days	2,920

Table 10 Exposure Assumptions - Kangaroo

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/day	3
	EF	Exposure frequency	day/yr	10
	ED	Exposure duration	yr	15
	BW	Body weight	kg	25
	AT-NC	Averaging time - noncancer	days	5,475

Table 11 Exposure Assumptions - Dingo

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/day	0.75
	EF	Exposure frequency	day/yr	10
	ED	Exposure duration	yr	15
	BW	Body weight	kg	13
	AT-NC	Averaging time - noncancer	days	5,475

Table 12: Aquatic Toxicity Values (PNECs) for Hydraulic Fracturing Chemicals

Constituents	Endpoint	E(L)C50 or NOEC (mg/L)	Assessment Factor	$PNEC_{aquatic}$ (mg/L)
Hydroxypropyl guar	48-hr LC_{50} (*Daphnia*)	42	1,000	0.042
Triethanolamine	Chronic Daphnia	125	100	1.25
Monoethanolamine borate	Acute algae	13	1,000	0.013
Ulexite	Species Sensitivity Distribution	-	-	1.5[a,c] 0.37[b,c]
Ethylene glycol	Chronic invertebrates	3,469	10	347
Diethanolamine	Chronic Daphnia	0.78	50	0.0156
Acetic acid	Chronic Daphnia	23	50	0.5
Sodium hydroxide	ND[d]	ND	ND	ND
Lactose	Acute fish (QSAR)	81,045	1,000	81
Disodium octaborate tetrahydrate	Species Sensitivity Distribution	-	-	1.5[a,c] 0.37[b,c]
Crystalline Silica	ND	ND	ND	ND
Tribuyl tetradecyl phosphonium chloride	Acute Daphnia	0.025	1,000	2.5×10^{-5}
Silica dioxide	ND	ND	ND	ND
Sodium carbonate	Acute Daphnia	200	1,000	0.2
Hemicellulase enzyme	Acute fish	330	1,000	0.33

[a]Canadian water quality guideline for the protection of aquatic life: boron (CCME, 2009).
[b]Australia and New Zealand freshwater high reliability trigger value for boron (ANZECC, 2000).
[c]Value expressed as B equivalents
[d]ND = Not determined.

Table 13 Risk Estimates for Cattle Halliburton
Hydraulic Fracturing Fluid System – Well RM 08-14-3
Theoretical Exposure for Day 0

		Day 0	Toxicity	Halliburton Fluid System - Well RM 08-14-3	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Hydroxypropyl guar	39421-75-5	2.8E+02	2.1E+02	2.2E+00	1.0E-02
Triethanolamine	107-71-6	1.4E+02	1.7E+02	1.1E+00	6.7E-03
Monoethanolamine borate	26038-87-9	1.0E+02	1.7E+02	8.1E-01	4.9E-03
Ulexite	1319-33-1	1.4E+02	1.7E+00	1.1E+00	6.3E-01
Ethylene glycol	107-21-1	6.9E+01	2.5E+01	5.4E-01	2.2E-02
Diethanolamine	111-42-2	4.3E+01	1.7E+00	3.3E-01	2.0E-01
Acetic acid	64-19-2	2.4E+01	-	-	-
Sodium hydroxide	1310-73-2	2.8E+01	-	-	-
Lactose	63-42-3	7.8E+00	1.7E+02	6.0E-02	3.6E-04
Disodium octaborate tetrahydrate	12280-03-4	2.2E+00	1.7E+00	1.7E-02	9.8E-03
Crystalline Silica	14808-60-7	1.2E+01	-	-	-
Tributyl tetradecyl phosphonium chloride	81741-28-8	3.6E+00	1.4E+00	2.8E-02	2.0E-02
Silica dioxide	7631-86-9	2.8E+00	4.2E+02	2.2E-02	5.3E-05
Sodium carbonate	497-19-8	3.1E+00	-	-	-
Hemicellulase enzyme	9012-54-8	7.6E-01	1.0E+02	5.9E-03	5.9E-05

Hazard Index
9.0E-01

Table 14 Risk Estimates for Cattle Halliburton
Hydraulic Fracturing Fluid System – Well RM 08-14-3
Theoretical Exposure for Day 150

		Day 150	Toxicity	Halliburton Fluid System - Well RM 08-14-3	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Hydroxypropyl guar	39421-75-5	2.7E-01	2.1E+02	2.1E-03	1.0E-05
Triethanolamine	107-71-6	1.4E-01	1.7E+02	1.1E-03	6.5E-06
Monoethanolamine borate	26038-87-9	1.0E-01	1.7E+02	7.9E-04	4.8E-06
Ulexite	1319-33-1	1.4E+02	1.7E+00	1.1E+00	6.3E-01
Ethylene glycol	107-21-1	6.7E-02	2.5E+01	5.3E-04	2.1E-05
Diethanolamine	111-42-2	4.2E-02	1.7E+00	3.2E-04	1.9E-04
Acetic acid	64-19-2	2.3E-02	-	-	-
Sodium hydroxide	1310-73-2	2.8E+01	-	-	-
Lactose	63-42-3	7.6E-03	1.7E+02	5.9E-05	3.5E-07
Disodium octaborate tetrahydrate	12280-03-4	2.2E+00	1.7E+00	1.7E-02	9.8E-03
Crystalline Silica	14808-60-7	1.2E+01	-	-	-
Tributyl tetradecyl phosphonium chloride	81741-28-8	1.8E+00	1.4E+00	1.4E-02	9.8E-03
Silica dioxide	7631-86-9	2.8E+00	4.2E+02	2.2E-02	5.3E-05
Sodium carbonate	497-19-8	3.1E+00	-	-	-
Hemicellulase enzyme	9012-54-8	7.4E-04	1.0E+02	5.8E-06	5.8E-08

Hazard Index
6.5E-01

Table 15 Risk Estimates for Kangaroo Halliburton
Hydraulic Fracturing Fluid System – Well RM 08-14-3
Theoretical Exposure for Day 0

		Day 0	Toxicity	Halliburton Fluid System - Well RM 08-14-3	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Hydroxypropyl guar	39421-75-5	2.8E+02	4.3E+02	9.1E-01	2.1E-03
Triethanolamine	107-71-6	1.4E+02	3.4E+02	4.7E-01	1.4E-03
Monoethanolamine borate	26038-87-9	1.0E+02	3.4E+02	3.4E-01	1.0E-03
Ulexite	1319-33-1	1.4E+02	3.5E+00	4.6E-01	1.3E-01
Ethylene glycol	107-21-1	6.9E+01	5.2E+01	2.3E-01	4.4E-03
Diethanolamine	111-42-2	4.3E+01	3.4E+00	1.4E-01	4.1E-02
Acetic acid	64-19-2	2.4E+01	-	-	-
Sodium hydroxide	1310-73-2	2.8E+01	-	-	-
Lactose	63-42-3	7.8E+00	3.4E+02	2.6E-02	7.4E-05
Disodium octaborate tetrahydrate	12280-03-4	2.2E+00	3.5E+00	7.1E-03	2.0E-03
Crystalline Silica	14808-60-7	1.2E+01	-	-	-
Tributyl tetradecyl phosphonium chloride	81741-28-8	3.6E+00	3.0E+00	1.2E-02	4.0E-03
Silica dioxide	7631-86-9	2.8E+00	8.6E+02	9.3E-03	1.1E-05
Sodium carbonate	497-19-8	3.1E+00	-	-	-
Hemicellulase enzyme	9012-54-8	7.6E-01	2.1E+02	2.5E-03	1.2E-05

Hazard Index
1.8E-01

Table 16 Risk Estimates for Kangaroo Halliburton
Hydraulic Fracturing Fluid System – Well RM 08-14-3
Theoretical Exposure for Day 150

		Day 150	Toxicity	Halliburton Fluid System - Well RM 08-14-3	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Hydroxypropyl guar	39421-75-5	2.7E-01	4.3E+02	8.9E-04	2.1E-06
Triethanolamine	107-71-6	1.4E-01	3.4E+02	4.6E-04	1.3E-06
Monoethanolamine borate	26038-87-9	1.0E-01	3.4E+02	3.3E-04	9.7E-07
Ulexite	1319-33-1	1.4E+02	3.5E+00	4.6E-01	1.3E-01
Ethylene glycol	107-21-1	6.7E-02	5.2E+01	2.2E-04	4.3E-06
Diethanolamine	111-42-2	4.2E-02	3.4E+00	1.4E-04	4.0E-05
Acetic acid	64-19-2	2.3E-02	-	-	-
Sodium hydroxide	1310-73-2	2.8E+01	-	-	-
Lactose	63-42-3	7.6E-03	3.4E+02	2.5E-05	7.2E-08
Disodium octaborate tetrahydrate	12280-03-4	2.2E+00	3.5E+00	7.1E-03	2.0E-03
Crystalline Silica	14808-60-7	1.2E+01	-	-	-
Tributyl tetradecyl phosphonium chloride	81741-28-8	1.8E+00	3.0E+00	6.0E-03	2.0E-03
Silica dioxide	7631-86-9	2.8E+00	8.6E+02	9.3E-03	1.1E-05
Sodium carbonate	497-19-8	3.1E+00	-	-	-
Hemicellulase enzyme	9012-54-8	7.4E-04	2.1E+02	2.4E-06	1.2E-08

Hazard Index
1.3E-01

Table 17 Risk Estimates for Dingo Halliburton
Hydraulic Fracturing Fluid System – Well RM 08-14-3
Theoretical Exposure for Day 0

		Day 0	Toxicity	Halliburton Fluid System - Well RM 08-14-3	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Hydroxypropyl guar	39421-75-5	2.8E+02	5.1E+02	4.4E-01	8.7E-04
Triethanolamine	107-71-6	1.4E+02	4.1E+02	2.3E-01	5.6E-04
Monoethanolamine borate	26038-87-9	1.0E+02	4.1E+02	1.6E-01	4.1E-04
Ulexite	1319-33-1	1.4E+02	4.2E+00	2.2E-01	5.2E-02
Ethylene glycol	107-21-1	6.9E+01	6.1E+01	1.1E-01	1.8E-03
Diethanolamine	111-42-2	4.3E+01	4.1E+00	6.7E-02	1.7E-02
Acetic acid	64-19-2	2.4E+01	-	-	-
Sodium hydroxide	1310-73-2	2.8E+01	-	-	-
Lactose	63-42-3	7.8E+00	4.1E+02	1.2E-02	3.0E-05
Disodium octaborate tetrahydrate	12280-03-4	2.2E+00	4.2E+00	3.4E-03	8.2E-04
Crystalline Silica	14808-60-7	1.2E+01	-	-	-
Tributyl tetradecyl phosphonium chloride	81741-28-8	3.6E+00	3.5E+00	5.8E-03	1.6E-03
Silica dioxide	7631-86-9	2.8E+00	1.0E+03	4.5E-03	4.4E-06
Sodium carbonate	497-19-8	3.1E+00	-	-	-
Hemicellulase enzyme	9012-54-8	7.6E-01	2.4E+02	1.2E-03	4.9E-06

Hazard Index
7.5E-02

Table 18 Risk Estimates for Dingo Halliburton
Hydraulic Fracturing Fluid System – Well RM 08-14-3
Theoretical Exposure for Day 150

		Day 150	Toxicity	Halliburton Fluid System - Well RM 08-14-3	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Hydroxypropyl guar	39421-75-5	2.7E-01	5.1E+02	4.3E-04	8.5E-07
Triethanolamine	107-71-6	1.4E-01	4.1E+02	2.2E-04	5.5E-07
Monoethanolamine borate	26038-87-9	1.0E-01	4.1E+02	1.6E-04	4.0E-07
Ulexite	1319-33-1	1.4E+02	4.2E+00	2.2E-01	5.2E-02
Ethylene glycol	107-21-1	6.7E-02	6.1E+01	1.1E-04	1.8E-06
Diethanolamine	111-42-2	4.2E-02	4.1E+00	6.6E-05	1.6E-05
Acetic acid	64-19-2	2.3E-02	-	-	-
Sodium hydroxide	1310-73-2	2.8E+01	-	-	-
Lactose	63-42-3	7.6E-03	4.1E+02	1.2E-05	3.0E-08
Disodium octaborate tetrahydrate	12280-03-4	2.2E+00	4.2E+00	3.4E-03	8.2E-04
Crystalline Silica	14808-60-7	1.2E+01	-	-	-
Tributyl tetradecyl phosphonium chloride	81741-28-8	1.8E+00	3.5E+00	2.9E-03	8.2E-04
Silica dioxide	7631-86-9	2.8E+00	1.0E+03	4.5E-03	4.4E-06
Sodium carbonate	497-19-8	3.1E+00	-	-	-
Hemicellulase enzyme	9012-54-8	7.4E-04	2.4E+02	1.2E-06	4.8E-09

Hazard Index
5.4E-02

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Appendix C8-1

HALLIBURTON

HALLIBURTON CONFIDENTIAL INFORMATION - ONLY TO BE USED FOR REGULATOR NOTIFICATION (QLD FORMAT)

Comments:
Santos Queensland PreJob RM08-14-3, 10000 lb 20/40 Sand, 180000 lb 16/30 Sand

Total injected fluid volume (kiloliters):	985.679

Comprising of: (Kilograms, liters or kiloliters)		
Base Fluid type (e.g. water)	**Liters**	**% of total volume**
Makeup Water	946353	96.0%

Proppant type (e.g sand)	**Proppant Size**	**Kilograms**	**Liters**	**% of total volume**
20/40 Sand	20/40	4536	1712	0.174%
16/30 Sand	16/30	81647	30810	3.13%

Any wet chemical constitutes:	**Liters**	**% of total volume**
Water in Products	1949	0.198%
Hydroxylpropyl guar	1575	0.160%
Triethanol amine	938	0.0952%
Monoethanolamine borate	651	0.0660%
Ulexite	523	0.0531%
Ethylene glycol	460	0.0467%
Diethanol amine	289	0.0293%
Acetic acid	165	0.0168%
Sodium hydroxide	99	0.0100%
Lactose	38	0.00383%
Disodium octaborate tetrahydrate	33	0.00338%
Crystalline silica, quartz	32	0.00329%
Tributyl tetradecyl phosphonium chloride	28	0.00288%
Silica dioxide	10	0.00105%
Sodium carbonate	9.0	0.00091%
Hemicellulase enzyme	3.8	0.00038%

Appendix C8-Tables

Table C8-1 Surface Water Quality Data for Theoretical Scenario in Initial Flowback for Halliburton Hydraulic Fracturing Fluid System – Well RM 08-14-3

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Mud Pit Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Mud Pitcon = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)			
				Temporal Scenario (days)			
		Halliburton RM 08-14-3	Half-Life (days)	0	30	150	300
Hydroxypropyl guar	39421-75-5	2,080.0	15	277.33	69.3	0.3	0.0
Triethanolamine	102-71-6	1,075.8	15	143.4	35.9	0.1	0.0
Monoethanolamine borate	26038-87-9	781.4	15	104.2	26.0	0.10	0.00010
Ulexite	1319-33-1	1,038.1	NA	138.4	138.4	138.4	138.4
Ethylene glycol	107-21-1	518.4	15	69.1	17.3	0.067	0.000066
Diethanolamine	111-42-2	319.4	15	42.6	10.6	0.042	0.00004
Acetic acid	64-19-2	176.4	15	23.5	5.9	0.023	0.00002
Sodium hydroxide	1310-73-2	213.0	NA	28.40	28.40	28.40	28.40
Lactose	63-42-3	58.2	15	7.76	1.94	0.01	0.00001
Disodium octaborate tetrahydrate	12280-03-4	16.2	NA	2.16	2.16	2.16	2.16
Crystalline Silica	14808-60-7	87.19	NA	11.625	11.62	11.62	11.62
Tributyl tetradecyl phosphonium chloride	81741-28-8	27.36	150	3.648	3.176	1.824	0.912
Silica dioxide	7631-86-9	21.32	NA	2.842	2.842	2.842	2.842
Sodium carbonate	497-19-8	23.11	NA	3.082	3.082	3.082	3.082
Hemicellulase enzyme	9012-54-8	5.70	15	0.760	0.190	0.001	0.000

Table C8-2 Comparison of Estimated Theoretical Halliburton Hydraulic Fracturing Fluid System – Well RM 08-14-3 Concentrations to Human Health Drinking Water Guidelines

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Mud Pit Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Mud Pitcon = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)				Drinking Water Guideline (mg/L)	Ratio of COPC Concentrations and Screening Criteria (Ratio greater than one = unacceptable potential risk)			
				Temporal Scenario (days)					Temporal Scenario (days)			
		Halliburton RM 08-14-3	Half-Life (days)	0	30	150	300		0	30	150	300
Hydroxypropyl guar	39421-75-5	2,080.0	15	277.33	69.3	0.3	0.0	44	6.3E+00	1.6E+00	6.2E-03	6.0E-06
Triethanolamine	102-71-6	1,075.8	15	143.4	35.9	0.1	0.0	3.5	4.1E+01	1.0E+01	4.0E-02	3.9E-05
Monoethanolamine borate	26038-87-9	781.4	15	104.2	26.0	0.10	0.00010	3.5	3.0E+01	7.4E+00	2.9E-02	2.8E-05
Ulexite	1319-33-1	1,038.1	NA	138.4	138.4	138.4	138.4	0.7	2.0E+02	2.0E+02	2.0E+02	2.0E+02
Ethylene glycol	107-21-1	518.4	15	69.1	17.3	0.067	0.000066	5.3	1.3E+01	3.3E+00	1.3E-02	1.2E-05
Diethanolamine	111-42-2	319.4	15	42.6	10.6	0.0	0.0	0.0023	1.9E+04	4.6E+03	1.8E+01	1.8E-02
Acetic acid	64-19-2	176.4	15	23.5	5.9	0.0	0.0	-	-	-	-	-
Sodium hydroxide	1310-73-2	213.0	NA	28.40	28.40	28.40	28.40	-	-	-	-	-
Lactose	63-42-3	58.2	15	7.76	1.9E+00	7.6E-03	7.4E-06	3.5	2.2E+00	5.5E-01	2.2E-03	2.1E-06
Disodium octaborate tetrahydrate	12280-03-4	16.2	NA	2.16	2.16	2.16	2.16	0.7	3.1E+00	3.1E+00	3.1E+00	3.1E+00
Crystalline Silica	14808-60-7	87.19	NA	11.625	1.2E+01	1.2E+01	1.2E+01	-	-	-	-	-
Tributyl tetradecyl phosphonium chloride	81741-28-8	27.36	150	3.648	3.176	1.824	0.912	0.03	1.2E+02	1.1E+02	6.1E+01	3.0E+01
Silica dioxide	7631-86-9	21.32	NA	2.842	2.842	2.842	2.842	0.09	3.2E+01	3.2E+01	3.2E+01	3.2E+01
Sodium carbonate	497-19-8	23.11	NA	3.082	3.082	3.082	3.082	180	1.7E-02	1.7E-02	1.7E-02	1.7E-02
Hemicellulase enzyme	9012-54-8	5.70	15	0.760	0.190	0.001	0.000	2	3.8E-01	9.5E-02	3.7E-04	3.6E-07
								Cumulative Ratio	**18,960.9**	**4,990.0**	**311.4**	**262.8**

Table C8-3 Comparison of Estimated Theoretical Halliburton Hydraulic Fracturing Fluid System – Well RM 08-14-3 Concentrations to Aquatic Life Water Guidelines

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Mud Pit Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Mud Pitcon = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)				PNEC aquatic (mg/L)	Ratio of COPC Concentrations and Screening Criteria (Ratio greater than one = unacceptable potential risk)			
				Temporal Scenario (days)					Temporal Scenario (days)			
		Halliburton RM 08-14-3	Half-Life (days)	0	30	150	300		0	30	150	300
Hydroxypropyl guar	39421-75-5	2,080.0	15	277.33	69.3	0.3	0.0	4.2E-02	6.6E+03	1.7E+03	6.4E+00	6.3E-03
Triethanolamine	102-71-6	1,075.8	15	143.4	35.9	0.1	0.0	1.3E+00	1.1E+02	2.9E+01	1.1E-01	1.1E-04
Monoethanolamine borate	26038-87-9	781.4	15	104.2	26.0	0.10	0.00010	1.3E-02	8.0E+03	2.0E+03	7.8E+00	7.6E-03
Ulexite	1319-33-1	1,038.1	NA	138.4	138.4	138.4	138.4	3.7E-01	3.7E+02	3.7E+02	3.7E+02	3.7E+02
Ethylene glycol	107-21-1	518.4	15	69.1	17.3	0.067	0.000066	3.5E+02	2.0E-01	5.0E-02	1.9E-04	1.9E-07
Diethanolamine	111-42-2	319.4	15	42.6	10.6	0.0	0.0	1.6E-02	2.7E+03	6.8E+02	2.7E+00	2.6E-03
Acetic acid	64-19-2	176.4	15	23.5	5.9	0.0	0.0	5.0E-01	4.7E+01	1.2E+01	4.6E-02	4.5E-05
Sodium hydroxide	1310-73-2	213.0	NA	28.40	28.40	28.40	28.40	-	-	-	-	-
Lactose	63-42-3	58.2	15	7.76	1.9E+00	7.6E-03	7.4E-06	8.1E+01	9.6E-02	2.4E-02	9.4E-05	9.1E-08
Disodium octaborate tetrahydrate	12280-03-4	16.2	NA	2.16	2.16	2.16	2.16	3.7E-01	5.8E+00	5.8E+00	5.8E+00	5.8E+00
Crystalline Silica	14808-60-7	87.19	NA	11.625	1.2E+01	1.2E+01	1.2E+01	-	-	-	-	-
Tributyl tetradecyl phosphonium chloride	81741-28-8	27.36	150	3.648	3.176	1.824	0.912	2.5E-05	1.5E+05	1.3E+05	7.3E+04	3.6E+04
Silica dioxide	7631-86-9	21.32	NA	2.842	2.842	2.842	2.842	-	-	-	-	-
Sodium carbonate	497-19-8	23.11	NA	3.082	3.082	3.082	3.082	2.0E-01	1.5E+01	1.5E+01	1.5E+01	1.5E+01
Hemicellulase enzyme	9012-54-8	5.70	15	0.760	0.190	0.001	0.000	0	2.3E+00	5.8E-01	2.2E-03	2.2E-06
								Cumulative Ratio	**163,827.3**	**131,804.1**	**73,372.4**	**36,875.4**

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Appendix C9
Halliburton Fluorescein Dye Hydraulic Fracturing Fluid System

C1.0 Introduction

Santos Ltd. (Santos) is looking to use a water based (not gel based) Halliburton hydraulic fracturing fluid system (the fluid system) for development of coal seam gas (CSG) resources in the Surat and Bowen Basins of Queensland, specifically in the Roma Shallow Gas Project Area (RSGPA). The disclosure for well Mt Kingsley 6, including a listing of the chemical constituents and percent of total volume in the fluid system, is provided in **Appendix C9-1**. The fluid system components provided in **Appendix C9-1** comprises only three chemicals: BE-9 Algaecide (a biocide containing tributyl tetradecyl phosphonium chloride); Fluorescein Dye (sodium fluorescein); and potassium chloride (KCl) for clay inhibition. The anticipated chemical composition of the hydraulic fracturing fluid will comprise the following:

- Water 300,000 gallons
- KCl 100,200 pounds
- BE-9 180 gallons
- Flourescein Dye 5 pounds

As presented in **Section 5.0**, Santos used a weight-of-evidence approach to evaluate the potential for human health and environmental (e.g., ecological) risks as a result of the hydraulic fracturing processes and the use of the Halliburton Hydraulic Fracturing Fluid System in well Mt Kingsley 6.

EHS Support, LLC (EHS Support) conducted a Quantitative Risk Assessment (QRA) to meet Conditions 49e and 49f of the 2 October 2011 approval under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC 2008/4059) and the Environmental Amendment (EA) conditions to assess the toxicity of the mixtures.

The results and conclusions of the qualitative risk assessment components and the QRA are presented below. Refer to **Section 6.0** through **Section 8.0** for detailed discussions on the methodologies employed for the qualitative risk assessment and QRA components, which are referenced in the sections below.

C2.0 Qualitative Risk Assessment and Evaluation

C2.1 Chemicals Evaluated

The Halliburton Fluorescein Dye Hydraulic Fracturing Fluid System was assessed. The list of individual chemicals is presented in **Table 1** below. A mass balance of the chemicals is provided as **Table C9-1**.

Information regarding the chemical and physical properties of the individual chemicals listed below as well as the approximate percentage present in the hydraulic fracturing system can be found on the Safety Data Sheets in **Appendix E**.

The fluid system does not contain BTEX (benzene, toluene, ethylbenzene, xylenes) or polycyclic aromatic hydrocarbons (PAHs) based on EHS Support's understanding that Halliburton has tested all of their products. Field monitoring will also be conducted in accordance with regulatory requirements. While none of the fracturing fluid chemicals identified contain BTEX or PAHs, PAHs occur naturally in coal and it is possible that certain PAHs may naturally be present in the coal seam groundwater used in the hydraulic fracturing process.

Table 1: Hydraulic fracturing chemicals

Chemical	CAS Number
Sodium fluorescein	518-47-8
Tributyl tetradecyl phosphonium chloride	81741-28-8
Potassium chloride	7447-40-7

C2.2 Risk Assessment Framework and Findings

As discussed in **Section 5.0**, a systematic weight of evidence approach was utilised to complete the risk assessment for the Halliburton Fluorescein Dye Hydraulic Fracturing Fluid System. The work has involved the following evaluations:

Qualitative Assessment Methodologies

- PBT Assessment
- Exposure Assessment
- Mass Balance of Fluid System
- Fate and Transport Modeling.

Quantitative Risk Assessment Methodologies

- Quantitative Human Health Risk Assessment (HHRA)
- Quantitative Ecological Risk Assessment for Terrestrial and Aquatic Receptors.

C2.3 PBT Assessment

For the environmental hazard assessment, a PBT (persistence, bioaccumulative, toxicity) assessment was conducted in accordance with the guidance developed by DEWHA (2009), as presented in **Section 6.1**. The PBT assessment is conducted because of specific concerns for substances that can be shown to persist for long periods in the environment, to bioaccumulate in food chains, and can give rise to toxic effects after a longer time and over a greater spatial scale than chemicals without these properties. These effects may be difficult to detect at an early stage because of long-term exposures at normally low concentration levels and long life-cycles of species at the top of the food chain.

The PBT approach outlined in **Section 6.1** was undertaken to rank the hydraulic fracturing chemicals based on PBT potential. As a result of this assessment, no chemical constituents identified in the Halliburton Fluorescein Dye Hydraulic Fracturing Fluid System were classified as a PBT chemical and are therefore not considered to be inherently hazardous (**Appendix G**). The results of the PBT Assessment are presented in **Table 2**, attached.

C2.3 Exposure Assessment

As discussed in **Section 7.0**, the exposure assessment identified receptors potentially exposed to chemicals of potential concern (COPC) identified for the study and outlines the exposure pathways by which the receptors may come in to contact with the COPCs. A detailed exposure assessment was not conducted in the qualitative risk assessment.

C2.4 Mass Balance of Fluid System

A quantitative mass balance calculation was undertaken to identify the amount of each chemical additive of the hydraulic fracturing fluid system. The results of the mass balance calculations are presented in **Table C9-1**.

C2.5 Fate and Transport Modelling

As discussed in **Section 7.2**, fate and transport modelling was conducted on a range of key constituents of interest in typical hydraulic fracturing fluid systems. These results provided the framework for assessing potential mobility of all constituents used in hydraulic fracturing. The modelling demonstrated that despite the variability in chemical properties between fluid systems there is limited potential for chemicals to migrate within the coal seams. Refer to **Section 7.2** for further detail.

C3.0 Quantitative Risk Assessment

In accordance with the methodologies presented in **Section 8.0**, a QRA was conducted on theoretical datasets for those chemicals identified in the Halliburton Fluorescein Dye Hydraulic Fracturing Fluid System. The QRA approach evaluates the toxicity of the individual substances, and characterises the cumulative risks of the total effluent toxicity and ecotoxicity.

Generally, this methodology includes the identification of the hazards posed by constituents in the flowback water, compilation of the toxicity criteria for each constituent, development of exposure models to estimate the daily intake of the constituents, and calculations of individual constituent hazard quotients (daily intake divided by the toxicity criteria) and a cumulative constituent hazard index (HI) for each potentially complete exposure pathway for each human or terrestrial receptor.

Potential complete exposure pathways to the storage of flowback from hydraulically stimulated wells, and potential risks to humans, terrestrial and aquatic receptors from the potential storage and accidental releases are evaluated in the QRA.

No further assessment of groundwater was determined to be necessary due to lack of potentially complete exposure pathways. Detailed operational procedures have been provided that are designed to contain the hydraulic fracturing fluids within the coal sequences, and no connection exists between groundwater in the coal seams and surface-water or springs (and therefore Matters of National Environmental Significance [MNES]). Further, the potential risks to workers involved with the hydraulic fracturing process were not considered as detailed Health and Safety (H&S) procedures are employed to manage exposures. The QRA considered the following specific exposure pathways:

1. Exposure of trespassers to flowback water contained within flowback storage ponds.
2. Exposure of terrestrial receptors (e.g., livestock and wildlife) to flowback water contained within the flowback storage tank.
3. Exposure of aquatic receptors to flowback water in the situation of an accidental release, such as from piping or a release from the flowback storage tank. These potential releases could include a failure of containment systems, overtopping of the dam or in an extreme situation (considered highly unlikely) structural failure of the dam itself.

C3.1 Exposure Assessment

The purpose of the exposure assessment in the QRA was to predict the magnitude and frequency of potential human exposure to each COPC following the methodologies presented in **Section 8.1**. A conceptual site model (CSM) was developed which describes the potential receptors and exposure scenarios for the flowback water used in this exposure assessment. The potential exposures to receptors were evaluated based on the potential for a complete exposure pathway.

As discussed in **Section 8.2**, exposure point concentrations (EPCs) were derived for the theoretical assessment; empirical data were not available for evaluation. The EPCs for the theoretical assessment were calculated by estimating the mass and discharge flow of the COPCs in the flowback water.

C3.2 Human Health QRA

A human health hazard assessment was conducted according to the methodologies presented in **Section 8.4**. The purpose of the hazard assessment process was to summarise the environmental data, and to address the toxicological assessment of the COPCs that will be evaluated further in the risk assessment process.

Exposure assumptions for the human trespasser scenario were developed based on default or site-specific assumptions (**Section 8.4**). This receptor exposure pathway includes a small child to teenager

that may come in contact with the above grade water exposure scenario for approximately 20 days/year for a 10-year period with potential incidental ingestion [of 50 millilitres (ML) of water] and dermal contact (e.g., swimming where the whole body gets wet) for one half hour. The exposure parameters used in the QRA are presented on **Table 3**, attached.

Calculation of intake of COPCs was performed using the equations presented below:

Ingestion of water:

$$Intake\ (mg/kg-day)\ =\ (CW\ x\ IR\ X\ EF\ X\ ED)\ /\ (BW\ x\ AT)$$

Dermal contact with water:

$$Absorbed\ dose\ (mg/kg-day)\ =\ (CW\ x\ SA\ x\ DP\ x\ ET\ x\ EF\ x\ ED\ x\ CF)\ /\ (BW\ x\ AT)$$

Where:

CW = concentration in water (mg/l)
ET = exposure time (hr/day or hours/hours)
EF = exposure frequency (day/year)
ED = exposure duration (years)
CF = correction factor (1 x 10-3 l/cm3)
AT = averaging time (days)
IR = ingestion rate (l/hr)
BW = body weight (kg)
SA = skin surface area available for contact (cm2/d)
DP = dermal permeability factor (Kp – cm/hr).

C3.3 Toxicity Assessment

A toxicity assessment was conducted to determine the relationship between the dose of a COPC taken into the body, and the probability that an adverse effect will result from that dose. Quantitative estimates of the potency of COPCs include two sets of toxicity values, one for genotoxic carcinogens and one for other non-genotoxic carcinogens and non-carcinogenic effects. As discussed in **Section 8.4**, detailed toxicological profiles were developed for the chemicals. The toxicological profiles are included as **Appendix F9**.

The assessment of toxicity of the COPCs was used to develop initial screening criteria for human health exposure scenarios as discussed in **Section 8.4**. The derivation of Oral Reference Dose and Drinking Water Guideline Values are presented in **Table 4**, attached.

C3.4 Exposure Point Concentration

As presented above, the exposure scenarios are based on anticipated conditions, and the potential for exposure to the theoretical estimate of exposure. EPCs for the exposure assessment were calculated using the results of theoretical fate and transport modelling calculations and the existing environmental conditions within the fracturing fluids flowback storage ponds, and the flowback used in the irrigation fields.

To assess the potential flux of hydraulic fracturing chemicals to the environment, vendor disclosures for the hydraulic fracturing fluid systems were reviewed, and the chemical concentrations of key inputs were determined.

For the theoretical calculations, the mass and estimated chemical concentrations of the COPCs in the Halliburton Fluorescein Dye Hydraulic Fracturing Fluid System, as presented in **Table C9-1**, were used to estimate the potential concentrations in water within the fracturing fluids sump or flare pit, or flowback storage ponds. Based on stimulation flow back monitoring conducted by Santos and the QRA completed

for the Schlumberger Fluid Systems (**Appendix C**), 20 percent (%) of the total mass of constituents injected is assumed to be recovered in the flowback water. This mass is diluted within 150 % of the injected volume (the minimum volume that must be flowed back) to establish an "estimated" concentration (i.e., concentration expected due to full dilution of the back flow water) within the flowback storage ponds.

The flowback water will be contained within the flowback storage ponds for a projected maximum period of one year of operational activity before transfer or conveyance to the water treatment facilities and or transferred into Santos water convenyance systems (for treatment) and thereby blended with other coal seam gas (CSG) water not containing these constituents. To be conservative it has been assumed that the fluids are stored with ponds with theconcentration of COPCs in the flowback storage pond water adjusted, where applicable, to account for the biodegradation and photolytic degradation of constituents over time. The biodegradation information was obtained from the Organisation for Economic Cooperation and Development (OECD) ready tests (OECD, 1992) that were developed as a first-tier testing scheme to provide preliminary screening of organic chemicals. The ready tests are stringent screening tests that are conducted under aerobic conditions in which a high concentration of the test substance is used, and biodegradation is measured by non-specific parameters including dissolved organic carbon, biochemical oxygen demand and carbon dioxide production. **Table 5**, attached, presents the environmental fate information that was used to assess biodegradation of COPCs, and that was applied at the time periods of 0, 30, 150 and 300 days from initial flowback.

The water quality data derived using these assumptions for the theoretical COPCs are presented in **Table C9-1**.

The theoretical EPCs for the four exposure time periods (0, 30, 150 and 300 days) were compared to human health toxicity-based screening levels, and the results of this comparison, including the ratio of exceedance of screening levels, is presented in **Table C9-2**.

C3.5 Risk Estimation

Risk estimation was performed in accordance with the methodologies outlined in Section 8.4 of the RA Compendium. The total target risk range for carcinogens was 1×10^{-4} to 1×10^{-6}; the target HI for non-threshold effects is less than or equal to 1.0.

No carcinogenic compounds are present in the stimulation fluids injected into the subsurface and as a result, only non-carcinogenic risks were calculated.

The results of the theoretical assessments for Halliburton Fluorescein Dye Hydraulic Fracturing Fluid System for the trespasser exposure scenarios (day 0 and day 150, Halliburton Fluorescein Dye Hydraulic Fracturing Fluid System events) are summarized in **Tables 6** and **7**, attached. As discussed above, the theoretical assessment was only conducted at the well pad sites.

The exposure scenarios include the Halliburton Fluorescein Dye Hydraulic Fracturing Fluid System event, as presented in **Table C9-1** for day 0 and day 150 from the flowback storage tank. The trespasser for day 0 had no unacceptable risks for the Halliburton Fluorescein Dye Hydraulic Fracturing Fluid System (HI=0.04, **Table 6**, attached), and for day 150 (HI=0.028, **Table 7**, attached). There were no unacceptable risks for either day scenario.

On this basis and using the theoretical concentrations, on this basis and using the theoretical concentrations, no adverse effects are predicted on trespassers.

C3.6 Ecological Risk Assessment

As discussed in **Section 8.5**, a screening level ecological risk assessment (ERA) was conducted to evaluate the potential for adverse ecological effects to terrestrial and aquatic ecological receptors that may be exposed to residual levels of hydraulic fracturing fluids in surface water used in the CSG fields.

C3.7 Exposure Assessment

Terrestrial receptors evaluated in the ERA include domesticated livestock, large mammalian wildlife and small mammalian wildlife. Beef cattle were used to evaluate domesticated livestock, kangaroos evaluated for large mammalian wildlife, and dingos for small mammalian wildlife. Aquatic receptors evaluated included invertebrates and fishes.

The estimate for dose-based or intake rates for the assessment endpoints for wildlife representing domestic livestock and native mammalian species used the following general equation:

TI = Cwater x IRwater x EF x ED / BW x ED x 365 days/year

Where:

TI = Total intake of COPC (mg/kg/day)
Cwater = Concentration of COPC in water (mg/l)
IRwater = Ingestion rate (litres/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg).

The exposure assumptions are presented in **Tables 8** through **10**, attached.

C3.8 Toxicity Assessment

To evaluate the potential for adverse ecological effects, toxicity reference values (TRVs) are selected as measurement endpoints for the ERA that will be used in the risk analysis. The TRVs are based on COPC levels that imply no adverse effects or levels that represent the lowest concentration at which adverse effects may occur. The ERA used two types of TRVs (Section 8.5.3 of the RA Compendium). The first TRV is a concentration-based TRV to evaluate the concentration of the selected COPC in the surface water and direct exposure by the aquatic ecological receptor. The determination of TRVs for freshwater was conducted according to the predicted no-effects concentration (PNEC) guidance in the Environmental Risk Assessment Guidance Manual for Industrial Chemicals prepared by the Australian Environmental Agency (AEA, 2009). As discussed in **Section 8.4**, detailed environmental profiles were developed for the chemicals. The environmental profiles are included in the risk dossiers in **Appendix G**. **Table 11**, attached, presents the COPC, the endpoint, NOEC [milligrams per litre (mg/L)], assessment factor, and the aquatic PNEC (mg/L). The second TRV is a dose-based TRV to evaluate the intake dose of the selected COPC from exposure to surface water by ingestion. The calculated TRVs for each of the mammalian ecological receptors evaluated in the ERA are presented in the species-specific ecological risk models.

C3.9 Exposure Point Concentration

EPCs for the exposure assessment were calculated using the results of theoretical fate and transport modelling calculations. The potentially affected flowback water that represents complete exposure pathways for the ecological receptors includes the surface water systems (e.g., flowback storage ponds and mud pits) that were used to estimate the EPCs for the human health receptors. The EPCs for the ecological receptors were estimated assuming the same scenarios, with exposure occurring in the irrigation area where irrigation water may pool and wildlife may drink from the standing water. **Table C9-**

1 presents the calculated EPCs for the ecological receptor exposure scenarios. The theoretical EPCs for the four exposure time periods (0, 30, 150, and 300 days) were compared to ecological based toxicity-based screening levels, and the results of this comparison, including the ratio of exceedance of screening levels, is presented in **Table C9-3**.

Risks were characterised in accordance with the methodologies discussed in Section 8.5.6 of the RA Compendium. The resulting ecological hazard quotient must be less than or equal to 1.0 for risks to be considered acceptable.

C3.10 Estimation of Risk

The HI calculated for flowback water for aquatic risk were elevated above the acceptable level for the majority of COPCs evaluated (**Table C9-3**). Where large discharges of flowback water occur to surface water and/or flux dilution within the surface-water was insufficient, potential impacts on aquatic receptors could occur. As noted in the toxicity assessment section above, the lack of a robust aquatic toxicological database resulted in highly conservative aquatic screening values for the theoretical exposure scenario COPCs to be conservatively very low.

The results of the theoretical assessments for Halliburton Fluorescein Dye Hydraulic Fracturing Fluid System for the livestock cattle, kangaroo and dingo are summarized in **Tables 12** through **17**, attached. The exposure scenarios include the Halliburton Fluorescein Dye Hydraulic Fracturing Fluid System EPCs presented in **Table C9-1**for day 0 and day 150 from the fracturing fluid well flowback. The modelled risks from Halliburton Fluorescein Dye Hydraulic Fracturing Fluid System chemicals in the flowback water were acceptable for the livestock (HI=0.15 to 0.14, **Table 12** and **13**, attached), kangaroo (HI=0.031 0.029, **Table 14** and **15**, attached), and dingo (HI=0.013 to 0.012, **Table 16** and **17**, attached), for all exposure scenarios.

C4.0 Summary of QRA Findings

The QRA was completed as discussed in **Section 8.0**. An assessment was conducted using highly conservative theoretical calculations based on the chemicals utilised by Halliburton in hydraulic fracturing. This assessment assumed that a range of theoretical concentrations of injected chemicals would be present in the flowback water based on biodegradation rates, where applicable.

Consistent with the risk assessment and groundwater fate and transport modelling conducted by Golder, no potentially complete exposure pathways were identified for groundwater. Potential exposures are limited to the aboveground storage and handling of flowback water as part of the CSG Water Management Plan (WMP). Management of CSG water involves the temporary storage of flowback water in flowback storage ponds.

The exposure scenario modelled for the QRA was a trespasser being exposed to flowback water under various EPC scenarios. Based on quantitative risk calculations, the potential risks for the trespasser were acceptable for the EPC scenarios. There were no carcinogenic risks identified.

The modelled risks from Halliburton Fluorescein Dye Hydraulic Fracturing Fluid System chemicals in the flowback water were acceptable for the livestock cattle, kangaroo, and dingo for all EPC exposure scenarios.

Potential impacts could occur if releases of flowback water were to occur to aquatic environments. Based on the use of low permeability materials (clay liners) and operational controls that limit the potential for turkey nest and dam overflows, the potential for these risks are also considered limited.

A combination of management and operational controls are being implemented to eliminate and control the potential for exposures. These include:

- Worker training and hazard identification
- Use of appropriate personal protective equipment (gloves, etc.)
- Flowback storage pond fencing to prevent entry of livestock and native fauna and minimise trespassing
- Use of low permeability materials or dam liners and routine dam inspections to prevent releases from flowback storage ponds
- Routine operational and security patrols to prevent trespassing.

C5.0 Conclusions

A weight-of-evidence evaluation of potential risks as described in **Section 5.0** was performed for the Halliburton Fluorescein Dye Hydraulic Fracturing Fluid System. Based on the qualitative and quantitative risk characterisations, the overall risk to human health and the environment is acceptable. Existing operational control activities employed by Santos are in place that will limit the potential risks to human health and the environment. These measures include:

- Occupational health and safety procedures implemented during hydraulic fracturing operations to prevent workers from direct contact with chemicals during spills and when handling flowback water or sediments;
- Environmental authority conditions that preclude the construction of well pads within 100 metres of a watercourse of water body;
- Implementation of spill containment procedures during operations to prevent migration of and exposure to chemicals;
- Disposal or capping of sediments contained within drained mud pits and turkey nests , to prevent exposure to contaminates in windborne dust;
- Fencing of drill pads to prevent trespassers and installation of signs to indicate that the water in the turkeys nest and mud pit is not potable and may contain contaminants;
- Installation and maintenance of fences around the well pad to prevent access to the drill pad by livestock and large native fauna;
- Santos operational procedures to ensure well integrity and design of fracture to stay within the target seam; and
- Mud pits and turkeys nests with clay liners, or similar material, to prevent seepage of flowback water into underlying aquifers.

Monitoring of water supply bores and surface water for a representative suite of chemicals within 2 kilometre of wells (and 200 m vertical separation) that are fractured will be conducted (as needed) to confirm the conclusion of incomplete exposure pathways and low risk.

No additional risks, other than those previously discussed, were identified with the chemicals or systems employed in hydraulic fracturing. Evaluation of other potential risks associated with hydraulic fracturing (i.e., noise and vibration) was conducted. Refer to **Section 9.0** for methodology specifics and results of this evaluation.

Tables

Table 2: PBT Assessment of the Halliburton Fluorescein Dye Fluid System

Substance	P/vP criteria fulfilled?	B/vB criteria fulfilled?	T criteria fulfilled?	Overall conclusion
Potassium chloride (14808-60-7)	Not applicable (inorganic salt)	No (estimated)	No (screening data available)	Not PBT (based on screening data and estimation)
Tributyl tetradecyl phosphonium chloride (81741-28-8)	Yes (measured data available)	No (screening data available)	Yes (screening data available)	Not PBT (based on measured and screening data)
Sodium fluorescein (518-47-8)	Yes (screening data available)	No (screening data available)	No (screening data available)	Not PBT (based on screening data)

Table 3 Exposure Assumptions - Trespasser

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/hr	0.05
	ET	Exposure time	hr/day	0.5
	EF	Exposure frequency	day/yr	20
	ED	Exposure duration	yr	10
	BW	Body weight	kg	47
	AT-NC	Averaging time - noncancer	days	3,650
	AT-C	Averaging time - cancer	days	25,550
Dermal	SA	Surface area for contact	cm^2/day	13,000
	DP	Dermal permeability factor	cm/h	chemical-specific
	ET	Exposure time	hr/day	1
	EF	Exposure frequency	day/yr	20
	ED	Exposure duration	yr	10
	BW	Body weight	kg	47
	AT-NC	Averaging time - noncancer	days	3,650
	AT-C	Averaging time - cancer	days	25,550
	CF	Conversion factor	l/cm^3	1.0E-03

Table 4: Oral Reference Doses and Drinking Water Guidelines Derived for Hydraulic Fracturing Chemicals

Constituent (CAS No.)	Study	Critical Effect/Target Organ(s)	NOAEL (mg/kg-day)	Uncertainty Factors	Oral Reference Dose (mg/kg-day)	Drinking Water Guideline (ppm)
Potassium chloride	Rat 2-yr dietary	None	1,820	100	18	64
Tributyl tetradecyl phosphonium chloride	Rat 90-day drinking water	General toxicity	8.66	1,000	0.009	0.03
Sodium fluorescein	Rabbit developmental	None	250	1,000	2.5	8.8

Table 5 Environmental Fate Information

Potassium chloride	Dissociates completely in aqueous media
Tributyl tetradecyl phosphonium chloride	Inherently biodegradable (half-life = 150 days)[a]
Sodium fluorescein	Not biodegradable

a Source: EU Guidance Document: Half-life estimates from in vitro biodegradation test results

Table 6 Risk Estimates for Trespasser
Halliburton Fluorescein Dye Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 0

		Day 0		Toxicity	Halliburton Fluorescein Dye Fluid System			
							Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**PC (cm/hr)**	**RfDo**	**$CADD_{oral}$**	**$CADD_{derm}$**	**Incidental Ingestion**	**Dermal**
Potassium chloride	7447-40-7	5.1E+03	NA	18	3.0E-01	-	1.7E-02	-
Tributyl tetradecyl phosphonium chloride	81741-28-8	3.6E+00	NA	0.009	2.1E-04	-	2.4E-02	-
Sodium fluorescein	518-47-8	2.6E-01	4.5E-06	2.5	1.5E-05	8.7E-09	6.0E-06	3.5E-09
							Hazard Index	4.0E-02

Table 7 Risk Estimates for Trespasser
Halliburton Fluorescein Dye Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 150

		Day 150		Toxicity	Halliburton Fluorescein Dye Fluid System			
							Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**PC (cm/hr)**	**RfDo**	**$CADD_{oral}$**	**$CADD_{derm}$**	**Incidental Ingestion**	**Dermal**
Potassium chloride	7447-40-7	5.1E+03	NA	18	3.0E-01	-	1.7E-02	-
Tributyl tetradecyl phosphonium chloride	81741-28-8	1.8E+00	NA	0.009	1.1E-04	-	1.2E-02	-
Sodium fluorescein	518-47-8	2.6E-01	4.5E-06	2.5	1.5E-05	8.7E-09	6.0E-06	3.5E-09
						Hazard Index		2.8E-02

Table 8 Exposure Assumptions - Cattle

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/day	86
	EF	Exposure frequency	day/yr	15
	ED	Exposure duration	yr	8
	BW	Body weight	kg	454
	AT-NC	Averaging time - noncancer	days	2,920

Table 9 Exposure Assumptions - Kangaroo

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/day	3
	EF	Exposure frequency	day/yr	10
	ED	Exposure duration	yr	15
	BW	Body weight	kg	25
	AT-NC	Averaging time - noncancer	days	5,475

Table 10 Exposure Assumptions - Dingo

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/day	0.75
	EF	Exposure frequency	day/yr	10
	ED	Exposure duration	yr	15
	BW	Body weight	kg	13
	AT-NC	Averaging time - noncancer	days	5,475

Table 11: Aquatic Toxicity Values (PNECs) for Hydraulic Fracturing Chemicals

Constituents	Endpoint	E(L)C50 or NOEC (mg/L)	Assessment Factor	$PNEC_{aquatic}$ (mg/L)
Potassium chloride	Acute Algae	100	1,000	0.1
Tribuyl tetradecyl phosphonium chloride	Acute *Daphnia*	0.025	1,000	2.5×10^{-5}
Sodium fluorescein	Acute *Daphnia*	337	1,000	0.34

Table 12 Risk Estimates for Cattle
Halliburton Fluorescein Dye Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 0

		Day 0	Toxicity	Halliburton Fluorescein Dye Fluid System	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Potassium chloride	7447-40-7	5.1E+03	3.0E+02	4.0E+01	1.3E-01
Tributyl tetradecyl phosphonium chloride	81741-28-8	3.6E+00	1.4E+00	2.8E-02	2.0E-02
Sodium fluorescein	518-47-8	2.6E-01	7.7E+01	2.0E-03	2.6E-05

Hazard Index
1.5E-01

Table 13 Risk Estimates for Cattle
Halliburton Fluorescein Dye Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 150

		Day 150	Toxicity	Halliburton Fluorescein Dye Fluid System	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Potassium chloride	7447-40-7	5.1E+03	3.0E+02	4.0E+01	1.3E-01
Tributyl tetradecyl phosphonium chloride	81741-28-8	1.8E+00	1.4E+00	1.4E-02	9.8E-03
Sodium fluorescein	518-47-8	2.6E-01	7.7E+01	2.0E-03	2.6E-05

Hazard Index
1.4E-01

Table 14 Risk Estimates for Kangaroo
Halliburton Fluorescein Dye Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 0

		Day 0	Toxicity	Halliburton Fluorescein Dye Fluid System	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Potassium chloride	7447-40-7	5.1E+03	6.3E+02	1.7E+01	2.7E-02
Tributyl tetradecyl phosphonium chloride	81741-28-8	3.6E+00	3.0E+00	1.2E-02	4.0E-03
Sodium fluorescein	518-47-8	2.6E-01	1.6E+02	8.4E-04	5.3E-06

Hazard Index
3.1E-02

Table 15 Risk Estimates for Kangaroo
Halliburton Fluorescein Dye Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 150

		Day 150	Toxicity	Halliburton Fluorescein Dye Fluid System	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Potassium chloride	7447-40-7	5.1E+03	6.3E+02	1.7E+01	2.7E-02
Tributyl tetradecyl phosphonium chloride	81741-28-8	1.8E+00	3.0E+00	6.0E-03	2.0E-03
Sodium fluorescein	518-47-8	2.6E-01	1.6E+02	8.4E-04	5.3E-06

Hazard Index
2.9E-02

Table 16 Risk Estimates for Dingo
Halliburton Fluorescein Dye Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 0

		Day 0	Toxicity	Halliburton Fluid System - Well RM 08-14-3	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Potassium chloride	7447-40-7	5.1E+03	7.4E+02	8.1E+00	1.1E-02
Tributyl tetradecyl phosphonium chloride	81741-28-8	3.6E+00	3.5E+00	5.8E-03	1.6E-03
Sodium fluorescein	518-47-8	2.6E-01	1.9E+02	4.0E-04	2.2E-06

Hazard Index
1.3E-02

Table 17 Risk Estimates for Dingo
Halliburton Fluorescein Dye Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 150

		Day 150	Toxicity	Halliburton Fluid System - Well RM 08-14-3	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Potassium chloride	7447-40-7	5.1E+03	7.4E+02	8.1E+00	1.1E-02
Tributyl tetradecyl phosphonium chloride	81741-28-8	1.8E+00	3.5E+00	2.9E-03	8.2E-04
Sodium fluorescein	518-47-8	2.6E-01	1.9E+02	4.0E-04	2.2E-06

Hazard Index
1.2E-02

Appendix C9-1

HALLIBURTON CONFIDENTIAL INFORMATION - ONLY TO BE USED FOR REGULATOR NOTIFICATION (QLD FORMAT)

Comments:
Santos CSG PreJob Mount Kinsley 6, 3000 lb 20/40 Sand, 135000 lb 16/30 Sand

Total injected fluid volume (kiloliters):	1182.800

Comprising of: (Kilograms, liters or kiloliters)		
Base Fluid type (e.g. water)	**Liters**	**% of total volume**
Makeup Water	1135623	96.0%

Proppant type (e.g sand)	**Proppant Size**	**Kilograms**	**Liters**	**% of total volume**
20/40 Sand	20/40	1361	514	0.0434%
16/30 Sand	16/30	61235	23108	1.95%

Any wet chemical constitutes:	**Liters**	**% of total volume**
Potassium chloride	22839	1.93%
Water in Products	681	0.0576%
Tributyl tetradecyl phosphonium chloride	34	0.00288%
Sodium fluorescein	1.4	0.00012%

Appendix C9-Tables

Table C9-1 Surface Water Quality Data for Theoretical Scenario in Initial Flowback for Halliburton Fluorescein Dye Hydraulic Fracturing Fluid System

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Mud Pit Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Mud Pitcon = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)			
				Temporal Scenario (days)			
		Halliburton Fluorescein Dye	Half-Life (days)	0	30	150	300
Potassium chloride	7447-40-7	38,425.8	NA	5123.4	5123.4	5123.4	5123.4
Tributyl tetradecyl phosphonium chloride	81741-28-8	27.4	150	3.6	3.2	1.8	0.9
Sodium fluorescein	518-47-8	1.9	NA	0.3	0.3	0.3	0.3

Table C9-2 Comparison of Estimated Theoretical Halliburton Fluorescein Dye Hydraulic Fracturing Fluid System Concentrations to Human Health Drinking Water Guidelines

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Mud Pit Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Mud Pitcon = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)				Drinking Water Guideline (mg/L)	Ratio of COPC Concentrations and Screening Criteria (Ratio greater than one = unacceptable potential risk)			
				Temporal Scenario (days)					Temporal Scenario (days)			
		Halliburton Fluorescein Dye	Half-Life (days)	0	30	150	300		0	30	150	300
Potassium chloride	7447-40-7	38,425.8	NA	5123.4	5123.4	5123.4	5123.4	64	8.0E+01	8.0E+01	8.0E+01	8.0E+01
Tributyl tetradecyl phosphonium chloride	81741-28-8	27.4	150	3.6	3.2	1.8	0.9	0.03	1.2E+02	1.1E+02	6.1E+01	3.0E+01
Sodium fluorescein	518-47-8	1.9	NA	0.3	0.3	0.3	0.3	8.8	2.9E-02	2.9E-02	2.9E-02	2.9E-02
								Cumulative Ratio	**201.7**	**186.0**	**140.9**	**110.5**

Table C9-3 Comparison of Estimated Theoretical Halliburton Fluorescein Dye Hydraulic Fracturing Fluid System Concentrations to Aquatic Life Water Guidelines

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Mud Pit Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Mud Pitcon = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)				PNEC aquatic (mg/L)	Ratio of COPC Concentrations and Screening Criteria (Ratio greater than one = unacceptable potential risk)			
				Temporal Scenario (days)					Temporal Scenario (days)			
		Halliburton Fluorescein Dye	Half-Life (days)	0	30	150	300		0	30	150	300
Potassium chloride	7447-40-7	38,425.8	NA	5123.44	5123.4	5123.4	5123.4	1.0E-01	5.1E+04	5.1E+04	5.1E+04	5.1E+04
Tributyl tetradecyl phosphonium chloride	81741-28-8	27.4	150	3.6	3.2	1.8	0.9	2.5E-05	1.5E+05	1.3E+05	7.3E+04	3.6E+04
Sodium fluorescein	518-47-8	1.9	NA	0.3	0.3	0.26	0.25566	3.4E-01	7.5E-01	7.5E-01	7.5E-01	7.5E-01
								Cumulative Ratio	**197,172.4**	**178,280.9**	**124,203.8**	**87,719.4**

Santos

Appendix C10
Condor Energy Services
Hydraulic Fracturing Fluid System

C1.0 Introduction

Santos Ltd. (Santos) is looking to use a borate, guar-based crosslinked Condor Energy Services hydraulic fracturing fluid system (the fluid system) for development of coal seam gas (CSG) resources in the Surat and Bowen Basins of Queensland. The disclosure for Condor Energy Services hydraulic fracturing fluid system, including a listing of the chemical constituents and percent of total volume in the fluid system, is provided in **Appendix C10-1**.

As presented in **Section 5.0** of the Hydraulic Fracturing Risk Assessment, Santos used a weight-of-evidence approach to evaluate the potential for human health and environmental (e.g., ecological) risks as a result of the hydraulic fracturing processes and the use of the Condor Energy Services hydraulic fracturing fluid system.

EHS Support, LLC (EHS Support) conducted a Quantitative Risk Assessment (QRA) to meet Conditions 49e and 49f of the 2 October 2011 approval under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC 2008/4059) and the Environmental Amendment (EA) conditions to assess the toxicity of the mixtures.

The results and conclusions of the qualitative risk assessment components and the QRA are presented below. Refer to **Section 6.0** through **Section 8.0** for detailed discussions on the methodologies employed for the qualitative risk assessment and QRA components, which are referenced in the sections below.

C2.0 Qualitative Risk Assessment and Evaluation

C2.1 Chemicals Evaluated

The Condor Energy Services hydraulic fracturing fluid system was assessed. The list of individual chemicals assessed is presented in **Table 1** below. A mass balance of the chemicals is provided as **Table C10-1**.

Information regarding the chemical and physical properties of the individual chemicals listed below as well as the approximate percentage present in the hydraulic fracturing system can be found on the Safety Data Sheets in **Appendix E**.

The fluid system does not contain BTEX (benzene, toluene, ethylbenzene, xylenes) or polycyclic aromatic hydrocarbons (PAHs) based on EHS Support's understanding that Condor Energy has tested all their products. Field monitoring will also be conducted in accordance with regulatory requirements. While none of the fracturing fluid chemicals identified contain BTEX or PAHs, PAHs occur naturally in coal and it is possible that certain PAHs may naturally be present in the coal seam groundwater used in the hydraulic fracturing process.

Table 1: Hydraulic fracturing chemicals

Chemical	CAS Number
Alcohols, C9-11, ethoxylated	68439-46-3
Ethoxylated C11 Alcohol	34398-01-1
Ethylene Glycol	107-21-1
Choline Chloride	67-48-1
Glutaraldehyde	111-30-8
Ammonium Sulphate	7783-20-2
Polyacrylamide	25085-02-3
Sodium polyacrylate	9003-04-7
Sodium bisulfite	7631-90-5
2-Propenoic acid, homopolymer, ammonium salt	9003-03-6
Ammonium Persulphate	7727-54-0
Potassium persulfate	7727-21-1
2-Ethoxy-naphthalene	93-18-5
Potassium Hydroxide	1310-58-3
Inorganic Salt	584-08-7
Glycerol	56-81-5
Sodium Tetraborate	1330-43-4
Sodium Hydroxide	1310-73-2
Hemicellulase	9025-56-3
Amylase, Alpha	9000-90-2
Sodium Benzoate	532-32-1
Pottasium Sorbate	24634-61-5
DISTILLATES, HYDROTREATED LIGHT	64742-47-8
Guar Gum	9000-30-0
Polyoxyethylene nonylphenol ether	9016-45-9
Quaternary ammonium compounds, bis(hydrogenated tallow alkyl)dimethyl, salts with bentonite	68953-58-2
1,6-Hexanediol	629-11-8
HydroChloric Acid	7647-01-0
Cinnamaldehyde	104-55-2

Chemical	CAS Number
Tar Bases, Quinoline Derivatives, Benzyl Chloride-Quat	72480-70-7
Castor Oil	61791-12-6
Isopropanol	67-63-0
Pine Oil	8002-09-3
N-Benzyl-Alkylpyridinium Chloride	68909-18-2
Water in Additive	7732-18-5
2-Mercaptoethyl Alcohol	60-24-2
Polyoxyethylene-polyoxypropylene Block Copolymer	9003-11-6
Diethylene Glycol	111-46-6
Methanol	67-56-1
Formic Acid	64-18-6
Sodium erythorbate	6381-77-7
Acetic Acid	64-19-7
Potassium Chloride	7447-40-7

C2.2 Risk Assessment Framework and Findings

As discussed in **Section 5.0**, a systematic weight of evidence approach was utilised to complete the risk assessment for the Condor Energy Services hydraulic fracturing fluid system. The work has involved the following evaluations:

Qualitative Assessment Methodologies

- PBT Assessment
- Exposure Assessment
- Mass Balance of Fluid System
- Fate and Transport Modelling

Quantitative Risk Assessment Methodologies

- Quantitative Human Health Risk Assessment (HHRA)
- Quantitative Ecological Risk Assessment for Terrestrial and Aquatic Receptors
-

C2.3 PBT Assessment

For the environmental hazard assessment, a PBT (persistence, bioaccumulative, toxicity) assessment was conducted in accordance with the guidance developed by DEWHA (2009), as presented in the **Section 6.1**. The PBT assessment is conducted because of specific concerns for substances that can be shown to persist for long periods in the environment, to bioaccumulate in food chains, and can give rise to toxic effects after a longer time and over a greater spatial scale than chemicals without these properties. These effects may be difficult to detect at an early stage because of long-term exposures at normally low concentration levels and long life-cycles of species at the top of the food chain.

The PBT approach outlined in **Section 6.1** was undertaken to rank the hydraulic fracturing chemicals based on PBT potential. As a result of this assessment, no chemical constituents identified in the Condor Energy Services hydraulic fracturing fluid system were classified as a PBT chemical and are therefore not considered to be inherently hazardous. The results of the PBT Assessment are presented in **Table 2**, attached.

C2.3 Exposure Assessment

As discussed in **Section 7.0**, the exposure assessment identified receptors potentially exposed to chemicals of potential concern (COPCs) identified for the study and outlined the exposure pathways by which the receptors may come in to contact with the COPCs. A detailed exposure assessment was not conducted in the qualitative risk assessment.

C2.4 Mass Balance of Fluid System

A quantitative mass balance calculation was undertaken to identify the amount of each chemical additive of the hydraulic fracturing fluid system. The results of the mass balance calculations are presented in **Table C10-1**.

C2.5 Fate and Transport Modelling

As discussed in **Section 7.2**, fate and transport modelling was conducted on a range of key constituents of interest in typical hydraulic fracturing fluid systems. These results provided the framework for assessing potential mobility of all constituents used in hydraulic fracturing. The modelling demonstrated that despite the variability in chemical properties between fluid systems there is limited potential for chemicals to migrate within the coal seams. Refer to **Section 7.2** for further details.

C3.0 Quantitative Risk Assessment

In accordance with the methodologies presented in **Section 8.0**, a QRA was conducted on theoretical datasets for those chemicals identified in the Condor Energy Services hydraulic fracturing fluid system. The QRA approach evaluates the toxicity of the individual substances and characterises the cumulative risks of the total effluent toxicity and ecotoxicity.

Generally, this methodology includes the identification of the hazards posed by constituents in the flowback water, compilation of the toxicity criteria for each constituent, development of exposure models to estimate the daily intake of the constituents, and calculations of individual constituent hazard quotients (daily intake divided by the toxicity criteria) and a cumulative constituent hazard index (HI) for each potentially complete exposure pathway for each human or terrestrial receptor.

Potential complete exposure pathways to the storage of flowback from hydraulically stimulated wells, and potential risks to humans, terrestrial and aquatic receptors from the potential storage and accidental releases are evaluated in the QRA.

No further assessment of groundwater was determined to be necessary due to lack of potentially complete exposure pathways. Detailed operational procedures have been provided that are designed to contain the hydraulic fracturing fluids within the coal sequences, and no connection exists between groundwater in the coal seams and surface-water or springs (and therefore Matters of National Environmental Significance [MNES]). Further, the potential risks to workers involved with the hydraulic fracturing process were not considered as detailed Health and Safety (H&S) procedures are employed to manage exposures. The QRA considered the following specific exposure pathways:

1. Exposure of trespassers to flowback water contained within flowback storage ponds.
2. Exposure of terrestrial receptors (e.g., livestock and wildlife) to flowback water contained within the flowback storage tank.
3. Exposure of aquatic receptors to flowback water in the situation of an accidental release, such as from piping or a release from the flowback storage tank. These potential releases could include a failure of containment systems, overtopping of the dam or in an extreme situation (considered highly unlikely) structural failure of the dam itself.

C3.1 Exposure Assessment

The purpose of the exposure assessment in the QRA was to predict the magnitude and frequency of potential human exposure to each COPC following the methodologies presented in **Section 8.1**. A conceptual site model (CSM) was developed which describes the potential receptors and exposure scenarios for the flowback water used in this exposure assessment. The potential exposures to receptors were evaluated based on the potential for a complete exposure pathway.

As discussed in **Section 8.3**, exposure point concentrations (EPCs) were derived for the theoretical assessment; empirical data were not available for evaluation. The EPCs for the theoretical assessment were calculated by estimating the mass and discharge flow of the COPCs in the flowback water.

C3.2 Human Health QRA

A human health hazard assessment was conducted according to the methodologies presented in **Section 8.4**. The purpose of the hazard assessment process was to summarise the environmental data, and to address the toxicological assessment of the COPCs that will be evaluated further in the risk assessment process.

Exposure assumptions for the human trespasser scenario were developed based on default or site-specific assumptions (**Section 8.4**). This receptor exposure pathway includes a small child to teenager

that may come in contact with the above grade water exposure scenario for approximately 20 days/year for a 10-year period with potential incidental ingestion [of 50 millilitres (ML) of water] and dermal contact (e.g., swimming where the whole body gets wet) for one-half hour. The exposure parameters used in the QRA are presented on **Table 3**, attached.

Calculation of intake of COPCs was performed using the equations presented below:

Ingestion of water:

$$Intake\ (mg/kg-day)\ =\ (CW\ x\ IR\ X\ EF\ X\ ED)\ /\ (BW\ x\ AT)$$

Dermal contact with water:

$$Absorbed\ dose\ (mg/kg-day)\ =\ (CW\ x\ SA\ x\ DP\ x\ ET\ x\ EF\ x\ ED\ x\ CF)\ /\ (BW\ x\ AT)$$

Where:

AT = averaging time (days)
BW = body weight (kg)
CF = correction factor (1 x 10-3 l/cm3)
CW = concentration in water (mg/l)
DP = dermal permeability factor (Kp – cm/hr).
ED = exposure duration (years)
EF = exposure frequency (day/year)
ET = exposure time (hr/day or hours/hours)
IR = ingestion rate (l/hr)
SA = skin surface area available for contact (cm2/d)

C3.3 Toxicity Assessment

A toxicity assessment was conducted to determine the relationship between the dose of a COPC taken into the body, and the probability that an adverse effect will result from that dose. Quantitative estimates of the potency of COPCs include two sets of toxicity values, one for genotoxic carcinogens and one for other non-genotoxic carcinogens and non-carcinogenic effects. As discussed in **Section 8.4**, detailed toxicological profiles were developed for the chemicals. The toxicological profiles are included as **Appendix F10**.

The assessment of toxicity of the COPCs was used to develop initial screening criteria for human health exposure scenarios as discussed in **Section 8.4**. The derivation of Oral Reference Dose and Drinking Water Guideline Values are presented in **Table 4**, attached. Australian Drinking Water Screening Values for the COPCs are also presented on **Table 4**, attached.

C3.4 Exposure Point Concentration

As presented above, the exposure scenarios are based on anticipated conditions, and the potential for exposure to the theoretical estimate of exposure. EPCs for the exposure assessment were calculated using the results of theoretical fate and transport modelling calculations and the existing environmental conditions within the fracturing fluids flowback storage ponds, and the flowback used in the irrigation fields.

To assess the potential flux of hydraulic fracturing chemicals to the environment, vendor disclosures for the hydraulic fracturing fluid systems were reviewed, and the chemical concentrations of key inputs were determined.

For the theoretical calculations, the mass and estimated chemical concentrations of the COPCs in the Condor Energy Services hydraulic fracturing fluid system, as presented in **Table C10-1**, were used to estimate the potential concentrations in water within the fracturing fluids sump or flare pit, or flowback

storage ponds. Based on stimulation flow back monitoring conducted by Santos and the QRA completed for the Schlumberger Fluid Systems (**Appendix C**), 20 percent (%) of the total mass of constituents injected is assumed to be recovered in the flowback water. This mass is diluted within 150 % of the injected volume (the minimum volume that must be flowed back) to establish an "estimated" concentration (i.e., concentration expected due to full dilution of the back-flow water) within the flowback storage ponds.

The flowback water will be contained within the flowback storage ponds for a projected maximum period of one year of operational activity before transfer or conveyance to the water treatment facilities and or transferred into Santos water conveyance systems (for treatment) and thereby blended with other conveyance systems water not containing these constituents. To be conservative it has been assumed that the fluids are stored with ponds with the concentration of COPCs in the flowback storage pond water adjusted, where applicable, to account for the biodegradation and photolytic degradation of constituents over time. The biodegradation information was obtained from the Organisation for Economic Cooperation and Development (OECD) ready tests (OECD, 1992) that were developed as a first-tier testing scheme to provide preliminary screening of organic chemicals. The ready tests are stringent screening tests that are conducted under aerobic conditions in which a high concentration of the test substance is used, and biodegradation is measured by non-specific parameters including dissolved organic carbon, biochemical oxygen demand and carbon dioxide production. **Table 5**, attached, presents the environmental fate information that was used to assess biodegradation of COPCs, and that was applied at the time periods of 0, 30, 150 and 300 days from initial flowback.

The water quality data derived using these assumptions for the theoretical COPCs are presented in **Table C10-1**.

The theoretical EPCs for the four exposure time periods (0, 30, 150 and 300 days) were compared to human health toxicity-based screening levels, and the results of this comparison, including the ratio of exceedance of screening levels, is presented in **Table C10-2**.

C3.5 Risk Estimation

Risk estimation was performed in accordance with the methodologies outlined in **Section 8.4**. The total target risk range for carcinogens was 1×10^{-4} to 1×10^{-6}; the target HI for non-threshold effects is less than or equal to 1.0.

The results of the theoretical assessments for Condor Energy Services hydraulic fracturing fluid system for the trespasser exposure scenarios (day 0 and day 150, Condor Energy Services hydraulic fracturing fluid system events) are summarized in **Tables 6 and 7**, attached. As discussed above, the theoretical assessment was conducted at the well pad sites.

The exposure scenarios include the Condor Energy Services hydraulic fracturing fluid system event, as presented in **Table C10-1** for day 0 and day 150 from the flowback storage tank. The trespasser for day 0 had risks slightly above the target of 1.0 for the Condor Energy Services hydraulic fracturing fluid system (HI=3.6, **Table 6**, attached), and for day 150 (HI=1.7, **Table 7**, attached). The elevated HI were due to the dermal exposure pathway for distiilates, hydrotreated light.

On this basis and using the theoretical concentrations, on this basis and using the theoretical concentrations, no adverse effects are predicted on trespassers.

C3.6 Ecological Risk Assessment

As discussed in **Section 8.5**, a screening level ecological risk assessment (ERA) was conducted to evaluate the potential for adverse ecological effects to terrestrial and aquatic ecological receptors that may be exposed to residual levels of hydraulic fracturing fluids in surface water used in the CSG fields.

C3.7 Exposure Assessment

Terrestrial receptors evaluated in the ERA include domesticated livestock, large mammalian wildlife and small mammalian wildlife. Beef cattle were used to evaluate domesticated livestock, kangaroos evaluated for large mammalian wildlife, and dingos for small mammalian wildlife. Aquatic receptors evaluated included invertebrates and fishes.

The estimate for dose-based or intake rates for the assessment endpoints for wildlife representing domestic livestock and native mammalian species used the following general equation:

TI = Cwater x IRwater x EF x ED / BW x ED x 365 days/year

Where:

TI = Total intake of COPC (mg/kg/day)
Cwater = Concentration of COPC in water (mg/l)
IRwater = Ingestion rate (litres/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)

The exposure assumptions are presented in **Tables 8** through **10**, attached.

C3.8 Toxicity Assessment

To evaluate the potential for adverse ecological effects, toxicity reference values (TRVs) are selected as measurement endpoints for the ERA that will be used in the risk analysis. The TRVs are based on COPC levels that imply no adverse effects or levels that represent the lowest concentration at which adverse effects may occur. The ERA used two types of TRVs (**Section 8.5.3**). The first TRV is a concentration-based TRV to evaluate the concentration of the selected COPC in the surface water and direct exposure by the aquatic ecological receptor. The determination of TRVs for freshwater was conducted according to the predicted no-effects concentration (PNEC) guidance in the Environmental Risk Assessment Guidance Manual for Industrial Chemicals prepared by the Australian Environmental Agency (AEA, 2009). As discussed in **Section 8.4**, detailed environmental profiles were developed for the chemicals. The environmental profiles are included in the risk dossiers in **Appendix G**. **Table 11**, attached, presents the COPC, the endpoint, NOEC [milligrams per litre (mg/L)], assessment factor, and the aquatic PNEC (mg/L). The second TRV is a dose-based TRV to evaluate the intake dose of the selected COPC from exposure to surface water by ingestion. The calculated TRVs for each of the mammalian ecological receptors evaluated in the ERA are presented in the species-specific ecological risk models.

C3.9 Exposure Point Concentration

EPCs for the exposure assessment were calculated using the results of theoretical fate and transport modelling calculations. The potentially affected flowback water that represents complete exposure pathways for the ecological receptors includes the surface water systems (e.g., flowback storage ponds and mud pits) that were used to estimate the EPCs for the human health receptors. The EPCs for the ecological receptors were estimated assuming the same scenarios, with exposure occurring in the irrigation area where irrigation water may pool and wildlife may drink from the standing water. **Table C10-1** presents the calculated EPCs for the ecological receptor exposure scenarios. The theoretical EPCs for the four exposure time periods (0, 30, 150, and 300 days) were compared to ecological based toxicity-based screening levels, and the results of this comparison, including the ratio of exceedance of screening levels, is presented in **Table C10-3**.

Risks were characterised in accordance with the methodologies discussed in **Section 8.5.6**. The resulting ecological hazard quotient must be less than or equal to 1.0 for risks to be considered acceptable.

C3.10 Estimation of Risk

The HI calculated for flowback water for aquatic risk were elevated above the acceptable level for the majority of COPCs evaluated (**Table C10-3**). Where large discharges of flowback water occur to surface water and/or flux dilution within the surface-water was insufficient, potential impacts on aquatic receptors could occur. As noted in the toxicity assessment section above, the lack of a robust aquatic toxicological database resulted in highly conservative aquatic screening values for the theoretical exposure scenario COPCs to be conservatively very low.

The results of the theoretical assessments for Condor Energy Services hydraulic fracturing fluid system for the livestock cattle, kangaroo and dingo are summarized in **Tables 12** through **17**, attached. The exposure scenarios include the Condor Energy Services hydraulic fracturing fluid system EPCs presented in **Table C10-1** for day 0 and day 150 from the fracturing fluid well flowback. The modelled risks from Condor Energy Services hydraulic fracturing fluid system chemicals in the flowback water were slightly above the target of 1.0 for the cattle (HI=2.1, **Table 12**, attached), but were acceptable for the modelled values for day 150 (HI = 0.024, **Table 13**, attached), and all exposure scenarios for the kangaroo (HI=0.44 0.005, **Table 14** and **15**, attached), and dingo (HI=0.18 to 0.002, **Table 16** and **17**, attached).

C4.0 Summary of QRA Findings

The QRA was completed as discussed in **Section 8.0**. An assessment was conducted using highly conservative theoretical calculations based on the chemicals utilised by Schlumberger in hydraulic fracturing. This assessment assumed that a range of theoretical concentrations of injected chemicals would be present in the flowback water based on biodegradation rates, where applicable.

Consistent with the risk assessment and groundwater fate and transport modelling conducted by Golder, no potentially complete exposure pathways were identified for groundwater. Potential exposures are limited to the aboveground storage and handling of flowback water as part of the CSG Water Management Plan (WMP). Management of CSG water involves the temporary storage of flowback water in flowback storage ponds.

The exposure scenario modelled for the QRA was a trespasser being exposed to flowback water under various EPC scenarios. Based on quantitative risk calculations, the potential risks for the trespasser were slightly unacceptable for the EPC scenarios. The QRA used very conservative exposure assumptions. There were no carcinogenic risks identified.

The modelled risks from Condor Energy Services hydraulic fracturing fluid system chemicals in the flowback water were unacceptable for the livestock cattle on day 0, but were acceptable for cattle on day 150, and all EPC exposure scenarios for the kangaroo, and dingo.

Similarly, potential impacts could occur if releases of flowback water were to occur to aquatic environments. Based on the use of low permeability materials (clay liners) and operational controls that limit the potential for turkey nest and dam overflows, the potential for these risks are also considered limited.

A combination of management and operational controls are being implemented to eliminate and control the potential for exposures. These include:

- Worker training and hazard identification
- Use of appropriate personal protective equipment (gloves, etc.)
- Flowback storage pond fencing to prevent entry of livestock and native fauna and minimise trespassing
- Use of low permeability materials or dam liners and routine dam inspections to prevent releases from flowback storage ponds
- Routine operational and security patrols to prevent trespassing

C5.0 Conclusions

A weight-of-evidence evaluation of potential risks as described in **Section 5.0** was performed for the Condor Energy Services hydraulic fracturing fluid system. Based on the qualitative and quantitative risk characterisations, the overall risk to human health and the environment is acceptable. Existing operational control activities employed by Santos are in place that will limit the potential risks to human health and the environment. These measures include:

- Occupational health and safety procedures implemented during hydraulic fracturing operations to prevent workers from making direct contact with chemicals during spills and when handling flowback water or sediments
- Environmental authority conditions that preclude the construction of well pads within 100 metres of a watercourse of water body
- Implementation of spill containment procedures during operations to prevent migration of and exposure to chemicals
- Disposal or capping of sediments contained within drained mud pits and turkey nests, to prevent exposure to contaminates in windborne dust
- Fencing of drill pads to prevent trespassers from entering and installation of signs to indicate that the water in the turkey nests and mud pit is not potable and may contain contaminants
- Installation and maintenance of fences around the well pad to prevent access to the drill pad by livestock and large native fauna
- Santos operational procedures to ensure well integrity and design of fracture to stay within the target seam
- Mud pits and turkey nests with clay liners, or similar material, to prevent seepage of flowback water into underlying aquifers

Monitoring of water supply bores and surface water for a representative suite of chemicals within 2 kilometres of the wells (and 200 m vertical separation) that are fractured will be conducted (as needed) to confirm the conclusion of incomplete exposure pathways and low risk.

No additional risks, other than those previously discussed, were identified with the chemicals or systems employed in hydraulic fracturing. Evaluation of other potential risks associated with hydraulic fracturing (i.e., noise and vibration) was conducted. Refer to **Section 9.0** for methodology specifics and results of this evaluation.

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Tables

Table 2: Condor Water Treatment PBT Assessment
Condor Energy Services Hydraulic Fracturing Fluid System

Substance	P/vP criteria fulfilled?	B/vB criteria fulfilled?	T criteria fulfilled?	Overall conclusion
Acetic acid (64-19-7)	No (screening data available)	No (acetate is naturally found in biological organisms)	No (experimental data available)	Not PBT (based on screening and experimental data; naturally found in organisms)
Acrylamide/sodium acrylate copolymer (25085-02-3)	Yes (polymer, not readily biodegradable)	No (polymer, physico-chemical properties)	No (polymer, physico-chemical properties)	No (based on polymer, physico-chemical properties)
Alcohols, C9-11, ethoxylated (68439-46-3)	No (screening data available)	No (screening data available)	Yes (experimental data available)	Not PBT (based on screening data)
Ammonium persulfate (7727-54-0)	Not applicable (ionic species ubiquitous in environment)	No (essential ions to biological systems; actively regulated)	No (screening data available)	Not PBT (based on screening data and ubiquitous inorganic salt)
Ammonium sulfate (7783-20-2)	Not applicable (ionic species ubiquitous in environment)	No (essential ions to biological systems; actively regulated)	No (screening data available)	Not PBT (based on screening data and ubiquitous inorganic salt)
Amylase, alpha (9000-90-2)	No (screening data available)	No (screening data available)	No (screening data available)	Not PBT (based on screening data)
Castor oil, ethoxylated (61791-12-6)	No (screening data available)	No (screening data available)	No (screening data available)	Not PBT (based on screening data)
Choline chloride (67-48-1)	No (screening data available)	No (screening data available)	No (screening data available)	Not PBT (based on screening data)
Cinnamaldehyde (104-55-2)	No (screening data available)	No (screening data available)	Yes (screening data available)	Not PBT (based on screening data)
Diethylene glycol (111-46-6)	No (screening data available)	No (screening data available)	No (screening data available)	Not PBT (based on screening data)
Distillates (petroleum), hydrotreated light (64742-47-8)	Yes (screening data available)	Yes (modeling data available)	No (screening and experimental data available	Not PBT (based on modeling, screening and experimental data)

Table 2: Condor Water Treatment PBT Assessment
Condor Energy Services Hydraulic Fracturing Fluid System

Substance	P/vP criteria fulfilled?	B/vB criteria fulfilled?	T criteria fulfilled?	Overall conclusion
Ethoxylated C11 alcohol (34398-01-1)	No (screening data available)	No (screening data available)	Yes (experimental data available)	Not PBT (based on screening data)
2-Ethyoxynaphthalene (93-18-5)	Yes (screening data available)	No (screening data available)	No (screening data available)	Not PBT (based on screening data)
Ethylene glycol (107-21-1)	No (screening data available)	No (experimental data available)	No (experimental data available)	Not PBT (based on screening and experimental data)
Formic acid (64-18-6)	No (screening data available)	No (screening data available)	No (screening data available)	Not PBT (based on screening data)
Glutaraldehyde (111-30-8)	No (screening data available)	No (screening data available)	Yes (experimental data available)	Not PBT (based on screening and experimental data)
Glycerol (56-81-5)	No (screening data available)	No (screening data available)	No (screening data available)	Not PBT (based on screening data)
Guar gum (9000-30-0)	No (estimated)	No (based on physico-chemical properties)	Potentially Yes (based on experimental data)	Not PBT (based on estimation, physico-chemical properties, experimental data)
Hemicellulase (9025-56-3)	No (screening data available)	No (based on physico-chemical properties)	No (screening data available)	Not PBT (based on screening data)
1,6-Hexanediol (629-11-8)	No (screening data available)	No (screening data available)	No (screening data available)	Not PBT (based on screening data)
Hydrochloric acid (7647-01-0)	Not applicable (ionic species ubiquitous in environment)	No (essential ions to biological systems; actively regulated)	No (screening data available)	Not PBT (based on screening data and ubiquitous inorganic salt)
Isopropanol (67-63-0)	No (screening data available)	No (screening data available)	No (experimental data available)	Not PBT (based on screening data)
2-Mercaptoethyl alcohol (60-24-2)	No (experimental data available)	No (screening data available)	Yes (experimental data available)	Not PBT (based on screening and experimental data)

Table 2: Condor Water Treatment PBT Assessment
Condor Energy Services Hydraulic Fracturing Fluid System

Substance	P/vP criteria fulfilled?	B/vB criteria fulfilled?	T criteria fulfilled?	Overall conclusion
Methanol (67-56-1)	No (screening data available)	No (experimental data available)	No (screening data available)	Not PBT (based on screening and experimental data)
N-benzyl-alkylpyridium chloride (68909-18-2)	No data.	No (screening data available)	Yes (screening data available)	Not PBT (based on screening data)
Quat. Ammonium compds, bis (hydrogenated tallow alkyl) dimethyl, salts with bentonite (68955-58-2)	Yes (screening data available)	No (based on physico-chemical properties)	No (experimental data available)	Not PBT (based on screening and experimental data)
Pine oil (8002-09-3)	No (screening data available)	Potentially yes (screening data available on components)	No (screening data available)	Not PBT (based on screening and experimental data)
Polyoxyethylene nonylphenol ether (9016-45-9)	No (screening data available)	No (screening data available)	Yes (experimental data available)	Not PBT (based on screening and experimental data)
Polyoxyethylene-polyoxypropylene block copolymer (9003-11-6)	Yes (polymer, not readily biodegradable)	No (polymer, physico-chemical properties)	No (screening data available)	No (based on polymer, physico-chemical properties)
Potassium carbonate (584-08-7)	Not applicable (ionic species from inorganic salt is ubiquitous in environment)	No (ionic species)	No experimental data available)	Not PBT (based on experimental data and ionic species)
Potassium chloride (7447-40-7)	Not applicable (ionic species from inorganic salt is ubiquitous in environment)	No (ionic species)	No experimental data available)	Not PBT (based on experimental data and ionic species)
Potassium hydroxide (1310-73-2)	Not applicable (ionic species from inorganic salt is ubiquitous in environment)	No (ionic species)	No experimental data available)	Not PBT (based on experimental data and ionic species)

Table 2: Condor Water Treatment PBT Assessment
Condor Energy Services Hydraulic Fracturing Fluid System

Substance	P/vP criteria fulfilled?	B/vB criteria fulfilled?	T criteria fulfilled?	Overall conclusion
Potassium persulfate (7727-21-1)	Not applicable (ionic species ubiquitous in environment)	No (essential ions to biological systems; actively regulated)	No (screening data available)	Not PBT (based on screening data and ubiquitous inorganic salt)
Potassium sorbate (24634-61-5)	No (screening data available)	No (screening data available)	No (screening data available)	Not PBT (based on screening data)
2-Propenoic acid, homopolymer, ammonium salt (9003-03-6)	Yes (polymer, not readily biodegradable)	No (polymer, physico-chemical properties)	No (experimental data available)	Not PBT based on physico-chemical properties and experimental data)
Sodium benzoate (532-32-1)	No (screening data available)	No (screening data available)	No (screening data available)	Not PBT (based on screening data)
Sodium bisulfite (7631-90-5)	Not applicable (ionic species ubiquitous in environment)	No (essential ions to biological systems; actively regulated)	No (screening data available)	Not PBT (based on screening data and ubiquitous inorganic salt)
Sodium erythrobate (6381-77-7)	Yes (screening data available)	No (screening data available)	No (screening data available)	Not PBT (based on screening data)
Sodium hydroxide (1310-72-2)	Not applicable (ionic species from inorganic salt is ubiquitous in environment)	No (ionic species)	No experimental data available)	Not PBT (based on experimental data and ionic species)
Sodium polyacrylate ((9003-04-7)	Yes (polymer, not readily biodegradable)	No (polymer, physico-chemical properties)	No (experimental data available)	Not PBT based on physico-chemical properties and experimental data)
Sodium tetraborate decahydrate (1303-96-4)	Not applicable (ionic species from inorganic salt is ubiquitous in environment)	No (ionic species)	Yes (known or presumed human reproductive toxicant - GHS Cat. 1B)	Not PBT (based on experimental data and ionic species)
Tar bases, quinoline deriv., benzyl chloride – Quat. (72480-70-7)	No data	No data	No data	No data

PBT = persistence, bioaccumulative, toxicity

Table 3 Exposure Assumptions - Trespasser
Condor Energy Services Hydraulic Fracturing Fluid System

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/hr	0.05
	ET	Exposure time	hr/day	0.5
	EF	Exposure frequency	day/yr	20
	ED	Exposure duration	yr	10
	BW	Body weight	kg	47
	AT-NC	Averaging time - noncancer	days	3,650
	AT-C	Averaging time - cancer	days	25,550
Dermal	SA	Surface area for contact	cm^2/day	13,000
	DP	Dermal permeability factor	cm/h	chemical-specific
	ET	Exposure time	hr/day	1
	EF	Exposure frequency	day/yr	20
	ED	Exposure duration	yr	10
	BW	Body weight	kg	47
	AT-NC	Averaging time - noncancer	days	3,650
	AT-C	Averaging time - cancer	days	25,550
	CF	Conversion factor	l/cm^3	1.0E-03

Table 4: Condor Oral Reference Doses and Drinking Water Guidelines
Condor Energy Services Hydraulic Fracturing Fluid System

Constituent (CAS No.)	Study	Critical Effect/Target Organ(s)	NOAEL (mg/kg-day)	Uncertainty Factors	Oral Reference Dose (mg/kg-day)	Drinking Water Guideline (mg/L)
Acrylamide/sodium acrylate copolymer (25085-02-3)	2-yr rat dietary	No systemic effects.	5,000	100	50	175
Alcohols, C9-11, ethoxylated (68439-46-3)	90-day rat dietary	No systemic effects.	150	300	0.5	1.8
Amylase, alpha (9000-90-2)	13-wk rat oral gavage	No systemic effects.	1,110	300	4	13
Castor oil, ethoxylated (61791-12-6)	13-wk dietary	No systemic effects.	2,500	300	8	28
Choline chloride (67-48-1)	Human study	Slight hypotensive effect	107[a]	2	50[b]	175[b]
Cinnamaldehyde (104-55-2)	2-yr mouse dietary	↓ body weights	125	100	1.0	4
Diethylene glycol (111-46-6)	225-d rat dietary	Kidney toxicity	105	100	1.0	3.5
Distillates (petroleum), hydrotreated light (64742-47-8)	13-wk rat oral gavage	No systemic toxicity	1,000	300	3	12
Ethoxylated C11 alcohol (34398-01-1)	90-day rat dietary	No systemic effects.	150	300	0.5	1.8
2-Ethyoxynaphthalene (93-18-5)	90-day rat dietary	No systemic effects.	5	300	0.02	0.07
Ethylene glycol (107-21-1)	2-yr rat dietary	Kidney toxicity	150[c]	10	15	53
Formic acid (64-18-6)	1-yr. dietary	↓ body weights	220	100	2	7

Table 4: Condor Oral Reference Doses and Drinking Water Guidelines
Condor Energy Services Hydraulic Fracturing Fluid System

Constituent (CAS No.)	Study	Critical Effect/Target Organ(s)	NOAEL (mg/kg-day)	Uncertainty Factors	Oral Reference Dose (mg/kg-day)	Drinking Water Guideline (mg/L)
Glutaraldehyde (111-30-8)	2-yr rat drinking water	↓ body wt. gain, food consumption	4	100	0.04	0.14
Glycerol (56-81-5)	90-d rat dietary	Liver	4,580	1,000	4.6	16
Guar gum (9000-30-0)	2-yr rat dietary	↓ body weights	1,250	100	13	46
Hemicellulase (9025-56-3)	13-wk rat oral gavage	None	1,000	1,000	1.0	3.5
1,6-Hexanediol (629-11-8)	90-d rat oral gavage	↓ body weights	400	300	1.0	3.5
Isopropanol (67-63-0)	Rat 2-generation reproductive	Decrease male mating index	420[d]	1,000	0.4	1.4
2-Mercaptoethyl alcohol (60-24-2)	OECD 422	Liver, heart, reproductive effects	15	300	0.05	0.18
Methanol (67-56-1)	Mouse developmental	Increased cervical ribs per litter	43.1 mg/L[e]	100	2[e]	7
N-benzyl-alkylpyridium chloride (68909-18-2)	[f]	-	-	-	-	-
Pine oil (8002-09-3)	Rat developmental	↓ body weight gain and food consumption (maternal); ↓ fetal body weights, malformations, delayed ossification	50 (maternal, developmental)	300	0.17	0.6
Polyoxyethylene nonylphenol ether (9016-45-9)	[f]	-	-	-	-	-

Table 4: Condor Oral Reference Doses and Drinking Water Guidelines
Condor Energy Services Hydraulic Fracturing Fluid System

Constituent (CAS No.)	Study	Critical Effect/Target Organ(s)	NOAEL (mg/kg-day)	Uncertainty Factors	Oral Reference Dose (mg/kg-day)	Drinking Water Guideline (mg/L)
Polyoxyethylene-polyoxypropylene block copolymer (9003-11-6)	2-yr rat dietary	Reduced body weight gain	2,500	100	25	88
Potassium chloride (7447-40-7)	2-yr rat dietary	None	1,820	100	18	63
Potassium sorbate (24634-61-5)	2-yr rat dietary	Spleen, focal fatty changes	1,000	100	10	35
2-Propenoic acid, homopolymer, ammonium salt (9003-03-6)	4-wk rat dietary	No systemic toxicity	1,136	1,000	1.0	3.5
Quat. Ammonium compds, bis (hydrogenated tallow alkyl) dimethyl, salts with bentonite (68955-58-2)	12-wk rat dietary	↓ Food efficiency	2,500	300	8	29
Sodium benzoate (532-32-1)	90-d rat dietary	Mortality; ↓ body weights	3,145	300	10	35
Sodium bisulfite (7631-90-5)	2-yr rat dietary study	None	523	100	5	18
Sodium erythrobate (6381-77-7)	10-wk mouse drinking water	Spleen, kidney, liver effects	4,250	300	14	49
Sodium polyacrylate ((9003-04-7)	28-d rat dietary	None	1,136	1000	1	4
Sodium tetraborate decahydrate (1303-96-4)	Rat developmental	↓ Fetal body weights	10.3[g]	66	0.2	0.7
Tar bases, quinoline deriv., benzyl chloride – Quat. (72480-70-7)	[e]	-	-	-	-	-

Table 4: Condor Oral Reference Doses and Drinking Water Guidelines
Condor Energy Services Hydraulic Fracturing Fluid System

[a]LOAEL.
[b]Value for choline.
[c]Human Equivalent Dose derived from benchmark dose and PBPK modeling.
[d]Point of departure calculated for benchmark dose modeling.
[e]The Point of Departure (POD) value is the internal C_{max} methanol blood concentration obtained using BMD analysis from an inhalation study.
[f]No data.
[g]$BMDL_{50}$ (U.S. EPA IRIS).

Australian Drinking Water Guidance Values

Constituent (CAS No.)	Drinking Water Guideline	Drinking Water Guidance Value
Acetic acid (64-19-7)	pH	6.5 to 8.5
Ammonium persulfate (7727-54-0)	Sulfate	500 mg/L (health) and 250 mg/L (aesthetics)
Ammonium sulfate (7783-20-2)	Sulfate	500 mg/L (health) and 250 mg/L (aesthetics)
Hydrochloric acid (7647-01-0)	pH; chloride	6.5 to 8.5; 250 mg/L (aesthetics)
Potassium carbonate (584-08-7)	pH	6.5 to 8.5
Potassium hydroxide (1310-73-2)	pH	6.5 to 8.5
Potassium persulfate (7727-21-1)	Sulfate	500 mg/L (health) and 250 mg/L (aesthetics)
Sodium hydroxide (1310-72-2)	Sodium; pH	180 mg/L (aesthetic); 6.5 to 8.5

Table 5 Environmental Fate Information
Condor Energy Services Hydraulic Fracturing Fluid System

Acetic acid	Dissociates completely in aqueous media; acetate ion is readily biodegradable (half-life = 15 days)[a]
Acrylamide/sodium acrylate copolymer	Not biodegradable.
Alcohols, C9-11, ethoxylated	Readily biodegradable (half-life = 15 days)[a]
Ammonium persulfate	Dissociates completely in aqueous media
Ammonium sulfate	Dissociates completely in aqueous media
Amylase, alpha	Readily biodegradable (half-life = 15 days)[a]
Castor oil, ethoxylated	Readily biodegradable (half-life = 15 days)[a]
Choline chloride	Readily biodegradable (half-life = 15 days)[a]
Cinnamaldehyde	Readily biodegradable (half-life = 15 days)[a]
Diethylene glycol	Readily biodegradable (half-life = 15 days)[a]
Distillates (petroleum), hydrotreated light	Inherently biodegradable (half-life = 150 days)[a]
Ethoxylated C11 alcohol	Readily biodegradable (half-life = 15 days)[a]
2-Ethoxynaphthalene	Not readily biodegradable.
Ethylene glycol	Readily biodegradable (half-life = 15 days)[a]
Formic acid	Readily biodegradable (half-life = 15 days)[a]
Glutaraldehyde	Readily biodegradable (half-life = 15 days)[a]
Glycerol	Readily biodegradable (half-life = 15 days)[a]
Guar gum	Readily biodegradable (half-life = 15 days)[a]
Hemicellulase	Readily biodegradable (half-life = 15 days)[a]
1,6-hexanediol	Readily biodegradable (half-life = 15 days)[a]
Hydrochloric acid	Dissociates completely in aqueous media
Isopropanol	Readily biodegradable (half-life = 15 days)[a]
2-Mercaptoethyl alcohol	Readily biodegradable (half-life = 15 days)[a]
Methanol	Readily biodegradable (half-life = 15 days)[a]
N-benzyl-alkylpyridium chloride	No data.
Quat. Ammonium compds. Bis (hydrogenated tallow alkyl) dimethyl, salts with bentonite	Organic component: not readily biodegradable.
Pine oil	Readily biodegradable (half-life = 15 days)[a]
Polyoxyethylene nonylphenol ether	Readily biodegradable (half-life = 15 days)[a]
Polyoxyethylene-polyoxypropylene block copolymer	Not biodegradable.
Potassium chloride	Dissociates completely in aqueous media
Potassium hydroxide	Dissociates completely in aqueous media
Potassium persulfate	Dissociates completely in aqueous media
Potassium sorbate	Readily biodegradable (half-life = 15 days)[a]
2-Propenoic acid, homopolymer, ammonium salt	Not readily biodegradable
Sodium benzoate	Readily biodegradable (half-life = 15 days)[a]
Sodium bisulfite	Dissociates completely in aqueous media
Sodium erythrobate	Readily biodegradable (half-life = 15 days)[a]
Sodium hydroxide	Dissociates completely in aqueous media
Sodium polyacrylate	Not readily biodegradable
Sodium tetraborate decahydrate	Dissociates completely in aqueous media
Tar bases, quinoline deriv., benzyl chloride - Quat.	No data

Table 5 Environmental Fate Information
Condor Energy Services Hydraulic Fracturing Fluid System

[a]EU Guidance Document: Half-life estimates from in vitro biodegradation test results	

Table 6 Risk Estimates for Trespasser
Condor Energy Services Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 0

		Day 0		Toxicity	Condor Energy Services Hydraulic Fracturing Fluid System			
							Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**PC (cm/hr)**	**RfDo**	**$CADD_{oral}$**	**$CADD_{derm}$**	**Incidental Ingestion**	**Dermal**
Acetic Acid	64-19-7	99.857	5.6E-04	-	5.8E-03	4.3E-04	NA	NA
Alcohols, C9-11, ethoxylated	68439-46-3	16.64	4.8E-04	5.0E-01	9.7E-04	6.0E-05	1.9E-03	1.2E-04
Ammonium Persulphate	7727-54-0	14.947	NA	7.1E+01	8.7E-04	-	1.2E-05	-
Ammonium Sulphate	7783-20-2	33.67	NA	7.1E+01	2.0E-03	-	2.7E-05	-
Amylase, Alpha	9000-90-2	0.7133	2.2E-228	4.0E+00	4.2E-05	1.2E-230	1.0E-05	3.0E-231
Castor Oil	61791-12-6	0.8521	4.7E-05	8.0E+00	5.0E-05	3.0E-07	6.2E-06	3.8E-08
Choline Chloride	67-48-1	9.6	8.5E-07	5.0E+01	5.6E-04	6.2E-08	1.1E-05	1.2E-09
Cinnamaldehyde	104-55-2	0.9317	7.1E-03	1.0E+00	5.4E-05	5.0E-05	5.4E-05	5.0E-05
Diethylene Glycol	111-46-6	0.1418	2.0E-05	1.0E+00	8.3E-06	2.1E-08	8.3E-06	2.1E-08
DISTILLATES, HYDROTREATED LIGHT	64742-47-8	532.57	2.3E+00	3.0E+00	3.1E-02	9.2E+00	1.0E-02	3.1E+00
Ethoxylated C11 Alcohol	34398-01-1	49.9	4.8E-04	5.0E-01	2.9E-03	1.8E-04	5.8E-03	3.6E-04
2-Ethoxy-naphthalene	93-18-5	0.6340	5.1E-02	2.0E-02	3.7E-05	2.5E-04	1.8E-03	1.2E-02
Ethylene Glycol	107-21-1	0.1408	9.0E-05	1.5E+01	8.2E-06	9.6E-08	5.5E-07	6.4E-09
Formic Acid	64-18-6	6.2	3.6E-05	2.0E+00	3.6E-04	1.7E-06	1.8E-04	8.5E-07
Glutaraldehyde	111-30-8	176.4	2.5E-04	4.0E-02	1.0E-02	3.4E-04	2.6E-01	8.4E-03
Glycerol	56-81-5	287.6	3.4E-05	4.6E+00	1.7E-02	7.4E-05	3.6E-03	1.6E-05
Guar Gum	9000-30-0	564.2	NA	1.3E+01	3.3E-02	-	2.5E-03	-
Hemicellulase	9025-56-3	3.8	1.1E-114	1.0E+00	2.2E-04	3.3E-116	2.2E-04	3.3E-116
1,6-Hexanediol	629-11-8	15.98	3.5E-04	1.0E+00	9.3E-04	4.2E-05	9.3E-04	4.2E-05
HydroChloric Acid	7647-01-0	364.3	2.3E-03	7.1E+01	2.1E-02	6.2E-03	3.0E-04	8.7E-05
Inorganic Salt	584-08-7	97.1	2.2E-08	-	5.7E-03	1.6E-08	NA	NA
Isopropanol	67-63-0	39.9	1.4E-01	4.0E-01	2.3E-03	4.4E-02	5.8E-03	1.1E-01
2-Mercaptoethyl Alcohol	60-24-2	0.7063	5.3E-04	5.0E-02	4.1E-05	2.8E-06	8.2E-04	5.7E-05
Methanol	67-56-1	0.4017	3.3E-04	2.0E+00	2.3E-05	9.9E-07	1.2E-05	5.0E-07
N-Benzyl-Alkylpyridinium Chloride	68909-18-2	0.63401	6.2E-03	-	3.7E-05	3.0E-05	NA	NA
Pine Oil	8002-09-3	0.8432	3.0E-02	1.7E-01	4.9E-05	1.9E-04	2.9E-04	1.1E-03
Polyacrylamide	25085-02-3	24.7	NA	5.0E+01	1.4E-03	-	2.9E-05	-
Polyoxyethylene nonylphenol ether	9016-45-9	165.9	4.9E-03	-	9.7E-03	6.1E-03	NA	NA
Polyoxyethylene-polyoxypropylene Block Copolymer	9003-11-6	0.6942	NA	2.5E+01	4.0E-05	-	1.6E-06	-
Potassium Chloride	7447-40-7	16.5	NA	1.8E+01	9.6E-04	-	5.3E-05	-
Potassium Hydroxide	1310-58-3	84.7	NA	-	4.9E-03	-	NA	-
Potassium persulfate	7727-21-1	1.57045	NA	7.1E+01	9.2E-05	-	1.3E-06	-
Potasium Sorbate	24634-61-5	0.1555	2.8E-05	1.0E+01	9.1E-06	3.3E-08	9.1E-07	3.3E-09
2-Propenoic acid, homopolymer, ammonium salt	9003-03-6	0.6340	NA	1.0E+00	3.7E-05	-	3.7E-05	-
Quaternary ammonium compounds, bis(hydrogenated tallow alkyl)dimethyl, salts with bentonite	68953-58-2	166.4	NA	8.0E+00	9.7E-03	-	1.2E-03	-
Sodium Benzoate	532-32-1	0.1708	1.1E-05	1.0E+01	1.0E-05	1.4E-08	1.0E-06	1.4E-09
Sodium bisulfite	7631-90-5	0.9383	NA	5.0E+00	5.5E-05	-	1.1E-05	-
Sodium erythorbate	6381-77-7	5.325	1.1E-06	1.4E+01	3.1E-04	4.5E-08	2.2E-05	3.2E-09
Sodium Hydroxide	1310-73-2	162.05	NA	5.1E+01	9.4E-03	-	1.8E-04	-
Sodium polyacrylate	9003-04-7	3.867	NA	1.0E+00	2.3E-04	-	2.3E-04	-
Sodium Tetraborate Decahydrate	1303-96-4	540.9	NA	2.0E-01	3.2E-02	-	1.6E-01	-
							Hazard Index	3.6E+00

Table 7 Risk Estimates for Trespasser
Condor Energy Services Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 150

		Day 150		Toxicity	Condor Energy Services Hydraulic fracturing Fluid System			
							Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**PC (cm/hr)**	**RfDo**	**$CADD_{oral}$**	**$CADD_{derm}$**	**Incidental Ingestion**	**Dermal**
Acetic Acid	64-19-7	0.09752	5.6E-04	-	5.7E-06	4E-07	NA	NA
Alcohols, C9-11, ethoxylated	68439-46-3	0.01625	4.8E-04	5.0E-01	9.5E-07	5.9E-08	1.9E-06	1.2E-07
Ammonium Persulphate	7727-54-0	14.947	NA	7.1E+01	8.7E-04	NA	1.2E-05	NA
Ammonium Sulphate	7783-20-2	33.67	NA	7.1E+01	2.0E-03	NA	2.7E-05	NA
Amylase, Alpha	9000-90-2	0.0006965	2.2E-228	4.0E+00	4.1E-08	1.2E-233	1.0E-08	2.9E-234
Castor Oil	61791-12-6	0.0008321	4.7E-05	8.0E+00	4.9E-08	2.9E-10	6.1E-09	3.7E-11
Choline Chloride	67-48-1	0.009399	8.5E-07	5.0E+01	5.5E-07	6.1E-11	1.1E-08	1.2E-12
Cinnamaldehyde	104-55-2	0.0009099	7.1E-03	1.0E+00	5.3E-08	4.9E-08	5.3E-08	4.9E-08
Diethylene Glycol	111-46-6	0.0001384	2.0E-05	1.0E+00	8.1E-09	2.1E-11	8.1E-09	2.1E-11
DISTILLATES, HYDROTREATED LIGHT	64742-47-8	266.29	2.3E+00	3.0E+00	1.6E-02	4.6E+00	5.2E-03	1.5E+00
Ethoxylated C11 Alcohol	34398-01-1	0.04876	4.8E-04	5.0E-01	2.8E-06	1.8E-07	5.7E-06	3.5E-07
2-Ethoxy-naphthalene	93-18-5	0.6340	5.1E-02	2.0E-02	3.7E-05	2.5E-04	1.8E-03	1.2E-02
Ethylene Glycol	107-21-1	0.0001375	9.0E-05	1.5E+01	8.0E-09	9.4E-11	5.3E-10	6.3E-12
Formic Acid	64-18-6	0.006043	3.6E-05	2.0E+00	3.5E-07	1.7E-09	1.8E-07	8.3E-10
Glutaraldehyde	111-30-8	0.1723	2.5E-04	4.0E-02	1.0E-05	3.3E-07	2.5E-04	8.2E-06
Glycerol	56-81-5	0.2808	3.4E-05	4.6E+00	1.6E-05	7.2E-08	3.6E-06	1.6E-08
Guar Gum	9000-30-0	0.5510	NA	1.3E+01	3.2E-05	NA	2.5E-06	NA
Hemicellulase	9025-56-3	0.003678	1.1E-114	1.0E+00	2.1E-07	3.2E-119	2.1E-07	3.2E-119
1,6-Hexanediol	629-11-8	0.01560	3.5E-04	1.0E+00	9.1E-07	4.1E-08	9.1E-07	4.1E-08
HydroChloric Acid	7647-01-0	364.3	2.3E-03	7.1E+01	2.1E-02	6.2E-03	3.0E-04	8.7E-05
Inorganic Salt	584-08-7	97.1	2.2E-08	-	5.7E-03	1.6E-08	NA	NA
Isopropanol	67-63-0	0.0	1.4E-01	4.0E-01	2.3E-06	4.3E-05	5.7E-06	1.1E-04
2-Mercaptoethyl Alcohol	60-24-2	0.0007	5.3E-04	5.0E-02	4.0E-08	2.8E-09	8.0E-07	5.6E-08
Methanol	67-56-1	0.0003923	3.3E-04	2.0E+00	2.3E-08	9.7E-10	1.1E-08	4.8E-10
N-Benzyl-Alkylpyridinium Chloride	68909-18-2	0.63401	6.2E-03	-	3.7E-05	3.0E-05	NA	NA
Pine Oil	8002-09-3	0.0008235	3.0E-02	1.7E-01	4.8E-08	1.9E-07	2.8E-07	1.1E-06
Polyacrylamide	25085-02-3	24.7	NA	5.0E+01	1.4E-03	NA	2.9E-05	NA
Polyoxyethylene nonylphenol ether	9016-45-9	0.2	4.9E-03	-	9.4E-06	6.0E-06	NA	NA
Polyoxyethylene-polyoxypropylene Block Copolymer	9003-11-6	0.6942	NA	2.5E+01	4.0E-05	NA	1.6E-06	NA
Potassium Chloride	7447-40-7	16.5	NA	1.8E+01	9.6E-04	NA	5.3E-05	NA
Potassium Hydroxide	1310-58-3	84.7	NA	-	4.9E-03	NA	NA	NA
Potassium persulfate	7727-21-1	1.57045	NA	7.1E+01	9.2E-05	NA	1.3E-06	NA
Potasium Sorbate	24634-61-5	0.0001519	2.8E-05	1.0E+01	8.9E-09	3.2E-11	8.9E-10	3.2E-12
2-Propenoic acid, homopolymer, ammonium salt	9003-03-6	0.6340	NA	1.0E+00	3.7E-05	NA	3.7E-05	NA
Quaternary ammonium compounds, bis(hydrogenated tallow alkyl)dimethyl, salts with bentonite	68953-58-2	166.4	NA	8.0E+00	9.7E-03	NA	1.2E-03	NA
Sodium Benzoate	532-32-1	0.0001668	1.1E-05	1.0E+01	9.7E-09	1.3E-11	9.7E-10	1.3E-12
Sodium bisulfite	7631-90-5	0.9383	NA	5.0E+00	5.5E-05	NA	1.1E-05	NA
Sodium erythorbate	6381-77-7	0.005200	1.1E-06	1.4E+01	3.0E-07	4.4E-11	2.2E-08	3.1E-12
Sodium Hydroxide	1310-73-2	162.05	NA	5.1E+01	9.4E-03	NA	1.8E-04	NA
Sodium polyacrylate	9003-04-7	3.867	NA	1.0E+00	2.3E-04	NA	2.3E-04	NA
Sodium Tetraborate Decahydrate	1303-96-4	540.9	NA	2.0E-01	3.2E-02	NA	1.6E-01	NA
							Hazard Index	1.7E+00

Table 8 Exposure Assumptions - Cattle
Condor Energy Services Hydraulic Fracturing Fluid System

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/day	86
	EF	Exposure frequency	day/yr	15
	ED	Exposure duration	yr	8
	BW	Body weight	kg	454
	AT-NC	Averaging time - noncancer	days	2,920

Table 9 Exposure Assumptions - Kangaroo
Condor Energy Services Hydraulic Fracturing Fluid System

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/day	3
	EF	Exposure frequency	day/yr	10
	ED	Exposure duration	yr	15
	BW	Body weight	kg	25
	AT-NC	Averaging time - noncancer	days	5,475

Table 10 Exposure Assumptions - Dingo
Condor Energy Services Hydraulic Fracturing Fluid System

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/day	0.75
	EF	Exposure frequency	day/yr	10
	ED	Exposure duration	yr	15
	BW	Body weight	kg	13
	AT-NC	Averaging time - noncancer	days	5,475

Table 11
Condor Energy Services Hydraulic Fracturing Fluid System

ANZECC Water Quality Guideline (2000)

Constituent (CAS No.)	Substance	Freshwater Trigger Value
Alcohols, C9-11, ethoxylated (68439-46-3)	Alcohol ethoxylates	140 µg/L
Ethoxylated C11 alcohol (34398-01-1)	Alcohol ethoxylates	140 µg/L
Sodium tetraborate decahydrate (1303-96-4)	Boron	370 µg/L

$PNEC_{water}$ Values

Constituents	Endpoint	$E(L)C_{50}$ or NOEC (mg/L)	Assessment Factor	$PNEC_{water}$ (mg/L)
Acetic acid (64-19-7)	Acute fish or *Daphnia*	300.82	100	3.0
Acrylamide/sodium acrylate copolymer (25085-02-3)	Acute fish	100	1,000	0.1
Ammonium persulfate (7727-54-0)	Acute fish	76.3	100	0.8
Ammonium sulfate (7783-20-2)	Chronic fish	3.12	50	0.06
Amylase, alpha (9000-90-2)	Acute algae	5.2	100	0.05
Castor oil, ethoxylated (61791-12-6)	Acute fish	45	100	0.45
Choline chloride (67-48-1)	Chronic *Daphnia*	30	100	0.3
Cinnamaldehyde (104-55-2)	Acute fish	4.15	100	0.04
Diethylene glycol (111-46-6)	Chronic algae	2,700	100	27
Distillates (petroleum), hydrotreated light (64742-47-8)	-[a]	-	-	-
2-Ethyoxynaphthalene (93-18-5)	Acute algae	3.9	100	0.04
Ethylene glycol (107-21-1)	Acute fish	100	10	10
Formic acid	Acute fish	100	100	1

$PNEC_{water}$ Values

Constituents	Endpoint	E(L)C_{50} or NOEC (mg/L)	Assessment Factor	$PNEC_{water}$ (mg/L)
(64-18-6)				
Glutaraldehyde (111-30-8)	Chronic algae	0.025	10	0.0025
Glycerol (56-81-5)	Acute *Daphnia*	10,000	1,000	10
Guar gum (9000-30-0)	Acute *Daphnia*	6.2	1,000	0.006
Hemicellulase (9025-56-3)	Acute fish	52.1	100	0.5
1,6-Hexanediol (629-11-8)	Acute *Daphnia*	500	100	5
Hydrochloric acid (7647-01-0)	-[a]	-	-	-
Isopropanol (67-63-0)	Chronic *Daphnia*	30	100	0.3
2-Mercaptoethyl alcohol (60-24-2)	Chronic *Daphnia*	0.063	50	0.0013
Methanol (67-56-1)	Acute *Daphnia*	10,000	1,000	10
N-benzyl-alkylpyridium chloride (68909-18-2)	Acute algae	0.47	1,000	0.005
Quat. Ammonium compds, bis (hydrogenated tallow alkyl) dimethyl, salts with bentonite (68955-58-2)	Chronic *Daphnia*	3.2	50	0.06
Pine oil (8002-09-3)	Acute fish	18.4	1,000	0.02
Polyoxyethylene nonylphenol ether (9016-45-9)	Chronic *Daphnia*	0.285	50	0.006
Polyoxyethylene-polyoxypropylene block copolymer (9003-11-6)	Acute aquatic organisms	100	1,000	0.1
Potassium carbonate (584-08-7)	-[a]	-	-	-
Potassium chloride (7447-40-7)	Acute algae	100	1,000	0.1
Potassium hydroxide (1310-73-2)	-[a]	-	-	-
Potassium persulfate (7727-21-1)	Acute fish	76.3	100	0.8
Potassium sorbate (24634-61-5)	Chronic *Daphnia*	8.46	50	0.17
2-Propenoic acid,	Chronic *Daphnia*	12	10	1.2

$PNEC_{water}$ Values

Constituents	Endpoint	$E(L)C_{50}$ or NOEC (mg/L)	Assessment Factor	$PNEC_{water}$ (mg/L)
homopolymer, ammonium salt (9003-03-6)				
Sodium benzoate (532-32-1)	Acute algae	30.5	100	0.3
Sodium bisulfite (7631-90-5)	Chronic *Daphnia*	8.3	10	0.8
Sodium erythrobate (6381-77-7)	Acute fish, *Daphnia*, algae	100	100	1
Sodium hydroxide (1310-72-2)	-[a]	-	-	-
Sodium polyacrylate (9003-04-7)	Chronic *Daphnia*	12	10	1.2
Tar bases, quinoline deriv., benzyl chloride – Quat. (72480-70-7)	No data	-	-	-

[a]Not calculated.

Table 12 Risk Estimates for Cattle
Condor Energy Services Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 0

		Day 0	Toxicity	Condor Energy System Hydraulic Fracturing Fluid System	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Acetic Acid	64-19-7	1.0E+02	NA	7.8E-01	NA
Alcohols, C9-11, ethoxylated	68439-46-3	1.7E+01	2.5E+01	1.3E-01	5.2E-03
Ammonium Persulphate	7727-54-0	1.5E+01	NA	1.2E-01	NA
Ammonium Sulphate	7783-20-2	3.4E+01	NA	2.6E-01	NA
Amylase, Alpha	9000-90-2	7.1E-01	1.8E+02	5.6E-03	3.0E-05
Castor Oil	61791-12-6	8.5E-01	4.2E+02	6.6E-03	1.6E-05
Choline Chloride	67-48-1	9.6E+00	NA	7.5E-02	NA
Cinnamaldehyde	104-55-2	9.3E-01	2.6E+01	7.3E-03	2.8E-04
Diethylene Glycol	111-46-6	1.4E-01	1.7E+01	1.1E-03	6.3E-05
DISTILLATES, HYDROTREATED LIGHT	64742-47-8	5.3E+02	1.7E+02	4.1E+00	2.5E-02
Ethoxylated C11 Alcohol	34398-01-1	5.0E+01	2.5E+01	3.9E-01	1.6E-02
2-Ethoxy-naphthalene	93-18-5	6.3E-01	8.3E-01	4.9E-03	5.9E-03
Ethylene Glycol	107-21-1	1.4E-01	NA	1.1E-03	NA
Formic Acid	64-18-6	6.2E+00	3.7E+01	4.8E-02	1.3E-03
Glutaraldehyde	111-30-8	1.8E+02	6.7E-01	1.4E+00	2.1E+00
Glycerol	56-81-5	2.9E+02	7.6E+02	2.2E+00	2.9E-03
Guar Gum	9000-30-0	5.6E+02	2.1E+02	4.4E+00	2.1E-02
Hemicellulase	9025-56-3	3.8E+00	1.7E+02	2.9E-02	1.8E-04
1,6-Hexanediol	629-11-8	1.6E+01	6.7E+01	1.2E-01	1.9E-03
HydroChloric Acid	7647-01-0	3.6E+02	NA	2.8E+00	NA
Inorganic Salt	584-08-7	9.7E+01	NA	7.6E-01	NA
Isopropanol	67-63-0	4.0E+01	NA	3.1E-01	NA
2-Mercaptoethyl Alcohol	60-24-2	7.1E-01	NA	5.5E-03	NA
Methanol	67-56-1	4.0E-01	NA	3.1E-03	NA
N-Benzyl-Alkylpyridinium Chloride	68909-18-2	6.3E-01	NA	4.9E-03	NA
Pine Oil	8002-09-3	8.4E-01	8.3E+00	6.6E-03	7.9E-04
Polyacrylamide	25085-02-3	2.5E+01	8.3E+02	1.9E-01	2.3E-04
Polyoxyethylene nonylphenol ether	9016-45-9	1.7E+02	NA	1.3E+00	NA
Polyoxyethylene-polyoxypropylene Block Copolymer	9003-11-6	6.9E-01	4.2E+02	5.4E-03	1.3E-05
Potassium Chloride	7447-40-7	1.6E+01	3.0E+02	1.3E-01	4.2E-04
Potassium Hydroxide	1310-58-3	8.5E+01	NA	6.6E-01	NA
Potassium persulfate	7727-21-1	1.6E+00	NA	1.2E-02	NA
Potasium Sorbate	24634-61-5	1.6E-01	1.7E+02	1.2E-03	7.3E-06
2-Propenoic acid, homopolymer, ammonium salt	9003-03-6	6.3E-01	1.9E+02	4.9E-03	2.6E-05
Quaternary ammonium compounds, bis(hydrogenated tallow al	68953-58-2	1.7E+02	4.2E+02	1.3E+00	3.1E-03
Sodium Benzoate	532-32-1	1.7E-01	5.2E+02	1.3E-03	2.5E-06
Sodium bisulfite	7631-90-5	9.4E-01	8.7E+01	7.3E-03	8.4E-05
Sodium erythorbate	6381-77-7	5.3E+00	8.7E+02	4.1E-02	4.8E-05
Sodium Hydroxide	1310-73-2	1.6E+02	NA	1.3E+00	NA
Sodium polyacrylate	9003-04-7	3.9E+00	1.9E+02	3.0E-02	1.6E-04
Sodium Tetraborate Decahydrate	1303-96-4	5.4E+02	NA	4.2E+00	NA
				Hazard Index	2.1E+00

Table 13 Risk Estimates for Cattle
Condor Energy Services Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 150

		Day 150	Toxicity	Condor Energy System Hydraulic Fracturing Fluid System	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Acetic Acid	64-19-7	9.8E-02	NA	7.6E-04	NA
Alcohols, C9-11, ethoxylated	68439-46-3	1.6E-02	2.5E+01	1.3E-04	5.1E-06
Ammonium Persulphate	7727-54-0	1.5E+01	NA	1.2E-01	NA
Ammonium Sulphate	7783-20-2	3.4E+01	NA	2.6E-01	NA
Amylase, Alpha	9000-90-2	7.0E-04	1.8E+02	5.4E-06	2.9E-08
Castor Oil	61791-12-6	8.3E-04	4.2E+02	6.5E-06	1.6E-08
Choline Chloride	67-48-1	9.4E-03	NA	7.3E-05	NA
Cinnamaldehyde	104-55-2	9.1E-04	2.6E+01	7.1E-06	2.8E-07
Diethylene Glycol	111-46-6	1.4E-04	1.7E+01	1.1E-06	6.2E-08
DISTILLATES, HYDROTREATED LIGHT	64742-47-8	2.7E+02	1.7E+02	2.1E+00	1.2E-02
Ethoxylated C11 Alcohol	34398-01-1	4.9E-02	2.5E+01	3.8E-04	1.5E-05
2-Ethoxy-naphthalene	93-18-5	6.3E-01	8.3E-01	4.9E-03	5.9E-03
Ethylene Glycol	107-21-1	1.4E-04	NA	1.1E-06	NA
Formic Acid	64-18-6	6.0E-03	3.7E+01	4.7E-05	1.3E-06
Glutaraldehyde	111-30-8	1.7E-01	6.7E-01	1.3E-03	2.0E-03
Glycerol	56-81-5	2.8E-01	7.6E+02	2.2E-03	2.9E-06
Guar Gum	9000-30-0	5.5E-01	2.1E+02	4.3E-03	2.1E-05
Hemicellulase	9025-56-3	3.7E-03	1.7E+02	2.9E-05	1.7E-07
1,6-Hexanediol	629-11-8	1.6E-02	6.7E+01	1.2E-04	1.8E-06
HydroChloric Acid	7647-01-0	3.6E+02	NA	2.8E+00	NA
Inorganic Salt	584-08-7	9.7E+01	NA	7.6E-01	NA
Isopropanol	67-63-0	3.9E-02	NA	3.0E-04	NA
2-Mercaptoethyl Alcohol	60-24-2	6.9E-04	NA	5.4E-06	NA
Methanol	67-56-1	3.9E-04	NA	3.1E-06	NA
N-Benzyl-Alkylpyridinium Chloride	68909-18-2	6.3E-01	NA	4.9E-03	NA
Pine Oil	8002-09-3	8.2E-04	8.3E+00	6.4E-06	7.7E-07
Polyacrylamide	25085-02-3	2.5E+01	8.3E+02	1.9E-01	2.3E-04
Polyoxyethylene nonylphenol ether	9016-45-9	1.6E-01	NA	1.3E-03	NA
Polyoxyethylene-polyoxypropylene Block Copolymer	9003-11-6	6.9E-01	4.2E+02	5.4E-03	1.3E-05
Potassium Chloride	7447-40-7	1.6E+01	3.0E+02	1.3E-01	4.2E-04
Potassium Hydroxide	1310-58-3	8.5E+01	NA	6.6E-01	NA
Potassium persulfate	7727-21-1	1.6E+00	NA	1.2E-02	NA
Potasium Sorbate	24634-61-5	1.5E-04	1.7E+02	1.2E-06	7.1E-09
2-Propenoic acid, homopolymer, ammonium salt	9003-03-6	6.3E-01	1.9E+02	4.9E-03	2.6E-05
Quaternary ammonium compounds, bis(hydrogenated tallow alkyl)dimethyl, salts with bentonite	68953-58-2	1.7E+02	4.2E+02	1.3E+00	3.1E-03
Sodium Benzoate	532-32-1	1.7E-04	5.2E+02	1.3E-06	2.5E-09
Sodium bisulfite	7631-90-5	9.4E-01	8.7E+01	7.3E-03	8.4E-05
Sodium erythorbate	6381-77-7	5.2E-03	8.7E+02	4.0E-05	4.6E-08
Sodium Hydroxide	1310-73-2	1.6E+02	NA	1.3E+00	NA
Sodium polyacrylate	9003-04-7	3.9E+00	1.9E+02	3.0E-02	1.6E-04
Sodium Tetraborate Decahydrate	1303-96-4	5.4E+02	NA	4.2E+00	NA
				Hazard Index	2.4E-02

Table 14 Risk Estimates for Kangaroo
Condor Energy Services Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 0

		Day 0	Toxicity	Condor Energy Services Hydraulic Fracturing Fluid System	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Acetic Acid	64-19-7	1.0E+02	NA	3.3E-01	NA
Alcohols, C9-11, ethoxylated	68439-46-3	1.7E+01	5.2E+01	5.5E-02	1.1E-03
Ammonium Persulphate	7727-54-0	1.5E+01	NA	4.9E-02	NA
Ammonium Sulphate	7783-20-2	3.4E+01	NA	1.1E-01	NA
Amylase, Alpha	9000-90-2	7.1E-01	3.8E+02	2.3E-03	6.1E-06
Castor Oil	61791-12-6	8.5E-01	8.6E+02	2.8E-03	3.3E-06
Choline Chloride	67-48-1	9.6E+00	NA	3.2E-02	NA
Cinnamaldehyde	104-55-2	9.3E-01	5.3E+01	3.1E-03	5.8E-05
Diethylene Glycol	111-46-6	1.4E-01	3.6E+01	4.7E-04	1.3E-05
DISTILLATES, HYDROTREATED LIGHT	64742-47-8	5.3E+02	3.4E+02	1.8E+00	5.1E-03
Ethoxylated C11 Alcohol	34398-01-1	5.0E+01	5.2E+01	1.6E-01	3.2E-03
2-Ethoxy-naphthalene	93-18-5	6.3E-01	1.7E+00	2.1E-03	1.2E-03
Ethylene Glycol	107-21-1	1.4E-01	NA	4.6E-04	NA
Formic Acid	64-18-6	6.2E+00	7.6E+01	2.0E-02	2.7E-04
Glutaraldehyde	111-30-8	1.8E+02	1.4E+00	5.8E-01	4.2E-01
Glycerol	56-81-5	2.9E+02	1.6E+03	9.5E-01	6.0E-04
Guar Gum	9000-30-0	5.6E+02	4.3E+02	1.9E+00	4.3E-03
Hemicellulase	9025-56-3	3.8E+00	3.4E+02	1.2E-02	3.6E-05
1,6-Hexanediol	629-11-8	1.6E+01	1.4E+02	5.3E-02	3.8E-04
HydroChloric Acid	7647-01-0	3.6E+02	NA	1.2E+00	NA
Inorganic Salt	584-08-7	9.7E+01	NA	3.2E-01	NA
Isopropanol	67-63-0	4.0E+01	NA	1.3E-01	NA
2-Mercaptoethyl Alcohol	60-24-2	7.1E-01	NA	2.3E-03	NA
Methanol	67-56-1	4.0E-01	NA	1.3E-03	NA
N-Benzyl-Alkylpyridinium Chloride	68909-18-2	6.3E-01	NA	2.1E-03	NA
Pine Oil	8002-09-3	8.4E-01	1.7E+01	2.8E-03	1.6E-04
Polyacrylamide	25085-02-3	2.5E+01	1.7E+03	8.1E-02	4.7E-05
Polyoxyethylene nonylphenol ether	9016-45-9	1.7E+02	NA	5.5E-01	NA
Polyoxyethylene-polyoxypropylene Block Copolymer	9003-11-6	6.9E-01	8.6E+02	2.3E-03	2.7E-06
Potassium Chloride	7447-40-7	1.6E+01	6.3E+02	5.4E-02	8.7E-05
Potassium Hydroxide	1310-58-3	8.5E+01	NA	2.8E-01	NA
Potassium persulfate	7727-21-1	1.6E+00	NA	5.2E-03	NA
Potasium Sorbate	24634-61-5	1.6E-01	3.4E+02	5.1E-04	1.5E-06
2-Propenoic acid, homopolymer, ammonium salt	9003-03-6	6.3E-01	3.9E+02	2.1E-03	5.3E-06
Quaternary ammonium compounds, bis(hydrogenated tallow alkyl)dimethyl, salts with bentonite	68953-58-2	1.7E+02	8.6E+02	5.5E-01	6.4E-04
Sodium Benzoate	532-32-1	1.7E-01	1.1E+03	5.6E-04	5.2E-07
Sodium bisulfite	7631-90-5	9.4E-01	1.8E+02	3.1E-03	1.7E-05
Sodium erythorbate	6381-77-7	5.3E+00	1.8E+03	1.8E-02	9.7E-06
Sodium Hydroxide	1310-73-2	1.6E+02	NA	5.3E-01	NA
Sodium polyacrylate	9003-04-7	3.9E+00	3.9E+02	1.3E-02	3.3E-05
Sodium Tetraborate Decahydrate	1303-96-4	5.4E+02	NA	1.8E+00	NA
				Hazard Index	4.4E-01

Table 15 Risk Estimates for Kangaroo
Condor Energy Services Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 150

		Day 150	Toxicity	Condor Energy Services Hydraulic Fracturing Fluid System	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Acetic Acid	64-19-7	9.8E-02	NA	3.2E-04	NA
Alcohols, C9-11, ethoxylated	68439-46-3	1.6E-02	5.2E+01	5.3E-05	1.0E-06
Ammonium Persulphate	7727-54-0	1.5E+01	NA	4.9E-02	NA
Ammonium Sulphate	7783-20-2	3.4E+01	NA	1.1E-01	NA
Amylase, Alpha	9000-90-2	7.0E-04	3.8E+02	2.3E-06	6.0E-09
Castor Oil	61791-12-6	8.3E-04	8.6E+02	2.7E-06	3.2E-09
Choline Chloride	67-48-1	9.4E-03	NA	3.1E-05	NA
Cinnamaldehyde	104-55-2	9.1E-04	5.3E+01	3.0E-06	5.7E-08
Diethylene Glycol	111-46-6	1.4E-04	3.6E+01	4.6E-07	1.3E-08
DISTILLATES, HYDROTREATED LIGHT	64742-47-8	2.7E+02	3.4E+02	8.8E-01	2.5E-03
Ethoxylated C11 Alcohol	34398-01-1	4.9E-02	5.2E+01	1.6E-04	3.1E-06
2-Ethoxy-naphthalene	93-18-5	6.3E-01	1.7E+00	2.1E-03	1.2E-03
Ethylene Glycol	107-21-1	1.4E-04	NA	4.5E-07	NA
Formic Acid	64-18-6	6.0E-03	7.6E+01	2.0E-05	2.6E-07
Glutaraldehyde	111-30-8	1.7E-01	1.4E+00	5.7E-04	4.1E-04
Glycerol	56-81-5	2.8E-01	1.6E+03	9.2E-04	5.9E-07
Guar Gum	9000-30-0	5.5E-01	4.3E+02	1.8E-03	4.2E-06
Hemicellulase	9025-56-3	3.7E-03	3.4E+02	1.2E-05	3.5E-08
1,6-Hexanediol	629-11-8	1.6E-02	1.4E+02	5.1E-05	3.7E-07
HydroChloric Acid	7647-01-0	3.6E+02	NA	1.2E+00	NA
Inorganic Salt	584-08-7	9.7E+01	NA	3.2E-01	NA
Isopropanol	67-63-0	3.9E-02	NA	1.3E-04	NA
2-Mercaptoethyl Alcohol	60-24-2	6.9E-04	NA	2.3E-06	NA
Methanol	67-56-1	3.9E-04	NA	1.3E-06	NA
N-Benzyl-Alkylpyridinium Chloride	68909-18-2	6.3E-01	NA	2.1E-03	NA
Pine Oil	8002-09-3	8.2E-04	1.7E+01	2.7E-06	1.6E-07
Polyacrylamide	25085-02-3	2.5E+01	1.7E+03	8.1E-02	4.7E-05
Polyoxyethylene nonylphenol ether	9016-45-9	1.6E-01	NA	5.3E-04	NA
Polyoxyethylene-polyoxypropylene Block Copolymer	9003-11-6	6.9E-01	8.6E+02	2.3E-03	2.7E-06
Potassium Chloride	7447-40-7	1.6E+01	6.3E+02	5.4E-02	8.7E-05
Potassium Hydroxide	1310-58-3	8.5E+01	NA	2.8E-01	NA
Potassium persulfate	7727-21-1	1.6E+00	NA	5.2E-03	NA
Potasium Sorbate	24634-61-5	1.5E-04	3.4E+02	5.0E-07	1.5E-09
2-Propenoic acid, homopolymer, ammonium salt	9003-03-6	6.3E-01	3.9E+02	2.1E-03	5.3E-06
Quaternary ammonium compounds, bis(hydrogenated tallow	68953-58-2	1.7E+02	8.6E+02	5.5E-01	6.4E-04
Sodium Benzoate	532-32-1	1.7E-04	1.1E+03	5.5E-07	5.1E-10
Sodium bisulfite	7631-90-5	9.4E-01	1.8E+02	3.1E-03	1.7E-05
Sodium erythorbate	6381-77-7	5.2E-03	1.8E+03	1.7E-05	9.5E-09
Sodium Hydroxide	1310-73-2	1.6E+02	NA	5.3E-01	NA
Sodium polyacrylate	9003-04-7	3.9E+00	3.9E+02	1.3E-02	3.3E-05
Sodium Tetraborate Decahydrate	1303-96-4	5.4E+02	NA	1.8E+00	NA
				Hazard Index	5.0E-03

Table 16 Risk Estimates for Dingo
Condor Energy Services Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 0

		Day 0	Toxicity	Condor Energy Services Hydraulic Fracturing Fluid System	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Acetic Acid	64-19-7	1.0E+02	NA	1.6E-01	NA
Alcohols, C9-11, ethoxylated	68439-46-3	1.7E+01	6.1E+01	2.6E-02	4.3E-04
Ammonium Persulphate	7727-54-0	1.5E+01	NA	2.4E-02	NA
Ammonium Sulphate	7783-20-2	3.4E+01	NA	5.3E-02	NA
Amylase, Alpha	9000-90-2	7.1E-01	4.5E+02	1.1E-03	2.5E-06
Castor Oil	61791-12-6	8.5E-01	1.0E+03	1.3E-03	1.3E-06
Choline Chloride	67-48-1	9.6E+00	NA	1.5E-02	NA
Cinnamaldehyde	104-55-2	9.3E-01	6.2E+01	1.5E-03	2.4E-05
Diethylene Glycol	111-46-6	1.4E-01	4.3E+01	2.2E-04	5.3E-06
DISTILLATES, HYDROTREATED LIGHT	64742-47-8	5.3E+02	4.1E+02	8.4E-01	2.1E-03
Ethoxylated C11 Alcohol	34398-01-1	5.0E+01	6.1E+01	7.9E-02	1.3E-03
2-Ethoxy-naphthalene	93-18-5	6.3E-01	2.0E+00	1.0E-03	4.9E-04
Ethylene Glycol	107-21-1	1.4E-01	NA	2.2E-04	NA
Formic Acid	64-18-6	6.2E+00	8.9E+01	9.8E-03	1.1E-04
Glutaraldehyde	111-30-8	1.8E+02	1.6E+00	2.8E-01	1.7E-01
Glycerol	56-81-5	2.9E+02	1.9E+03	4.5E-01	2.5E-04
Guar Gum	9000-30-0	5.6E+02	5.1E+02	8.9E-01	1.8E-03
Hemicellulase	9025-56-3	3.8E+00	4.1E+02	6.0E-03	1.5E-05
1,6-Hexanediol	629-11-8	1.6E+01	1.6E+02	2.5E-02	1.6E-04
HydroChloric Acid	7647-01-0	3.6E+02	NA	5.8E-01	NA
Inorganic Salt	584-08-7	9.7E+01	NA	1.5E-01	NA
Isopropanol	67-63-0	4.0E+01	NA	6.3E-02	NA
2-Mercaptoethyl Alcohol	60-24-2	7.1E-01	NA	1.1E-03	NA
Methanol	67-56-1	4.0E-01	NA	6.3E-04	NA
N-Benzyl-Alkylpyridinium Chloride	68909-18-2	6.3E-01	NA	1.0E-03	NA
Pine Oil	8002-09-3	8.4E-01	2.0E+01	1.3E-03	6.6E-05
Polyacrylamide	25085-02-3	2.5E+01	2.0E+03	3.9E-02	1.9E-05
Polyoxyethylene nonylphenol ether	9016-45-9	1.7E+02	NA	2.6E-01	NA
Polyoxyethylene-polyoxypropylene Block Copolymer	9003-11-6	6.9E-01	1.0E+03	1.1E-03	1.1E-06
Potassium Chloride	7447-40-7	1.6E+01	7.4E+02	2.6E-02	3.5E-05
Potassium Hydroxide	1310-58-3	8.5E+01	NA	1.3E-01	NA
Potassium persulfate	7727-21-1	1.6E+00	NA	2.5E-03	NA
Potasium Sorbate	24634-61-5	1.6E-01	4.1E+02	2.5E-04	6.1E-07
2-Propenoic acid, homopolymer, ammonium salt	9003-03-6	6.3E-01	4.6E+02	1.0E-03	2.2E-06
Quaternary ammonium compounds, bis(hydrogenated tallow alkyl)dimethyl, salts with bentonite	68953-58-2	1.7E+02	1.0E+03	2.6E-01	2.6E-04
Sodium Benzoate	532-32-1	1.7E-01	1.3E+03	2.7E-04	2.1E-07
Sodium bisulfite	7631-90-5	9.4E-01	2.1E+02	1.5E-03	7.0E-06
Sodium erythorbate	6381-77-7	5.3E+00	2.1E+03	8.4E-03	4.0E-06
Sodium Hydroxide	1310-73-2	1.6E+02	NA	2.6E-01	NA
Sodium polyacrylate	9003-04-7	3.9E+00	4.6E+02	6.1E-03	1.3E-05
Sodium Tetraborate Decahydrate	1303-96-4	5.4E+02	NA	8.6E-01	NA
				Hazard Index	1.8E-01

Table 17 Risk Estimates for Dingo
Condor Energy Services Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 150

		Day 150	Toxicity	Condor Energy Services Hydraulic Fracturing Fluid System	
					Hazard Quotient
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Acetic Acid	64-19-7	9.8E-02	NA	1.5E-04	NA
Alcohols, C9-11, ethoxylated	68439-46-3	1.6E-02	6.1E+01	2.6E-05	4.2E-07
Ammonium Persulphate	7727-54-0	1.5E+01	NA	2.4E-02	NA
Ammonium Sulphate	7783-20-2	3.4E+01	NA	5.3E-02	NA
Amylase, Alpha	9000-90-2	7.0E-04	4.5E+02	1.1E-06	2.4E-09
Castor Oil	61791-12-6	8.3E-04	1.0E+03	1.3E-06	1.3E-09
Choline Chloride	67-48-1	9.4E-03	NA	1.5E-05	NA
Cinnamaldehyde	104-55-2	9.1E-04	6.2E+01	1.4E-06	2.3E-08
Diethylene Glycol	111-46-6	1.4E-04	4.3E+01	2.2E-07	5.1E-09
DISTILLATES, HYDROTREATED LIGHT	64742-47-8	2.7E+02	4.1E+02	4.2E-01	1.0E-03
Ethoxylated C11 Alcohol	34398-01-1	4.9E-02	6.1E+01	7.7E-05	1.3E-06
2-Ethoxy-naphthalene	93-18-5	6.3E-01	2.0E+00	1.0E-03	4.9E-04
Ethylene Glycol	107-21-1	1.4E-04	NA	2.2E-07	NA
Formic Acid	64-18-6	6.0E-03	8.9E+01	9.6E-06	1.1E-07
Glutaraldehyde	111-30-8	1.7E-01	1.6E+00	2.7E-04	1.7E-04
Glycerol	56-81-5	2.8E-01	1.9E+03	4.4E-04	2.4E-07
Guar Gum	9000-30-0	5.5E-01	5.1E+02	8.7E-04	1.7E-06
Hemicellulase	9025-56-3	3.7E-03	4.1E+02	5.8E-06	1.4E-08
1,6-Hexanediol	629-11-8	1.6E-02	1.6E+02	2.5E-05	1.5E-07
HydroChloric Acid	7647-01-0	3.6E+02	NA	5.8E-01	NA
Inorganic Salt	584-08-7	9.7E+01	NA	1.5E-01	NA
Isopropanol	67-63-0	3.9E-02	NA	6.2E-05	NA
2-Mercaptoethyl Alcohol	60-24-2	6.9E-04	NA	1.1E-06	NA
Methanol	67-56-1	3.9E-04	NA	6.2E-07	NA
N-Benzyl-Alkylpyridinium Chloride	68909-18-2	6.3E-01	NA	1.0E-03	NA
Pine Oil	8002-09-3	8.2E-04	2.0E+01	1.3E-06	6.4E-08
Polyacrylamide	25085-02-3	2.5E+01	2.0E+03	3.9E-02	1.9E-05
Polyoxyethylene nonylphenol ether	9016-45-9	1.6E-01	NA	2.6E-04	NA
Polyoxyethylene-polyoxypropylene Block Copolymer	9003-11-6	6.9E-01	1.0E+03	1.1E-03	1.1E-06
Potassium Chloride	7447-40-7	1.6E+01	7.4E+02	2.6E-02	3.5E-05
Potassium Hydroxide	1310-58-3	8.5E+01	NA	1.3E-01	NA
Potassium persulfate	7727-21-1	1.6E+00	NA	2.5E-03	NA
Potasium Sorbate	24634-61-5	1.5E-04	4.1E+02	2.4E-07	5.9E-10
2-Propenoic acid, homopolymer, ammonium salt	9003-03-6	6.3E-01	4.6E+02	1.0E-03	2.2E-06
Quaternary ammonium compounds, bis(hydrogenated tallow alkyl)dimethyl, salts with bentonite	68953-58-2	1.7E+02	1.0E+03	2.6E-01	2.6E-04
Sodium Benzoate	532-32-1	1.7E-04	1.3E+03	2.6E-07	2.1E-10
Sodium bisulfite	7631-90-5	9.4E-01	2.1E+02	1.5E-03	7.0E-06
Sodium erythorbate	6381-77-7	5.2E-03	2.1E+03	8.2E-06	3.9E-09
Sodium Hydroxide	1310-73-2	1.6E+02	NA	2.6E-01	NA
Sodium polyacrylate	9003-04-7	3.9E+00	4.6E+02	6.1E-03	1.3E-05
Sodium Tetraborate Decahydrate	1303-96-4	5.4E+02	NA	8.6E-01	NA
				Hazard Index	2.0E-03

Appendix C10-1

CONFIDENTIAL INFORMATION - ONLY TO BE USED FOR REGULATOR NOTIFICATION (QLD FORMAT)

5/25/2018

Comments: 20# Borate XL system with Acid Spearhead
Santos Limited Pre Job Fairview Generic Condor Energy Servies Fluid System Disclosure

Total injected fluid volume (kilolitres):	**397.468**

Comprising of:		
Base fluid type (e.g. water)	**Litres**	**% of total volume**
Makeup Water	331180.513	83.323%

Proppant type (e.g. sand)	**Proppant size**	**Kilograms**	**Litres**	**% of total volume**
Sand	40/70	3401.361	1283.254	0.323%
Sand	20/40	141428.571	53357.701	13.424%

Any wet chemical constitutes:	**Litres**	**CAS Number**	**% of total volume**
Alcohols, C9-11, ethoxylated	49.613	68439-46-3	0.0125%
Ethoxylated C11 Alcohol	148.838	34398-01-1	0.0374%
Ethylene Glycol	0.378	107-21-1	0.0001%
Choline Chloride	26.082	67-48-1	0.0066%
Glutaraldehyde	496.125	111-30-8	0.1248%
Ammonium Sulphate	56.700	7783-20-2	0.0143%
Polyacrylamide	56.700	25085-02-3	0.0143%
Sodium polyacrylate	9.450	9003-04-7	0.0024%
Sodium bisulfite	1.890	7631-90-5	0.0005%
2-Propenoic acid, homopolymer, ammonium salt	1.890	9003-03-6	0.0005%
Ammonium Persulphate	22.504	7727-54-0	0.0057%
Potassium persulfate	1.890	7727-21-1	0.0005%
2-Ethoxy-naphthalene	1.890	93-18-5	0.0005%
Potassium Hydroxide	119.070	1310-58-3	0.0300%
Inorganic Salt	119.070	584-08-7	0.0300%
Glycerol	680.400	56-81-5	0.1712%
Sodium Tetraborate	680.400	1330-43-4	0.1712%
Sodium Hydroxide	226.800	1310-73-2	0.0571%
Hemicellulase	11.227	9025-56-3	0.0028%
Amylase, Alpha	1.701	9000-90-2	0.0004%
Sodium Benzoate	0.340	532-32-1	0.0001%
Pottasium Sorbate	0.340	24634-61-5	0.0001%
DISTILLATES, HYDROTREATED LIGHT	1984.500	64742-47-8	0.4993%
Guar Gum	1681.864	9000-30-0	0.4231%
Polyoxyethylene nonylphenol ether	496.125	9016-45-9	0.1248%
Quaternary ammonium compounds, bis(hydrogenated	496.125	68953-58-2	0.1248%
1,6-Hexanediol	49.613	629-11-8	0.0125%
HydroChloric Acid	945.000	7647-01-0	0.2378%
Cinnamaldehyde	2.646	104-55-2	0.0007%
Tar Bases, Quinoline Derivatives, Benzyl Chloride-Qua	2.646	72480-70-7	0.0007%
Castor Oil	2.646	61791-12-6	0.0007%
Isopropanol	151.484	67-63-0	0.0381%
Pine Oil	2.646	8002-09-3	0.0007%
N-Benzyl-Alkylpyridinium Chloride	1.890	68909-18-2	0.0005%
Water in Additive	2752.357	7732-18-5	0.6925%
2-Mercaptoethyl Alcohol	1.890	60-24-2	0.0005%
Polyoxyethylene-polyoxypropylene Block Copolymer	1.890	9003-11-6	0.0005%
Diethylene Glycol	0.378	111-46-6	0.0001%
Methanol	1.512	67-56-1	0.0004%
Formic Acid	15.120	64-18-6	0.0038%
Sodium erythorbate	13.228	6381-77-7	0.0033%
Acetic Acid	283.500	64-19-7	0.0713%
Potassium Chloride	24.806	7447-40-7	0.0062%
			0.00%
	[insert volume]		Calculated %

*Note: display all values to 3 significant figures.

Total 100.00%

Appendix C10-Tables

Table C10-1 Surface Water Quality Data for Theoretical Scenario in Initial Flowback
Condor Energy Services Hydraulic Fracturing Fluid System

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Mud Pit Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Mud Pitcon =			
				Temporal Scenario (days)			
		Condor Fluid System	Half-Life (days)	0	30	150	300
DISTILLATES, HYDROTREATED LIGHT	64742-47-8	3994.3	150	532.57	463.63	266.29	133.14
1,6-Hexanediol	629-11-8	119.83	15	15.98	3.994	0.01560	0.00001524
2-Ethoxy-naphthalene	93-18-5	4.7551	NA	0.6340	0.6340	0.6340	0.6340
2-Mercaptoethyl Alcohol	60-24-2	5.2972	15	0.7063	0.1766	0.0007	0.0000
2-Propenoic acid, homopolymer, ammonium salt	9003-03-6	4.7551	NA	0.6340	0.6340	0.6340	0.6340
Acetic Acid	64-19-7	748.93	15	99.857	24.964	0.09752	0.00009523
Alcohols, C9-11, ethoxylated	68439-46-3	124.82	15	16.64	4.161	0.01625	0.00001587
Ammonium Persulphate	7727-54-0	112.106	NA	14.947	14.947	14.947	14.947
Ammonium Sulphate	7783-20-2	252.50	NA	33.67	33.67	33.67	33.67
Amylase, Alpha	9000-90-2	5.3495	15	0.7133	0.1783	0.0006965	0.0000006802
Castor Oil	61791-12-6	6.3909	15	0.8521	0.2130	0.0008321	0.0000008126
Choline Chloride	67-48-1	72.182	15	9.6	2.406	0.009399	0.000009178
Cinnamaldehyde	104-55-2	6.9880	15	0.9317	0.2329	0.0009099	0.0000008886
Diethylene Glycol	111-46-6	1.06324	15	0.1418	0.0354	0.0001384	0.0000001352
Ethoxylated C11 Alcohol	34398-01-1	374.46	15	49.9	12.5	0.04876	0.00004762
Ethylene Glycol	107-21-1	1.05563	15	0.1408	0.03519	0.0001375	0.0000001342
Formic Acid	64-18-6	46.410	15	6.2	1.547	0.006043	0.000005901
Glutaraldehyde	111-30-8	1323.1	15	176.4	44.1	0.1723	0.0001682
Glycerol	56-81-5	2156.9	15	287.6	71.9	0.2808	0.0002743
Guar Gum	9000-30-0	4231.4	15	564.2	141.0	0.5510	0.0005381
Hemicellulase	9025-56-3	28.245	15	3.8	0.942	0.003678	0.000003592
HydroChloric Acid	7647-01-0	2732.5	NA	364.3	364.3	364.3	364.3
Inorganic salt	584-08-7	727.96	NA	97.1	97.1	97.1	97.1
Isopropanol	67-63-0	299.56	15	39.9	10.0	0.0	0.0
Methanol	67-56-1	3.0128	15	0.4017	0.1004	0.0003923	0.0000003831
N-Benzyl-Alkylpyridinium Chloride	68909-18-2	4.7551	NA	0.63401	0.63401	0.63401	0.63401
Pine Oil	8002-09-3	6.3243	15	0.8432	0.2108	0.0008235	0.0000008042
Polyacrylamide	25085-02-3	185.45	NA	24.7	24.7	24.7	24.7
Polyoxyethylene nonylphenol ether	9016-45-9	1244.5	15	165.9	41.5	0.2	0.0
Polyoxyethylene-polyoxypropylene Block Copolymer	9003-11-6	5.2068	NA	0.6942	0.6942	0.6942	0.6942
Potassium Chloride	7447-40-7	123.573	NA	16.5	16.5	16.5	16.5
Potassium Hydroxide	1310-58-3	635.09	NA	84.7	84.7	84.7	84.7
Potassium persulfate	7727-21-1	11.7784	NA	1.57045	1.57045	1.57045	1.57045
Pottasium Sorbate	24634-61-5	1.16662	15	0.1555	0.03889	0.0001519	0.0000001483
Quaternary ammonium compounds, bis(hydrogenated tallow alkyl)dimethyl, salts with bentonite	68953-58-2	1248.2	NA	166.4	166.4	166.4	166.4
Sodium Benzoate	532-32-1	1.28131	15	0.1708	0.04271	0.0001668	0.0000001629
Sodium bisulfite	7631-90-5	7.0375	NA	0.9383	0.9383	0.9383	0.9383
Sodium erythorbate	6381-77-7	39.935	15	5.325	1.331	0.005200	0.000005078
Sodium Hydroxide	1310-73-2	1215.40	NA	162.05	162.05	162.05	162.05

Table C10-1 Surface Water Quality Data for Theoretical Scenario in Initial Flowback
Condor Energy Services Hydraulic Fracturing Fluid System

Sodium polyacrylate	9003-04-7	29.006	NA	3.867	3.867	3.867	3.867
Sodium Tetraborate Decahydrate	1303-96-4	4057.1	NA	540.9	540.9	540.9	540.9

Table C10-2 Comparison of Estimated Theoretical
Condor Energy Services Hydraulic Fracturing Fluid System
Concentrations to Human Health Drinking Water Guidelines

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Mud Pit Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Mud Pitcon = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)				Drinking Water Guideline (mg/L)	Ratio of COPC Concentrations and Screening Criteria (Ratio greater than one = unacceptable potential risk)			
				Temporal Scenario (days)					Temporal Scenario (days)			
		Condor Fluid System	Half-Life (days)	0	30	150	300		0	30	150	300
DISTILLATES, HYDROTREATED LIGHT	64742-47-8	3994.3	150	532.57	463.63	266.29	133.14	12	4.4E+01	3.9E+01	2.2E+01	1.1E+01
1,6-Hexanediol	629-11-8	119.83	15	15.98	3.994	0.01560	0.00001524	3.5	4.6E+00	1.1E+00	4.5E-03	4.4E-06
2-Ethoxy-naphthalene	93-18-5	4.7551	NA	0.6340	0.6340	0.6340	0.6340	0.07	9.1E+00	9.1E+00	9.1E+00	9.1E+00
2-Mercaptoethyl Alcohol	60-24-2	5.2972	15	0.7063	0.1766	0.0007	0.0000	0.18	3.9E+00	9.8E-01	3.8E-03	3.7E-06
2-Propenoic acid, homopolymer, ammonium salt	9003-03-6	4.7551	NA	0.6340	0.6340	0.6340	0.6340	3.5	1.8E-01	1.8E-01	1.8E-01	1.8E-01
Acetic Acid	64-19-7	748.93	15	99.857	24.964	0.09752	0.00009523	NA	NA	NA	NA	NA
Alcohols, C9-11, ethoxylated	68439-46-3	124.82	15	16.64	4.161	0.01625	0.00001587	1.8	9.2E+00	2.3E+00	9.0E-03	8.8E-06
Ammonium Persulphate	7727-54-0	112.106	NA	14.947	14.947	14.947	14.947	250	6.0E-02	6.0E-02	6.0E-02	6.0E-02
Ammonium Sulphate	7783-20-2	252.50	NA	33.67	33.67	33.67	33.67	250	1.3E-01	1.3E-01	1.3E-01	1.3E-01
Amylase, Alpha	9000-90-2	5.3495	15	0.7133	0.1783	0.0006965	0.0000006802	13	5.5E-02	1.4E-02	5.4E-05	5.2E-08
Castor Oil	61791-12-6	6.3909	15	0.8521	0.2130	0.0008321	0.0000008126	28	3.0E-02	7.6E-03	3.0E-05	2.9E-08
Choline Chloride	67-48-1	72.182	15	9.6	2.406	0.009399	0.000009178	175	5.5E-02	1.4E-02	5.4E-05	5.2E-08
Cinnamaldehyde	104-55-2	6.9880	15	0.9317	0.2329	0.0009099	0.0000008886	4	2.3E-01	5.8E-02	2.3E-04	2.2E-07
Diethylene Glycol	111-46-6	1.06324	15	0.1418	0.0354	0.0001384	0.0000001352	3.5	4.1E-02	1.0E-02	4.0E-05	3.9E-08
Ethoxylated C11 Alcohol	34398-01-1	374.46	15	49.9	12.5	0.04876	0.00004762	1.8	2.8E+01	6.9E+00	2.7E-02	2.6E-05
Ethylene Glycol	107-21-1	1.05563	15	0.1408	0.03519	0.0001375	0.0000001342	53	2.7E-03	6.6E-04	2.6E-06	2.5E-09
Formic Acid	64-18-6	46.410	15	6.2	1.547	0.006043	0.000005901	7	8.8E-01	2.2E-01	8.6E-04	8.4E-07
Glutaraldehyde	111-30-8	1323.1	15	176.4	44.1	0.1723	0.0001682	0.14	1.3E+03	3.2E+02	1.2E+00	1.2E-03
Glycerol	56-81-5	2156.9	15	287.6	71.9	0.2808	0.0002743	16	1.8E+01	4.5E+00	1.8E-02	1.7E-05
Guar Gum	9000-30-0	4231.4	15	564.2	141.0	0.5510	0.0005381	46	1.2E+01	3.1E+00	1.2E-02	1.2E-05
Hemicellulase	9025-56-3	28.245	15	3.8	0.942	0.003678	0.000003592	3.5	1.1E+00	2.7E-01	1.1E-03	1.0E-06
HydroChloric Acid	7647-01-0	2732.5	NA	364.3	364.3	364.3	364.3	250	1.5E+00	1.5E+00	1.5E+00	1.5E+00
Inorganic Salt	584-08-7	727.96	NA	97.1	97.1	97.1	97.1	NA	NA	NA	NA	NA
Isopropanol	67-63-0	299.56	15	39.9	10.0	0.0	0.0	1.4	2.9E+01	7.1E+00	2.8E-02	2.7E-05
Methanol	67-56-1	3.0128	15	0.4017	0.1004	0.0003923	0.0000003831	7	5.7E-02	1.4E-02	5.6E-05	5.5E-08
N-Benzyl-Alkylpyridinium Chloride	68909-18-2	4.7551	NA	0.63401	0.63401	0.63401	0.63401	NA	NA	NA	NA	NA
Pine Oil	8002-09-3	6.3243	15	0.8432	0.2108	0.0008235	0.0000008042	0.6	1.4E+00	3.5E-01	1.4E-03	1.3E-06
Polyacrylamide	25085-02-3	185.45	NA	24.7	24.7	24.7	24.7	175	1.4E-01	1.4E-01	1.4E-01	1.4E-01
Polyoxyethylene nonylphenol ether	9016-45-9	1244.5	15	165.9	41.5	0.2	0.0	NA	NA	NA	NA	NA
Polyoxyethylene-polyoxypropylene Block Copolymer	9003-11-6	5.2068	NA	0.6942	0.6942	0.6942	0.6942	88	7.9E-03	7.9E-03	7.9E-03	7.9E-03
Potasium Sorbate	24634-61-5	1.16662	15	0.1555	0.03889	0.0001519	0.0000001483	35	4.4E-03	1.1E-03	4.3E-06	4.2E-09
Inorganic Salt	7447-40-7	123.573	NA	16.5	16.5	16.5	16.5	63	2.6E-01	2.6E-01	2.6E-01	2.6E-01
Potassium Hydroxide	1310-58-3	635.09	NA	84.7	84.7	84.7	84.7	NA	NA	NA	NA	NA
Potassium persulfate	7727-21-1	11.7784	NA	1.57045	1.57045	1.57045	1.57045	250	6.3E-03	6.3E-03	6.3E-03	6.3E-03
Quaternary ammonium compounds, bis(hydrogenated tallow alkyl)dimethyl, salts with bentonite	68953-58-2	1248.2	NA	166.4	166.4	166.4	166.4	29	5.7E+00	5.7E+00	5.7E+00	5.7E+00
Sodium Benzoate	532-32-1	1.28131	15	0.1708	0.04271	0.0001668	0.0000001629	35	4.9E-03	1.2E-03	4.8E-06	4.7E-09
Sodium bisulfite	7631-90-5	7.0375	NA	0.9383	0.9383	0.9383	0.9383	18	5.2E-02	5.2E-02	5.2E-02	5.2E-02
Sodium erythorbate	6381-77-7	39.935	15	5.325	1.331	0.005200	0.000005078	49	1.1E-01	2.7E-02	1.1E-04	1.0E-07
Sodium Hydroxide	1310-73-2	1215.40	NA	162.05	162.05	162.05	162.05	180	9.0E-01	9.0E-01	9.0E-01	9.0E-01
Sodium polyacrylate	9003-04-7	29.006	NA	3.867	3.867	3.867	3.867	4	9.7E-01	9.7E-01	9.7E-01	9.7E-01
Sodium Tetraborate Decahydrate	1303-96-4	4057.1	NA	540.9	540.9	540.9	540.9	0.7	7.7E+02	7.7E+02	7.7E+02	7.7E+02
							Cumulative Ratio		**2,160.0**	**1,133.8**	**793.1**	**791.7**

Table C10-3 Comparison of Estimated Theoretical
Condor Energy Services Hydraulic Fracturing Fluid System
Concentrations to Aquatic Life Water Guidelines

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Mud Pit Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Mud Pitcon = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)				PNEC Aquatic	Ratio of COPC Concentrations and Screening Criteria (Ratio greater than one = unacceptable potential risk)			
				Temporal Scenario (days)					Temporal Scenario (days)			
		Condor Fluid System	Half-Life (days)	0	30	150	300	(mg/l)	0	30	150	300
DISTILLATES, HYDROTREATED LIGHT	64742-47-8	3994.3	150	532.57	463.63	266.29	133.14	NA	NA	NA	NA	NA
1,6-Hexanediol	629-11-8	119.83	15	15.98	3.994	0.01560	0.00001524	5	3.2E+00	8.0E-01	3.1E-03	3.0E-06
2-Ethoxy-naphthalene	93-18-5	4.7551	NA	0.6340	0.6340	0.6340	0.6340	0.04	1.6E+01	1.6E+01	1.6E+01	1.6E+01
2-Mercaptoethyl Alcohol	60-24-2	5.2972	15	0.7063	0.1766	0.0007	0.0000	0.0013	5.4E+02	1.4E+02	5.3E-01	5.2E-04
2-Propenoic acid, homopolymer, ammonium salt	9003-03-6	4.7551	NA	0.6340	0.6340	0.6340	0.6340	1.2	5.3E-01	5.3E-01	5.3E-01	5.3E-01
Acetic Acid	64-19-7	748.93	15	99.857	24.964	0.09752	0.00009523	3	3.3E+01	8.3E+00	3.3E-02	3.2E-05
Alcohols, C9-11, ethoxylated	68439-46-3	124.82	15	16.64	4.161	0.01625	0.00001587	0.14	1.2E+02	3.0E+01	1.2E-01	1.1E-04
Ammonium Persulphate	7727-54-0	112.106	NA	14.947	14.947	14.947	14.947	0.8	1.9E+01	1.9E+01	1.9E+01	1.9E+01
Ammonium Sulphate	7783-20-2	252.50	NA	33.67	33.67	33.67	33.67	0.06	5.6E+02	5.6E+02	5.6E+02	5.6E+02
Amylase, Alpha	9000-90-2	5.3495	15	0.7133	0.1783	0.0006965	0.0000006802	0.05	1.4E+01	3.6E+00	1.4E-02	1.4E-05
Castor Oil	61791-12-6	6.3909	15	0.8521	0.2130	0.0008321	0.0000008126	0.45	1.9E+00	4.7E-01	1.8E-03	1.8E-06
Choline Chloride	67-48-1	72.182	15	9.6	2.406	0.009399	0.000009178	0.3	3.2E+01	8.0E+00	3.1E-02	3.1E-05
Cinnamaldehyde	104-55-2	6.9880	15	0.9317	0.2329	0.0009099	0.0000008886	0.04	2.3E+01	5.8E+00	2.3E-02	2.2E-05
Diethylene Glycol	111-46-6	1.06324	15	0.1418	0.0354	0.0001384	0.0000001352	27	5.3E-03	1.3E-03	5.1E-06	5.0E-09
Ethoxylated C11 Alcohol	34398-01-1	374.46	15	49.9	12.5	0.04876	0.00004762	0.14	3.6E+02	8.9E+01	3.5E-01	3.4E-04
Ethylene Glycol	107-21-1	1.05563	15	0.1408	0.03519	0.0001375	0.0000001342	10	1.4E-02	3.5E-03	1.4E-05	1.3E-08
Formic Acid	64-18-6	46.410	15	6.2	1.547	0.006043	0.000005901	1	6.2E+00	1.5E+00	6.0E-03	5.9E-06
Glutaraldehyde	111-30-8	1323.1	15	176.4	44.1	0.1723	0.0001682	0.0025	7.1E+04	1.8E+04	6.9E+01	6.7E-02
Glycerol	56-81-5	2156.9	15	287.6	71.9	0.2808	0.0002743	10	2.9E+01	7.2E+00	2.8E-02	2.7E-05
Guar Gum	9000-30-0	4231.4	15	564.2	141.0	0.5510	0.0005381	0.006	9.4E+04	2.4E+04	9.2E+01	9.0E-02
Hemicellulase	9025-56-3	28.245	15	3.8	0.942	0.003678	0.000003592	0.5	7.5E+00	1.9E+00	7.4E-03	7.2E-06
HydroChloric Acid	7647-01-0	2732.5	n	364.3	364.3	364.3	364.3	NA	NA	NA	NA	NA
Inorganic Salt	584-08-7	727.96	NA	97.1	97.1	97.1	97.1	NA	NA	NA	NA	NA
Isopropanol	67-63-0	299.56	15	39.9	10.0	0.0	0.0	0.3	1.3E+02	3.3E+01	1.3E-01	1.3E-04
Methanol	67-56-1	3.0128	15	0.4017	0.1004	0.0003923	0.0000003831	10	4.0E-02	1.0E-02	3.9E-05	3.8E-08
N-Benzyl-Alkylpyridinium Chloride	68909-18-2	4.7551	NA	0.63401	0.63401	0.63401	0.63401	0.005	1.3E+02	1.3E+02	1.3E+02	1.3E+02
Pine Oil	8002-09-3	6.3243	15	0.8432	0.2108	0.0008235	0.0000008042	0.02	4.2E+01	1.1E+01	4.1E-02	4.0E-05
Polyacrylamide	25085-02-3	185.45	NA	24.7	24.7	24.7	24.7	0.1	2.5E+02	2.5E+02	2.5E+02	2.5E+02
Polyoxyethylene nonylphenol ether	9016-45-9	1244.5	15	165.9	41.5	0.2	0.0	0.006	2.8E+04	6.9E+03	2.7E+01	2.6E-02
Polyoxyethylene-polyoxypropylene Block Copolymer	9003-11-6	5.2068	NA	0.6942	0.6942	0.6942	0.6942	0.1	6.9E+00	6.9E+00	6.9E+00	6.9E+00
Potasium Sorbate	24634-61-5	1.16662	15	0.1555	0.03889	0.0001519	0.0000001483	0.17	9.1E-01	2.3E-01	8.9E-04	8.7E-07
Potassium Chloride	7447-40-7	123.573	NA	16.5	16.5	16.5	16.5	0.1	1.6E+02	1.6E+02	1.6E+02	1.6E+02
Potassium Hydroxide	1310-58-3	635.09	NA	84.7	84.7	84.7	84.7	NA	NA	NA	NA	NA
Potassium persulfate	7727-21-1	11.7784	NA	1.57045	1.57045	1.57045	1.57045	0.8	2.0E+00	2.0E+00	2.0E+00	2.0E+00
Quaternary ammonium compounds, bis(hydrogenated tallow alkyl)dimethyl, salts with bentonite	68953-58-2	1248.2	NA	166.4	166.4	166.4	166.4	0.06	2.8E+03	2.8E+03	2.8E+03	2.8E+03
Sodium Benzoate	532-32-1	1.28131	15	0.1708	0.04271	0.0001668	0.0000001629	0.3	5.7E-01	1.4E-01	5.6E-04	5.4E-07
Sodium bisulfite	7631-90-5	7.0375	NA	0.9383	0.9383	0.9383	0.9383	0.8	1.2E+00	1.2E+00	1.2E+00	1.2E+00
Sodium erythorbate	6381-77-7	39.935	15	5.325	1.331	0.005200	0.000005078	1	5.3E+00	1.3E+00	5.2E-03	5.1E-06
Sodium Hydroxide	1310-73-2	1215.40	NA	162.05	162.05	162.05	162.05	NA	NA	NA	NA	NA
Sodium polyacrylate	9003-04-7	29.006	NA	3.867	3.867	3.867	3.867	1.2	3.2E+00	3.2E+00	3.2E+00	3.2E+00
Sodium Tetraborate Decahydrate	1303-96-4	4057.1	NA	540.9	540.9	540.9	540.9	0.37	1.5E+03	1.5E+03	1.5E+03	1.5E+03
								Cumulative Ratio	**198,988.2**	**53,785.1**	**5,573.2**	**5,384.3**

Santos

Appendix C11
Halliburton Hybor and Delta Hydraulic Fracturing Fluid Systems

C1.0 Introduction

Santos Ltd. (Santos) is looking to use two Halliburton Hybor (DFS-BCG-H) and Delta (DFS-BGB) hydraulic fracturing fluid systems for development of coal seam gas (CSG) resources in the Surat and Bowen Basins of Queensland. The disclosures for the Haliburton Hybor and Delta hydraulic fracturing fluid systems, including a listing of the chemical constituents and percent of total volume in the fluid system, are provided in **Appendix C11-1**.

As presented in **Section 5.0** of the Hydraulic Fracturing Risk Assessment, Santos used a weight-of-evidence approach to evaluate the potential for human health and environmental (e.g., ecological) risks as a result of the hydraulic fracturing processes and the use of the Halliburton Hybor and Delta hydraulic fracturing fluid systems.

EHS Support, LLC (EHS Support) conducted a Quantitative Risk Assessment (QRA) to meet Conditions 49e and 49f of the 2 October 2011 approval under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC 2008/4059) and the Environmental Amendment (EA) conditions to assess the toxicity of the mixtures.

The results and conclusions of the qualitative risk assessment components and the QRA are presented below. Refer to **Section 6.0** through **Section 8.0** for detailed discussions on the methodologies employed for the qualitative risk assessment and QRA components, which are referenced in the sections below.

C2.0 Qualitative Risk Assessment and Evaluation

C2.1 Chemicals Evaluated

The Halliburton Hybor ((DFS-BCG-H) and Delta (DFS-BGB) hydraulic fracturing fluid systems were assessed. The list of individual chemicals assessed is presented in **Table 1** below. A mass balance of the chemicals is provided as **Table C11-1a** and **Table C11-1b**.

Information regarding the chemical and physical properties of the individual chemicals listed below as well as the approximate percentage present in the hydraulic fracturing system can be found on the Safety Data Sheets in **Appendix E**.

The fluid system does not contain BTEX (benzene, toluene, ethylbenzene, xylenes) or polycyclic aromatic hydrocarbons (PAHs) based on EHS Support's understanding that Halliburton has tested all their products. Field monitoring will also be conducted in accordance with regulatory requirements. While none of the fracturing fluid chemicals identified contain BTEX or PAHs, PAHs occur naturally in coal and it is possible that certain PAHs may naturally be present in the coal seam groundwater used in the hydraulic fracturing process.

Table 1: Hydraulic fracturing chemicals

Chemical	CAS Number
Halliburton Hybor DFS-BCG-H Fluid System	
Acetic acid	64-19-7
Alcohols, C12-15, ethoxylated	68131-39-5
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4
Butyl alcohol	71-36-3
Chlorous acid, sodium salt	7758-19-2
Choline Chloride	67-48-1
Citric acid	77-92-9
Coffee Extract	68916-18-7
Crystalline silica, quartz	14808-60-7
Diethanolamine	111-42-2
Disodium octaborate tetrahydrate	12008-41-2
Ethanol	64-17-5
Ethylene glycol	107-21-1
Fatty acids, tall-oil, ethoxylated	61791-00-2
Glutaraldehyde	111-30-8
Hydrochloric acid	7647-01-0
Hydrotreated light petroleum distillate	64742-47-8
Hydroxylpropyl guar	39421-75-5
Methanol	67-56-1
Silica dioxide	112926-00-8
Sodium bisulfite	7631-90-5
Sodium carbonate	497-19-8
Sodium Chloride	7647-14-5
Sodium hydroxide	1310-73-2
Sodium persulfate	7775-27-1
Sodium polyacrylate	9003-04-7
Sodium Sulfate	7757-82-6
Tributyl tetradecyl phosphonium chloride	81741-28-8

Chemical	CAS Number
Triethanol amine	102-71-6
Ulexite	1319-33-1
Sodium polyacrylate	9003-04-7
DFS-BCG Fluid System	
Acetic acid	64-19-7
Alcohols, C12-15, ethoxylated	68131-39-5
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-28-4
Butyl alcohol	71-36-3
Cellulase enzyme	9012-54-8
Choline Chloride	67-48-1
Citric acid	77-92-9
Coffee Extract	68916-18-7
Diethanolamine	111-42-2
Ethanol	64-17-5
Ethylene glycol	107-21-1
Fatty acids, tall-oil, ethoxylated	61791-00-2
Glutaraldehyde	111-30-8
Guar gum	9000-30-0
Hydrochloric acid	7647-01-0
Hydrotreated light petroleum distillate	64742-47-8
Lactose	63-42-3
Methanol	67-56-1
Monoethanolamine borate	26038-87-9
Sodium hydroxide	1310-73-2
Sodium persulfate	7775-27-1
Sodium Sulfate	7757-82-6
Tributyl tetradecyl phosphonium chloride	81741-28-8

C2.2 Risk Assessment Framework and Findings

As discussed in **Section 5.0**, a systematic weight of evidence approach was utilised to complete the risk assessment for the Halliburton Hybor and Delta hydraulic fracturing fluid systems. The work has involved the following evaluations:

Qualitative Assessment Methodologies

- PBT Assessment
- Exposure Assessment
- Mass Balance of Fluid System
- Fate and Transport Modelling

Quantitative Risk Assessment Methodologies

- Quantitative Human Health Risk Assessment (HHRA)
- Quantitative Ecological Risk Assessment for Terrestrial and Aquatic Receptors

C2.3 PBT Assessment

For the environmental hazard assessment, a PBT (persistence, bioaccumulative, toxicity) assessment was conducted in accordance with the guidance developed by DEWHA (2009), as presented in the RA Compendium. The PBT assessment is conducted because of specific concerns for substances that can

be shown to persist for long periods in the environment, to bioaccumulate in food chains, and can give rise to toxic effects after a longer time and over a greater spatial scale than chemicals without these properties. These effects may be difficult to detect at an early stage because of long-term exposures at normally low concentration levels and long life-cycles of species at the top of the food chain.

The PBT approach outlined in **Section 6.1** was undertaken to rank the hydraulic fracturing chemicals based on PBT potential. As a result of this assessment, no chemical constituents identified in the Halliburton Hybor and Detla hydraulic fracturing fluid systems were classified as a PBT chemical and are therefore not considered to be inherently hazardous. The results of the PBT Assessment are presented in **Table 2**, attached.

C2.3 Exposure Assessment

As discussed in **Section 7.0**, the exposure assessment identified receptors potentially exposed to chemicals of potential concern (COPCs) identified for the study and outlined the exposure pathways by which the receptors may come in to contact with the COPCs. A detailed exposure assessment was not conducted in the qualitative risk assessment.

C2.4 Mass Balance of Fluid System

A quantitative mass balance calculation was undertaken to identify the amount of each chemical additive of the hydraulic fracturing fluid systems. The results of the mass balance calculations are presented in **Table C11-1a** and **Table C11-1b**.

C2.5 Fate and Transport Modelling

As discussed in **Section 7.2**, fate and transport modelling was conducted on a range of key constituents of interest in typical hydraulic fracturing fluid systems. These results provided the framework for assessing potential mobility of all constituents used in hydraulic fracturing. The modelling demonstrated that despite the variability in chemical properties between fluid systems there is limited potential for chemicals to migrate within the coal seams. Refer to **Section 7.2** for further details.

C3.0 Quantitative Risk Assessment

In accordance with the methodologies presented in **Section 8.0**, a QRA was conducted on theoretical datasets for those chemicals identified in the Halliburton Hybor-Delta hydraulic fracturing fluid systems. The QRA approach evaluates the toxicity of the individual substances and characterises the cumulative risks of the total effluent toxicity and ecotoxicity.

Generally, this methodology includes the identification of the hazards posed by constituents in the flowback water, compilation of the toxicity criteria for each constituent, development of exposure models to estimate the daily intake of the constituents, and calculations of individual constituent hazard quotients (daily intake divided by the toxicity criteria) and a cumulative constituent hazard index (HI) for each potentially complete exposure pathway for each human or terrestrial receptor.

Potential complete exposure pathways to the storage of flowback from hydraulically stimulated wells, and potential risks to humans, terrestrial and aquatic receptors from the potential storage and accidental releases are evaluated in the QRA.

No further assessment of groundwater was determined to be necessary due to lack of potentially complete exposure pathways. Detailed operational procedures have been provided that are designed to contain the hydraulic fracturing fluids within the coal sequences, and no connection exists between groundwater in the coal seams and surface-water or springs (and therefore Matters of National Environmental Significance [MNES]). Further, the potential risks to workers involved with the hydraulic fracturing process were not considered as detailed Health and Safety (H&S) procedures are employed to manage exposures. The QRA considered the following specific exposure pathways:

1. Exposure of trespassers to flowback water contained within flowback storage ponds.
2. Exposure of terrestrial receptors (e.g., livestock and wildlife) to flowback water contained within the flowback storage tank.
3. Exposure of aquatic receptors to flowback water in the situation of an accidental release, such as from piping or a release from the flowback storage tank. These potential releases could include a failure of containment systems, overtopping of the dam or in an extreme situation (considered highly unlikely) structural failure of the dam itself.

C3.1 Exposure Assessment

The purpose of the exposure assessment in the QRA was to predict the magnitude and frequency of potential human exposure to each COPC following the methodologies presented in **Section 8.1**. A conceptual site model (CSM) was developed which describes the potential receptors and exposure scenarios for the flowback water used in this exposure assessment. The potential exposures to receptors were evaluated based on the potential for a complete exposure pathway.

As discussed in **Section 8.2**, exposure point concentrations (EPCs) were derived for the theoretical assessment; empirical data were not available for evaluation. The EPCs for the theoretical assessment were calculated by estimating the mass and discharge flow of the COPCs in the flowback water.

C3.2 Human Health QRA

A human health hazard assessment was conducted according to the methodologies presented in **Section 8.4**. The purpose of the hazard assessment process was to summarise the environmental data, and to address the toxicological assessment of the COPCs that will be evaluated further in the risk assessment process.

Exposure assumptions for the human trespasser scenario were developed based on default or site-specific assumptions (**Section 8.4**). This receptor exposure pathway includes a small child to teenager

that may come in contact with the above grade water exposure scenario for approximately 20 days/year for a 10-year period with potential incidental ingestion [of 50 millilitres (ML) of water] and dermal contact (e.g., swimming where the whole body gets wet) for one-half hour. The exposure parameters used in the QRA are presented on **Table 3**, attached.

Calculation of intake of COPCs was performed using the equations presented below:

Ingestion of water:

$$Intake\ (mg/kg-day)\ =\ (CW\ x\ IR\ X\ EF\ X\ ED)\ /\ (BW\ x\ AT)$$

Dermal contact with water:

$$Absorbed\ dose\ (mg/kg-day)\ =\ (CW\ x\ SA\ x\ DP\ x\ ET\ x\ EF\ x\ ED\ x\ CF)\ /\ (BW\ x\ AT)$$

Where:

AT = averaging time (days)
BW = body weight (kg)
CF = correction factor (1 x 10-3 l/cm3)
CW = concentration in water (mg/l)
DP = dermal permeability factor (Kp – cm/hr).
ED = exposure duration (years)
EF = exposure frequency (day/year)
ET = exposure time (hr/day or hours/hours)
IR = ingestion rate (l/hr)
SA = skin surface area available for contact (cm2/d)

C3.3 Toxicity Assessment

A toxicity assessment was conducted to determine the relationship between the dose of a COPC taken into the body, and the probability that an adverse effect will result from that dose. Quantitative estimates of the potency of COPCs include two sets of toxicity values, one for genotoxic carcinogens and one for other non-genotoxic carcinogens and non-carcinogenic effects. As discussed in **Section 8.4**, detailed toxicological profiles were developed for the chemicals. The toxicological profiles are included in the risk dossiers in **Appendix F11**.

The assessment of toxicity of the COPCs was used to develop initial screening criteria for human health exposure scenarios as discussed in **Section 8.4**. The derivation of Oral Reference Dose and Drinking Water Guideline Values are presented in **Table 4**, attached. Australian Drinking Water Screening Values for the COPCs are also presented on **Table 4**, attached.

C3.4 Exposure Point Concentration

As presented above, the exposure scenarios are based on anticipated conditions, and the potential for exposure to the theoretical estimate of exposure. EPCs for the exposure assessment were calculated using the results of theoretical fate and transport modelling calculations and the existing environmental conditions within the fracturing fluids flowback storage ponds, and the flowback used in the irrigation fields.

To assess the potential flux of hydraulic fracturing chemicals to the environment, vendor disclosures for the hydraulic fracturing fluid systems were reviewed, and the chemical concentrations of key inputs were determined.

For the theoretical calculations, the mass and estimated chemical concentrations of the COPCs in the Halliburton Hybor and Delta hydraulic fracturing fluid systems, as presented in **Table C11-1a** and **Table C11-1b**, were used to estimate the potential concentrations in water within the fracturing fluids sump or flare pit, or flowback storage ponds. Based on stimulation flow back monitoring conducted by Santos and the QRA completed for the Schlumberger Fluid Systems (**Appendix C**), 20 percent (%) of the total mass of constituents injected is assumed to be recovered in the flowback water. This mass is diluted within 150 % of the injected volume (the minimum volume that must be flowed back) to establish an "estimated" concentration (i.e., concentration expected due to full dilution of the back-flow water) within the flowback storage ponds.

The flowback water will be contained within the flowback storage ponds for a projected maximum period of one year of operational activity before transfer or conveyance to the water treatment facilities and or transferred into Santos water conveyance systems (for treatment) and thereby blended with other conveyance systems water not containing these constituents. To be conservative it has been assumed that the fluids are stored with ponds with the concentration of COPCs in the flowback storage pond water adjusted, where applicable, to account for the biodegradation and photolytic degradation of constituents over time. The biodegradation information was obtained from the Organisation for Economic Cooperation and Development (OECD) ready tests (OECD, 1992) that were developed as a first-tier testing scheme to provide preliminary screening of organic chemicals. The ready tests are stringent screening tests that are conducted under aerobic conditions in which a high concentration of the test substance is used, and biodegradation is measured by non-specific parameters including dissolved organic carbon, biochemical oxygen demand and carbon dioxide production. **Table 5**, attached, presents the environmental fate information that was used to assess biodegradation of COPCs, and that was applied at the time periods of 0, 30, 150 and 300 days from initial flowback.

The water quality data derived using these assumptions for the theoretical COPCs are presented in **Table C11-1a and Table C11-1b**.

The theoretical EPCs for the four exposure time periods (0, 30, 150 and 300 days) were compared to human health toxicity-based screening levels, and the results of this comparison, including the ratio of exceedance of screening levels, is presented in **Table C11-2a** and **Table C11-2b**.

C3.5 Risk Estimation

Risk estimation was performed in accordance with the methodologies outlined in **Section 8.4**. The total target risk range for carcinogens was 1×10^{-4} to 1×10^{-6}; the target HI for non-threshold effects is less than or equal to 1.0.

The results of the theoretical assessments for Halliburton Hybor and Delta hydraulic fracturing fluid systems for the trespasser exposure scenarios (day 0 and day 150, Halliburton Hybor and Delta hydraulic fracturing fluid system events) are summarized in **Tables 6a, 6b, 7a and 7b,** attached. As discussed above, the theoretical assessment was conducted at the well pad sites.

The exposure scenarios include the Halliburton hydraulic fracturing fluid system event, as presented in **Table C11-1a** and **Table C11-1b** for day 0 and day 150 from the flowback storage tank. On day 0, the trespasser had risks above the target of 1.0 for the Hybor (DFS-BCG-H) hydraulic fracturing fluid system (HI=22, **Table 6a**, attached); the risks for the Delta (DFS-BGB) were below the target at a HI of 0.36 (**Table 6b**, attached). The elevated HI for the DFS-BCG-H were due to the ingestion exposure pathway of chlorous acid, sodium salt and diethanolamine. The risks for the trespasser on day 150 were less than the target HI of 1.0 for both the Hybor (DFS-BCG-H) hydraulic fracturing fluid system (HI=0.2, **Table 7a**, attached) and Delta (DFS-BGB) hydraulic fracturing fluid system (0.12, **Table 7b**, attached).

The potential exposures resulting in any unacceptable risks discussed above are subject to management and operational controls that can be implemented to control potential exposures. Additionally, the QRA used very conservative exposure assumptions.

C3.6 Ecological Risk Assessment

As discussed in **Section 8.5**, a screening level ecological risk assessment (ERA) was conducted to evaluate the potential for adverse ecological effects to terrestrial and aquatic ecological receptors that may be exposed to residual levels of hydraulic fracturing fluids in surface water used in the CSG fields.

C3.7 Exposure Assessment

Terrestrial receptors evaluated in the ERA include domesticated livestock, large mammalian wildlife and small mammalian wildlife. Beef cattle were used to evaluate domesticated livestock, kangaroos evaluated for large mammalian wildlife, and dingos for small mammalian wildlife. Aquatic receptors evaluated included invertebrates and fishes.

The estimate for dose-based or intake rates for the assessment endpoints for wildlife representing domestic livestock and native mammalian species used the following general equation:

TI = Cwater x IRwater x EF x ED / BW x ED x 365 days/year

Where:

TI = Total intake of COPC (mg/kg/day)

Cwater = Concentration of COPC in water (mg/l)

IRwater = Ingestion rate (litres/day)

EF = Exposure frequency (days/year)

ED = Exposure duration (years)

BW = Body weight (kg)

The exposure assumptions are presented in **Tables 8** through **10**, attached.

C3.8 Toxicity Assessment

To evaluate the potential for adverse ecological effects, toxicity reference values (TRVs) are selected as measurement endpoints for the ERA that will be used in the risk analysis. The TRVs are based on COPC levels that imply no adverse effects or levels that represent the lowest concentration at which adverse effects may occur. The ERA used two types of TRVs (**Section 8.5.3**). The first TRV is a concentration-based TRV to evaluate the concentration of the selected COPC in the surface water and direct exposure by the aquatic ecological receptor. The determination of TRVs for freshwater was conducted according to the predicted no-effects concentration (PNEC) guidance in the Environmental Risk Assessment Guidance Manual for Industrial Chemicals prepared by the Australian Environmental Agency (AEA, 2009). As discussed in **Section 8.4**, detailed environmental profiles were developed for the chemicals. The environmental profiles are included in the risk dossiers in **Appendix G11**. **Table 11**, attached, presents the COPC, the endpoint, NOEC [milligrams per litre (mg/L)], assessment factor, and the aquatic PNEC (mg/L). The second TRV is a dose-based TRV to evaluate the intake dose of the selected COPC from exposure to surface water by ingestion. The calculated TRVs for each of the mammalian ecological receptors evaluated in the ERA are presented in the species-specific ecological risk models.

C3.9 Exposure Point Concentration

EPCs for the exposure assessment were calculated using the results of theoretical fate and transport modelling calculations. The potentially affected flowback water that represents complete exposure pathways for the ecological receptors includes the surface water systems (e.g., flowback storage ponds and mud pits) that were used to estimate the EPCs for the human health receptors. The EPCs for the ecological receptors were estimated assuming the same Scenarios, with exposure occurring in the irrigation area where irrigation water may pool and wildlife may drink from the standing water. **Table C11-1a** and **Table C11-1b** presents the calculated EPCs for the ecological receptor exposure scenarios. The theoretical EPCs for the four exposure time periods (0, 30, 150, and 300 days) were compared to ecological based toxicity-based screening levels, and the results of this comparison, including the ratio of exceedance of screening levels, is presented in **Table C11-3a** and **Table C11-3b**.

Risks were characterised in accordance with the methodologies discussed in **Section 8.5.6**. The resulting ecological hazard quotient must be less than or equal to 1.0 for risks to be considered acceptable.

C3.10 Estimation of Risk

The HI calculated for flowback water for aquatic risk were elevated above the acceptable level for the majority of COPCs evaluated (**Table C11-3a** and **Table C11-3b**). Where large discharges of flowback water occur to surface water and/or flux dilution within the surface-water was insufficient, potential impacts on aquatic receptors could occur. As noted in the toxicity assessment section above, the lack of a robust aquatic toxicological database resulted in highly conservative aquatic screening values for the theoretical exposure scenario COPCs to be conservatively very low.

The results of the theoretical assessments for Halliburton hydraulic fracturing fluid system for the livestock cattle, kangaroo and dingo are summarized in **Tables 12a through 17b**, attached. The exposure scenarios include the Halliburton hydraulic fracturing fluid systems EPCs presented in **Table C11-1a** and **Table C11-1b** for day 0 and day 150 from the fracturing fluid well flowback. The modelled risks from Hybor (DFS-BCG-H) hydraulic fracturing fluid system chemicals in the flowback water were above the target of 1.0 for the cattle (HI=12, **Table 12a**, attached); the calculated risks were less than the target for the Delta (DFS-BGB) hydraulic fracturing fluid system (HI = 0.64, **Table 12b**, attached). The HI were acceptable for the modelled values for day 150 for both the Hybor (DFS-BCG-H; HI = 0.0053, **Table 13a**, attached) and Delta (DFS-BGB; HI = 0.00073, **Table 13b**, attached) hydraulic fracturing fluid systems.

The modelled risks for the kangaroo for the day 0 release scenario slightly exceeded the target of 1.0 for the DFS-BCG-H (HI = 2.5, **Table 14a**, attached); however, the risks for the Delta (DFS-BGB) hydraulic fracturing fluid system was less than 1.0 (HI = 0.13, **Table 14b**, attached). The modelled risks for day 150 for the kangaroo for both fluid systems did not exceed the target of 1.0: HI for Hybor (DFS-BCG-H) hydraulic fracturing fluid was 0.15 (**Table 15a**, attached); HI for Delta (DFS-BGB) hydraulic fracturing fluid system was 0.02 (**Table 15b**, attached).

For the dingo, the modelled risks for the day 0 and day 150 scenarios for both hydraulic fracturing fluid systems did not exceed the target of 1.0. The modelled HIs ranged from 1.0 to 0.054 for day 0 (**Table 16a,** and **16b**, attached) and from 0.06 to 0.0081 for day 150 (**Table 17a,** and **17b**, attached).

C4.0 Summary of QRA Findings

The QRA was completed as discussed in **Section 8.0**. An assessment was conducted using highly conservative theoretical calculations based on the chemicals utilised by Schlumberger in hydraulic fracturing. This assessment assumed that a range of theoretical concentrations of injected chemicals would be present in the flowback water based on biodegradation rates, where applicable.

Consistent with the risk assessment and groundwater fate and transport modelling conducted by Golder, no potentially complete exposure pathways were identified for groundwater. Potential exposures are limited to the aboveground storage and handling of flowback water as part of the CSG Water Management Plan (WMP). Management of CSG water involves the temporary storage of flowback water in flowback storage ponds.

The exposure scenario modelled for the QRA was a trespasser being exposed to flowback water under various EPC scenarios. Based on quantitative risk calculations, the potential risks for the trespasser were unacceptable for the EPC scenarios for the Hybor (DFS-BCG-H) hydraulic fracturing fluid system in day 0, but were significantly reduced to potential risks only exceeding the HI target of 1.0 in the day 150 scenario as a result of biodegradation of the risk drivers. The modelled risks for the Delta (DFS-BGB) hydraulic fracturing fluid system were acceptable for both the day 0 and day 150 scenarios for the trespasser. The potential exposures resulting in any unacceptable risks discussed above are subject to management and operational controls that can be implemented to control potential exposures. Additionally, the QRA used very conservative exposure assumptions. There were no carcinogenic risks identified.

The modelled risks from Halliburton Hybor (DFS-BCG-H) hydraulic fracturing fluid system chemicals in the flowback water were unacceptable for the livestock cattle and kangaroo on day 0, but were acceptable for the dingo on day 0 and all receptors on day 150. The modelled risks for the Halliburton Delta (DFS-BGB) hydraulic fracturing fluid system chemicals in flowback water were acceptable for the cattle, kangaroo, and dingo for both day 0 and day 150 scenarios. The potential exposures resulting in any unacceptable risks discussed above are subject to management and operational controls that can be implemented to control potential exposures. Similarly, potential impacts could occur if releases of flowback water were to occur to aquatic environments. Based on the use of low permeability materials (clay liners) and operational controls that limit the potential for turkey nest and dam overflows, the potential for these risks are also considered limited.

A combination of management and operational controls are being implemented to eliminate and control the potential for exposures. These include:

- Worker training and hazard identification
- Use of appropriate personal protective equipment (gloves, etc.)
- Flowback storage pond fencing to prevent entry of livestock and native fauna and minimise trespassing
- Use of low permeability materials or dam liners and routine dam inspections to prevent releases from flowback storage ponds
- Routine operational and security patrols to prevent trespassing

C5.0 Conclusions

A weight-of-evidence evaluation of potential risks as described in **Section 5.0** was performed for the Halliburton Hybor (DFS-BCG-H) and Delta (DFS-BGB) hydraulic fracturing fluid system. Based on the qualitative and quantitative risk characterisations, the overall risk to human health and the environment modelled were unacceptable for day 0 but were significantly reduced to potential risks not exceeding the HI target of 1.0 in day 150 scenario as a result of biodegradation of the risk drivers. Existing operational control activities employed by Santos are in place that will limit the potential risks to human health and the environment. These measures include:

- Occupational health and safety procedures implemented during hydraulic fracturing operations to prevent workers from making direct contact with chemicals during spills and when handling flowback water or sediments
- Environmental authority conditions that preclude the construction of well pads within 100 metres of a watercourse of water body
- Implementation of spill containment procedures during operations to prevent migration of and exposure to chemicals
- Disposal or capping of sediments contained within drained mud pits and turkey nests, to prevent exposure to contaminates in windborne dust
- Fencing of drill pads to prevent trespassers from entering and installation of signs to indicate that the water in the turkey nests and mud pit is not potable and may contain contaminants
- Installation and maintenance of fences around the well pad to prevent access to the drill pad by livestock and large native fauna
- Santos operational procedures to ensure well integrity and design of fracture to stay within the target seam
- Mud pits and turkey nests with clay liners, or similar material, to prevent seepage of flowback water into underlying aquifers

Monitoring of water supply bores and surface water for a representative suite of chemicals within 2 kilometres of the wells (and 200 m vertical separation) that are fractured will be conducted (as needed) to confirm the conclusion of incomplete exposure pathways and low risk.

No additional risks, other than those previously discussed, were identified with the chemicals or systems employed in hydraulic fracturing. Evaluation of other potential risks associated with hydraulic fracturing (i.e., noise and vibration) was conducted. Refer to **Section 9.0** for methodology specifics and results of this evaluation.

Tables

Table 2 PBT Assessment
Halliburton Hybor (DFS-BCG-H) and Delta (DFS-BGB) Hydraulic Fracturing Fluid Systems

Substance	P/vP criteria fulfilled?	B/vB criteria fulfilled?	T criteria fulfilled?	Overall conclusion
Acetic acid (64-19-7)	No (screening data available)	No (acetate is naturally found in biological organisms)	No (experimental data available)	Not PBT (based on screening and experimental data; naturally found in organisms)
Alcohols, C12-15, ethoxylated (68131-39-5)	No (screening data available)	No (experimental data available)	No (experimental data available)	Not PBT (based on screening and experimental data)
Amides, tall oil fatty, N,N-bis(hydroxyethyl) (68155-20-4)	No (screening data available)	No (QSAR data available)	Yes (experimental data available)	Not PBT (based on screening data)
Butyl alcohol (71-36-3)	No (screening data available)	No (screening data available)	No (experimental data available)	Not PBT (based on screening and experimental data)
Cellulase enzyme (9012-54-8)	No (screening data available)	No (physico-chemical properties)	No (experimental data available)	Not PBT (based on screening and experimental data and physico-chemical properties)
Chlorous acid, sodium salt (7758-19-2)	Not applicable (ionic species from inorganic salt is ubiquitous in environment)	No (ionic species)	Yes (experimental data available)	Not PBT (based on experimental data and ionic species)
Choline chloride (67-48-1)	No (screening data available)	No (screening data available)	No (screening data available)	Not PBT (based on screening data)
Citric acid (77-92-9)	No (screening data available)	No (screening data available)	No (screening data available)	Not PBT (based on screening data)
Coffee Extract (68916-18-7)	No (screening data available)	No (experimental data available)	No (experimental data available)	Not PBT (based on screening and experimental data)
Crystalline silica (14808-60-7)	Not applicable	No (water-insoluble mineral; not bioavailable)	Yes (Not toxic to aquatic organisms; CMR[1]: Known Human carcinogen (inhalation only)	Not PBT (based on physico-chemical properties)
Diethanolamine (111-42-2)	No (screening data available)	No (screening data available)	No (rodent carcinogenicity, not classified by NICNAS)*	Not PBT (based on screening data)

Table 2 PBT Assessment
Halliburton Hybor (DFS-BCG-H) and Delta (DFS-BGB) Hydraulic Fracturing Fluid Systems

Substance	P/vP criteria fulfilled?	B/vB criteria fulfilled?	T criteria fulfilled?	Overall conclusion
Disodium octaborate tetrahydrate (12008-41-2)	Not applicable (ionic species from inorganic salt is ubiquitous in environment)	No (ionic species)	Yes (known or presumed human reproductive toxicant - GHS Cat. 1B)	Not PBT (based on experimental data and ionic species)
Ethanol (64-17-5)	No (screening data available)	No (experimental data available)	No (experimental data available)	Not PBT (based on screening and experimental data)
Ethylene glycol (107-21-1)	No (screening data available)	No (experimental data available)	No (experimental data available)	Not PBT (based on screening and experimental data)
Fatty acids, tall oil, ethoxylated (61791-00-2)	No (screening data available)	No (screening data available)	No (screening data available)	Not PBT (based on screening data available)
Glutaraldehyde (111-30-8)	No (screening data available)	No (screening data available)	Yes (experimental data available)	Not PBT (based on screening and experimental data)
Guar gum (9000-30-0)	No (screening data available)	No (physico-chemical properties)	No (screening data available)	Not PBT (based on screening data and physico-chemical properties)
Hydrochloric acid (7647-01-0)	Not applicable (ionic species ubiquitous in environment)	No (essential ions to biological systems; actively regulated)	No (screening data available)	Not PBT (based on screening data and ubiquitous inorganic salt)
Hydroxypropyl guar (39421-75-5)	No (estimated)	No (based on physico-chemical properties)	Not determined	Unlikely to be PBT (based on estimation and physico-chemical properties)
Hydrotreated light petroleum distillate (64742-47-8)**	Yes (screening data available)	Possibly yes (screening data available)	No (screening data available)	Not PBT (based on screening data)
Lactose (63-42-3)	No (estimated)	No (QSAR modeling)	No (QSAR modeling)	Not PBT (based on estimation, QSAR models)
Methanol (67-56-1)	No (screening data available)	No (experimental data available)	No (screening data available)	Not PBT (based on screening and experimental data)
Monoethanolamine borate (26038-87-9)	No (screening data available)	Not determined	No (experimental data available)	Not PBT (based on screening and experimental data)
Silicon dioxide (112926-00-8)	No (not applicable)	No (low water-soluble mineral; low bioavailability)	No (low water-soluble mineral; low bioavailability)	Not PBT (based on physico-chemical properties)
Sodium bisulfite (7631-90-5)	Not applicable (ionic species from inorganic salt is ubiquitous in environment)	No (ionic species)	No (experimental data available)	Not PBT (based on experimental data and ionic species)

Table 2 PBT Assessment
Halliburton Hybor (DFS-BCG-H) and Delta (DFS-BGB) Hydraulic Fracturing Fluid Systems

Substance	P/vP criteria fulfilled?	B/vB criteria fulfilled?	T criteria fulfilled?	Overall conclusion
Sodium carbonate (497-19-8)	Not applicable (ionic species from inorganic salt is ubiquitous in environment)	No (ionic species)	No (experimental data available)	Not PBT (based on experimental data and ionic species)
Sodium chloride (7647-14-5)	Not applicable (ionic species ubiquitous in environment)	No (essential ions to biological systems; actively regulated)	No (screening data available)	Not PBT (based on screening data and ubiquitous inorganic salt)
Sodium hydroxide (1310-72-2)	Not applicable (ionic species from inorganic salt is ubiquitous in environment)	No (ionic species)	No (experimental data available)	Not PBT (based on experimental data and ionic species)
Sodium persulfate (7775-27-1)	Not applicable (ionic species from inorganic salt is ubiquitous in environment)	No (ionic species)	No (experimental data available)	Not PBT (based on experimental data and ionic species)
Sodium polyacrylate (9003-04-7)	Yes (polymer, not readily biodegradable)	No (polymer, physico-chemical properties)	No (experimental data available)	Not PBT based on physico-chemical properties and experimental data)
Sodium sulfate (7757-82-6)	Not applicable (ionic species from inorganic salt is ubiquitous in environment)	No (ionic species)	No (experimental data available)	Not PBT (based on experimental data and ionic species)
Tributyl tetradecyl phosphonium chloride (81741-28-8)	Yes (screening data available)	No (screening data available)	Yes (screening data available)	Not PBT (based on screening data)
Triethanolamine (102-71-6)	No (screening data available)	Yes (experimental data available)	No (experimental data available)	Not PBT (based on screening and experimental data)
Ulexite (1319-33-1)	Not applicable	No (slightly soluble mineral; not bioavailable)	No (slightly soluble mineral; not bioavailable)	Not PBT (based on physico-chemical properties)

*IARC 2B carcinogen based on liver and kidney tumors in mouse dermal carcinogenicity study. Not listed in NTP Report on Carcinogens. Diethanolamine is not classified as a carcinogen by NICNAS.
**Read-across from hydrocarbons, C12-C15, n-alkanes, isoalkanes, cyclics, <2% aromatics (CAS No. 869062-45-3).
B = bioaccumulative
NICNAS = National Industrial Chemicals Notification and Assessment Scheme
P = persistent
PBT = persistence, bioaccumulative, toxicity
QSAR = quantitative structure - activity relationship
T = toxic
vB = very bioaccumulative
vP = very persistent

Table 3 Exposure Assumptions - Trespasser
Halliburton Hybor (DFS-BCG-H) and Delta (DFS-BGB) Hydraulic Fracturing Fluid Systems

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	L/hr	0.05
	ET	Exposure time	hr/day	0.5
	EF	Exposure frequency	day/yr	20
	ED	Exposure duration	yr	10
	BW	Body weight	kg	47
	AT-NC	Averaging time - noncancer	days	3,650
	AT-C	Averaging time - cancer	days	25,550
Dermal	SA	Surface area for contact	cm^2/day	13,000
	DP	Dermal permeability factor	cm/h	chemical-specific
	ET	Exposure time	hr/day	1
	EF	Exposure frequency	day/yr	20
	ED	Exposure duration	yr	10
	BW	Body weight	kg	47
	AT-NC	Averaging time - noncancer	days	3,650
	AT-C	Averaging time - cancer	days	25,550
	CF	Conversion factor	L/cm^3	1.0E-03

cm/hours = centimetres per hour
cm^2/day = square centimetres per day
day/yr = days per year
hr/day = hours per day
kg = kilogram
L/cm^3 = litres per cubic cenitmetres
L/hr = litres per hour
yr = year

Table 4 Oral Reference Dose and Drinking Water Guidelines
Halliburton Hybor (DFS-BCG-H) and Delta (DFS-BGB) Hydraulic Fracturing Fluid Systems

Oral Reference Dose						
Constituent (CAS No.)	**Study**	**Critical Effect/Target Organ(s)**	**NOAEL (mg/kg-day)**	**Uncertainty Factors**	**Oral Reference Dose (mg/kg-day)**	**Drinking Water Guideline (mg/L)**
Alcohols, C12-15, ethoxylated (68131-39-5)	2-yr rat dietary	Increased organ weights	50	100	0.5	1.8
Amides, tall oil fatty, N,N-bis(hydroxyethyl) (68155-20-4)	[a]	-	-	-	-	-
Butyl alcohol (71-36-3)	90-d rat oral gavage	CNS effects	125	300	0.4	1.4
Cellulase enzyme (9012-54-8)	13-wk rat oral gavage	None	1000	1000	1	3.5
Chlorous acid, sodium salt (7758-19-2)	2-generation rat reproductive	Delayed post-natal development	4	1000	0.004	0.014
Choline chloride (67-48-1)	Human study	Slight hypotensive effect	107[b]	2	50[c]	175[c]
Citric acid (77-92-9)	2-yr rat dietary	Lower body weight gain	1200	100	12	42
Coffee Extract (68916-18-7)	-	-	-	-	-	100[d]
Crystalline silica (14808-60-7)	[a]	-	-	-	-	-
Diethanolamine (111-42-2)	13-wk rat drinking water	Anemia; kidney toxicity	14	3000	0.005	0.02
Disodium octaborate tetrahydrate (12008-41-2)	Rat developmental	Decreased fetal body weights	10.3[e]	66	0.2	0.7
Ethanol (64-17-5)	90-d rat dietary	Kidney: increased weights, toxicity	1730	300	6	20
Ethylene glycol (107-21-1)	2-yr rat dietary	Kidney toxicity	150[e]	10	15	53
Fatty acids, tall oil, ethoxylated (61791-00-2)	Rat oral OECD 422	None	1000	1000	1	3.5
Glutaraldehyde (111-30-8)	2-yr rat drinking water	Decreased body wt. gain, food consumption	4	100	0.04	0.14
Guar gum (9000-30-0)	2-yr rat dietary	Decreased body weights	1250	100	13	46
Hydroxypropyl guar (39421-75-5)	2-yr rat dietary	Decreased body weight	1250	100	13	46
Hydrotreated light petroleum distillate (64742-47-8)**	13-wk rat oral gavage	None	5000	300	17	60

Table 4 Oral Reference Dose and Drinking Water Guidelines
Halliburton Hybor (DFS-BCG-H) and Delta (DFS-BGB) Hydraulic Fracturing Fluid Systems

Oral Reference Dose						
Constituent (CAS No.)	Study	Critical Effect/Target Organ(s)	NOAEL (mg/kg-day)	Uncertainty Factors	Oral Reference Dose (mg/kg-day)	Drinking Water Guideline (mg/L)
Lactose (63-42-3)	130-wk rat dietary	Multiple effects from lactose metabolism in cecum/colon.	1000	1000	1	3.5
Methanol (67-56-1)	Mouse developmental	Increased cervical ribs per litter	43.1 mg/L[f]	100	2[e]	7
Monoethanolamine borate (26038-87-9)	28-day rat oral gavage	None	1000	1000	1	3.5
Silicon dioxide (112926-00-8)	2-yr rat dietary	None	2500	100	25	88
Sodium bisulfite (7631-90-5)	2-yr rat dietary study	None	523	100	5	18
Sodium polyacrylate (9003-04-7)	28-d rat dietary	None	1136	1000	1	4
Tributyl tetradecyl phosphonium chloride (81741-28-8)	90-d rat drinking water	Clinical signs; decreased body weight, food/water consumption	8.66	1000	0.009	0.03
Triethanolamine (102-71-6)	91-day rat dietary	None	1000	1000	1	3.5
Ulexite (1319-33-1)	[a]	-	-	-	-	-

BMD = bone mineral density
CAS No. = Chemical Abstracts Service number
CNS = central nervous system
d = day
mg/kg-day = milligram per kilogram per day
mg/L = milligram per litre
NOAEL = no observed adverse effect level
wk = week
yr = year

[a]Not determined

[b]LOAEL (lowest observed adverse effect level)

[c]Value for choline

[d]Based on American College of Obstetricians and Gynecologists (2010) recommended 200 mg per day and 2 liters per day water intake level (see Appendix F11)
ACOG (2010) Moderate Caffeine Consumption During Pregnancy, Committee on Obstetric Practice, No 462 August (Reaffirmed 2016)

[e]Human Equivalent Dose derived from benchmark dose and physiologically based pharmacokinetic (PBPK) modeling.

[f]The Point of Departure (POD) value is the internal C_{max} methanol blood concentration obtained using BMD analysis from an inhalation study.

Table 4 Oral Reference Dose and Drinking Water Guidelines
Halliburton Hybor (DFS-BCG-H) and Delta (DFS-BGB) Hydraulic Fracturing Fluid Systems

Australian Drinking Water Guidelines		
Constituent (CAS No.)	**Drinking Water Guideline**	**Drinking Water Guidance Value**
Acetic acid (64-19-7)	pH	6.5 to 8.5
Hydrochloric acid (7647-01-0)	pH; chloride	6.5 to 8.5; 250 mg/L (aesthetics)
Sodium carbonate (497-19-8)	Sodium; pH	180 mg/L (aesthetic); 6.5 to 8.5
Sodium chloride (7647-14-5)	Sodium; pH	180 mg/L (aesthetic); 6.5 to 8.5
Sodium hydroxide (1310-72-2)	Sodium; pH	180 ppm (aesthetic); 6.5 to 8.5
Sodium persulfate (7775-27-1)	Sodium; sulfate	180 ppm (aesthetic); 500 mg/L (health)
Sodium sulfate (7757-82-6)	Sodium; sulfate	180 ppm (aesthetic); 500 mg/L (health)

CAS No. = Chemical Abstracts Service number
mg/L = milligram per litre
ppm = parts per million

Table 5 Environmental Fate Information
Halliburton Hybor (DFS-BCG-H) and Delta (DFS-BGB) Hydraulic Fracturing Fluid Systems

Acetic acid	Readily biodegradable (half-life = 15 days)[a]
Alcohols, C12-15, ethoxylated	Readily biodegradable (half-life = 15 days)[a]
Amides, tall oil fatty, N,N-bis(hydroxyethyl)	Readily biodegradable (half-life = 15 days)[a]
Butyl alcohol	Readily biodegradable (half-life = 15 days)[a]
Cellulase enzyme	Readily biodegradable (half-life = 15 days)[a]
Chlorous acid, sodium salt	Readily biodegradable (half-life = 15 days)[a]
Choline chloride	Readily biodegradable (half-life = 15 days)[a]
Citric acid	Readily biodegradable (half-life = 15 days)[a]
Coffee Extract	Inherently biodegradable (half-life = 150 days)[a]
Crystalline silica	Not relevant
Diethanolamine	Readily biodegradable (half-life = 15 days)[a]
Disodium octaborate tetrahydrate	Dissociates completely in aqueous media
Ethanol	Readily biodegradable (half-life = 15 days)[a]
Ethylene glycol	Readily biodegradable (half-life = 15 days)[a]
Fatty acids, tall oil, ethoxylated	Readily biodegradable (half-life = 15 days)[a]
Glutaraldehyde	Readily biodegradable (half-life = 15 days)[a]
Guar gum	Readily biodegradable (half-life = 15 days)[a]
Hydrochloric acid	Dissociates completely in aqueous media
Hydroxypropyl guar	Readily biodegradable (half-life = 15 days)[a]
Hydrotreated light petroleum distillate	Inherently biodegradable (half-life = 150 days)[a]
Lactose	Readily biodegradable (half-life = 15 days)[a]
Methanol	Readily biodegradable (half-life = 15 days)[a]
Monoethanolamine borate	Readily biodegradable (half-life = 15 days)[a]
Silicon dioxide	Not relevant
Sodium bisulfite	Dissociates completely in aqueous media
Sodium carbonate	Dissociates completely in aqueous media
Sodium chloride	Dissociates completely in aqueous media
Sodium hydroxide	Dissociates completely in aqueous media
Sodium persulfate	Dissociates completely in aqueous media
Sodium polyacrylate	Not biodegradable.
Sodium sulfate	Dissociates completely in aqueous media
Tributyl tetradecyl phosphonium chloride	Inherently biodegradable (half-life = 150 days)a
Triethanolamine	Readily biodegradable (half-life = 15 days)[a]
Ulexite	Not relevant

[a]European Union (EU) Guidance Document: Half-life estimates from in vitro biodegradation test results

Table 6a Risk Estimates for Trespasser
Halliburton Hybor (DFS-BCG-H) Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 0

		Day 0		Toxicity	DFS-BCG-H Hydraulic Fracturing Fluid System			
							Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**PC (cm/hr)**	**RfDo**	**$CADD_{oral}$**	**$CADD_{derm}$**	**Incidental Ingestion**	**Dermal**
Acetic acid	64-19-7	2133	5.6E-04	-	1.2E-01	9.1E-03	NA	NA
Alcohols, C12-15, ethoxylated	68131-39-5	131	NA	5.0E-01	7.6E-03	-	1.5E-02	-
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	143	NA	-	8.3E-03	-	NA	-
Butyl alcohol	71-36-3	139	2.8E-03	4.0E-01	8.1E-03	2.9E-03	2.0E-02	7.3E-03
Chlorous acid, sodium salt	7758-19-2	585	8.2E-06	4.0E-03	3.4E-02	3.6E-05	8.5E+00	9.0E-03
Choline Chloride	67-48-1	2053	8.5E-07	5.0E+01	1.2E-01	1.3E-05	2.4E-03	2.6E-07
Citric acid	77-92-9	69	1.2E-05	1.2E+01	4.0E-03	6.0E-06	3.3E-04	5.0E-07
Coffee Extract	68916-18-7	4	NA	2.9E+01	2.2E-04	-	7.6E-06	-
Crystalline silica, quartz	14808-60-7	75	8.8E-03	-	4.4E-03	5.0E-03	NA	NA
Diethanolamine	111-42-2	1128	9.7E-06	5.0E-03	6.6E-02	8.3E-05	1.3E+01	1.7E-02
Disodium octaborate tetrahydrate	12008-41-2	129	NA	2.0E-01	7.5E-03	-	3.8E-02	-
Ethanol	64-17-5	287	5.1E-04	6.0E+00	1.7E-02	1.1E-03	2.8E-03	1.9E-04
Ethylene glycol	107-21-1	1105	9.0E-05	1.5E+01	6.4E-02	7.5E-04	4.3E-03	5.0E-05
Fatty acids, tall-oil, ethoxylated	61791-00-2	145	NA	1.0E+00	8.5E-03	-	8.5E-03	-
Glutaraldehyde	111-30-8	0.11	2.5E-04	4.0E-02	6.2E-06	2.0E-07	1.6E-04	5.1E-06
Hydrochloric acid	7647-01-0	185	NA	7.1E+01	1.1E-02	-	1.5E-04	-
Hydrotreated light petroleum distillate	64742-47-8	279	NA	1.3E+01	1.6E-02	-	1.2E-03	-
Hydroxylpropyl guar	39421-75-5	2987	NA	1.7E+01	1.7E-01	-	1.0E-02	-
Methanol	67-56-1	14	3.3E-04	2.0E+00	8.3E-04	3.5E-05	4.2E-04	1.8E-05
Silica dioxide	112926-00-8	20	NA	2.5E+01	1.2E-03	-	4.6E-05	-
Sodium bisulfite	7631-90-5	48	NA	5.0E+00	2.8E-03	-	5.6E-04	-
Sodium carbonate	497-19-8	17	NA	5.1E+01	1.0E-03	-	2.0E-05	-
Sodium Chloride	7647-14-5	2027	NA	5.1E+01	1.2E-01	-	2.3E-03	-
Sodium hydroxide	1310-73-2	643	NA	5.1E+01	3.7E-02	-	7.3E-04	-
Sodium persulfate	7775-27-1	118	NA	5.1E+01	6.9E-03	-	1.3E-04	-
Sodium polyacrylate	9003-04-7	235	NA	1.0E+00	1.4E-02	-	1.4E-02	-
Sodium Sulfate	7757-82-6	0.11	NA	5.1E+01	6.2E-06	-	1.2E-07	-
Tributyl tetradecyl phosphonium chloride	81741-28-8	37	2.4E-04	9.0E-03	2.1E-03	6.6E-05	2.4E-01	7.4E-03
Triethanol amine	102-71-6	2533	1.3E-05	1.0E+00	1.5E-01	2.5E-04	1.5E-01	2.5E-04
Ulexite	1319-33-1	1111	NA	-	6.5E-02	-	NA	-
							Hazard Index	2.2E+01

NA and "-" indicates not applicable
$CADD_{derm}$ = dermal chronic average daily dose
$CADD_{oral}$ = oral chronic average daily dose
CAS No. = Chemical Abstracts Service number
Cfrac = concentration in flowback
cm/hr = cenitmetres per hour
mg/l = milligrams per litre
PC = dermal permeability factor
RfDo = oral reference dose

Table 6b Risk Estimates for Trespasser
Halliburton Delta (DFS-BGB) Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 0

		Day 0		Toxicity	DFS-BGB Hydraulic Fracturing Fluid System			
							Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**PC (cm/hr)**	**RfDo**	**$CADD_{oral}$**	**$CADD_{derm}$**	**Incidental Ingestion**	**Dermal**
Acetic acid	64-19-7	2147	5.6E-04	-	1.3E-01	9.2E-03	NA	NA
Alcohols, C12-15, ethoxylated	68131-39-5	6.1	NA	5.0E-01	3.6E-04	-	7.2E-04	-
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	6.8	NA	-	4.0E-04	-	NA	-
Butyl alcohol	71-36-3	6.5	2.8E-03	4.0E-01	3.8E-04	1.4E-04	9.5E-04	3.4E-04
Cellulase enzyme	9012-54-8	39	1.1E-114	1.0E+00	2.2E-03	3.3E-115	2.2E-03	3.3E-115
Choline Chloride	67-48-1	1987	8.5E-07	5.0E+01	1.2E-01	1.3E-05	2.3E-03	2.6E-07
Citric acid	77-92-9	383	1.2E-05	1.2E+01	2.2E-02	3.3E-05	1.9E-03	2.8E-06
Coffee Extract	68916-18-7	21	NA	2.9E+01	1.2E-03	-	4.3E-05	-
Diethanolamine	111-42-2	0.49	9.7E-06	5.0E-03	2.9E-05	3.6E-08	5.8E-03	7.3E-06
Ethanol	64-17-5	14	5.1E-04	6.0E+00	7.9E-04	5.3E-05	1.3E-04	8.8E-06
Ethylene glycol	107-21-1	29	9.0E-05	1.5E+01	1.7E-03	2.0E-05	1.1E-04	1.3E-06
Fatty acids, tall-oil, ethoxylated	61791-00-2	6.8	NA	1.0E+00	4.0E-04	-	4.0E-04	-
Glutaraldehyde	111-30-8	0.00005	2.5E-04	4.0E-02	3.0E-09	9.8E-11	7.4E-08	2.4E-09
Guar gum	9000-30-0	2933	NA	1.3E+01	1.7E-01	-	1.3E-02	-
Hydrochloric acid	7647-01-0	1035	NA	7.1E+01	6.0E-02	-	8.4E-04	-
Hydrotreated light petroleum distillate	64742-47-8	13	NA	1.3E+01	7.7E-04	-	5.9E-05	-
Lactose	63-42-3	248	9.2E-09	1.0E+00	1.4E-02	1.7E-08	1.4E-02	1.7E-08
Methanol	67-56-1	0.68	3.3E-04	2.0E+00	4.0E-05	1.7E-06	2.0E-05	8.4E-07
Monoethanolamine borate	26038-87-9	1292	NA	1.0E+00	7.5E-02	-	7.5E-02	-
Sodium hydroxide	1310-73-2	269	NA	5.1E+01	1.6E-02	-	3.1E-04	-
Sodium persulfate	7775-27-1	14	NA	5.1E+01	8.2E-04	-	1.6E-05	-
Sodium Sulfate	7757-82-6	0.013	NA	5.1E+01	7.8E-07	-	1.5E-08	-
Tributyl tetradecyl phosphonium chloride	81741-28-8	36	2.4E-04	9.0E-03	2.1E-03	6.5E-05	2.3E-01	7.2E-03
							Hazard Index	3.6E-01

NA and "-" indicates not applicable
$CADD_{derm}$ = dermal chronic average daily dose
$CADD_{oral}$ = oral chronic average daily dose
CAS No. = Chemical Abstracts Service number
Cfrac = concentration in flowback
cm/hr = cenitmetres per hour
mg/l = milligrams per litre
PC = dermal permeability factor
RfDo = oral reference dose

Table 7a Risk Estimates for Trespasser
Halliburton Hybor (DFS-BCG-H) Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 150

		Day 150	Toxicity		DFS-BCG-H Hydraulic fracturing Fluid System			
							Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**PC (cm/hr)**	**RfDo**	**$CADD_{oral}$**	**$CADD_{derm}$**	**Incidental Ingestion**	**Dermal**
Acetic acid	64-19-7	2.1	5.6E-04	-	1.2E-04	9E-06	NA	NA
Alcohols, C12-15, ethoxylated	68131-39-5	0.13	NA	5.0E-01	7.4E-06	NA	1.5E-05	NA
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	0.14	NA	-	8.1E-06	NA	NA	NA
Butyl alcohol	71-36-3	0.14	2.8E-03	4.0E-01	7.9E-06	2.9E-06	2.0E-05	7.1E-06
Chlorous acid, sodium salt	7758-19-2	0.6	8.2E-06	4.0E-03	3.3E-05	3.5E-08	8.3E-03	8.8E-06
Choline Chloride	67-48-1	2.0	8.5E-07	5.0E+01	1.2E-04	1.3E-08	2.3E-06	2.6E-10
Citric acid	77-92-9	0.07	1.2E-05	1.2E+01	3.9E-06	5.8E-09	3.3E-07	4.9E-10
Coffee Extract	68916-18-7	1.9	NA	2.9E+01	1.1E-04	NA	3.8E-06	NA
Crystalline silica, quartz	14808-60-7	75.1	8.8E-03	-	4.4E-03	5.0E-03	NA	NA
Diethanolamine	111-42-2	1.1	9.7E-06	5.0E-03	6.4E-05	8.1E-08	1.3E-02	1.6E-05
Disodium octaborate tetrahydrate	12008-41-2	128.8	NA	2.0E-01	7.5E-03	NA	3.8E-02	NA
Ethanol	64-17-5	0.28	5.1E-04	6.0E+00	1.6E-05	1.1E-06	2.7E-06	1.8E-07
Ethylene glycol	107-21-1	1.1	9.0E-05	1.5E+01	6.3E-05	7.4E-07	4.2E-06	4.9E-08
Fatty acids, tall-oil, ethoxylated	61791-00-2	0.14	NA	1.0E+00	8.3E-06	NA	8.3E-06	NA
Glutaraldehyde	111-30-8	0.0001	2.5E-04	4.0E-02	6.1E-09	2.0E-10	1.5E-07	5.0E-09
Hydrochloric acid	7647-01-0	185	NA	7.1E+01	1.1E-02	NA	1.5E-04	NA
Hydrotreated light petroleum distillate	64742-47-8	139	NA	1.3E+01	8.1E-03	NA	6.2E-04	NA
Hydroxylpropyl guar	39421-75-5	2.92	NA	1.7E+01	1.7E-04	NA	1.0E-05	NA
Methanol	67-56-1	0.01	3.3E-04	2.0E+00	8.1E-07	3.4E-08	4.1E-07	1.7E-08
Silica dioxide	112926-00-8	20	NA	2.5E+01	1.2E-03	NA	4.6E-05	NA
Sodium bisulfite	7631-90-5	48	NA	5.0E+00	2.8E-03	NA	5.6E-04	NA
Sodium carbonate	497-19-8	17	NA	5.1E+01	1.0E-03	NA	2.0E-05	NA
Sodium Chloride	7647-14-5	2027	NA	5.1E+01	1.2E-01	NA	2.3E-03	NA
Sodium hydroxide	1310-73-2	643	NA	5.1E+01	3.7E-02	NA	7.3E-04	NA
Sodium persulfate	7775-27-1	118	NA	5.1E+01	6.9E-03	NA	1.3E-04	NA
Sodium polyacrylate	9003-04-7	235	NA	1.0E+00	1.4E-02	NA	1.4E-02	NA
Sodium Sulfate	7757-82-6	0.11	NA	5.1E+01	6.2E-06	NA	1.2E-07	NA
Tributyl tetradecyl phosphonium chloride	81741-28-8	18	2.4E-04	9.0E-03	1.1E-03	3.3E-05	1.2E-01	3.7E-03
Triethanol amine	102-71-6	2.5	1.3E-05	1.0E+00	1.4E-04	2.4E-07	1.4E-04	2.4E-07
Ulexite	1319-33-1	1111	NA	-	6.5E-02	NA	NA	NA
							Hazard Index	2.0E-01

NA and "-" indicates not applicable
$CADD_{derm}$ = dermal chronic average daily dose
$CADD_{oral}$ = oral chronic average daily dose
CAS No. = Chemical Abstracts Service number
Cfrac = concentration in flowback
cm/hr = cenitmetres per hour
mg/l = milligrams per litre
PC = dermal permeability factor
RfDo = oral reference dose

Table 7b Risk Estimates for Trespasser
Halliburton Delta (DFS-BGB) Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 150

		Day 150		Toxicity	DFS-BGB Hydraulic fracturing Fluid System			
							Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**PC (cm/hr)**	**RfDo**	**$CADD_{oral}$**	**$CADD_{derm}$**	**Incidental Ingestion**	**Dermal**
Acetic acid	64-19-7	2.1	5.6E-04	-	1.2E-04	9E-06	NA	NA
Alcohols, C12-15, ethoxylated	68131-39-5	0.006	NA	5.0E-01	3.5E-07	NA	7.0E-07	NA
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	0.007	NA	-	3.9E-07	NA	NA	NA
Butyl alcohol	71-36-3	0.006	2.8E-03	4.0E-01	3.7E-07	1.3E-07	9.3E-07	3.4E-07
Cellulase enzyme	9012-54-8	0.04	1.1E-114	1.0E+00	2.2E-06	3.3E-118	2.2E-06	3.3E-118
Choline Chloride	67-48-1	1.9	8.5E-07	5.0E+01	1.1E-04	1.3E-08	2.3E-06	2.5E-10
Citric acid	77-92-9	0.37	1.2E-05	1.2E+01	2.2E-05	3.3E-08	1.8E-06	2.7E-09
Coffee Extract	68916-18-7	10.5	NA	2.9E+01	6.1E-04	NA	2.1E-05	NA
Diethanolamine	111-42-2	0.0005	9.7E-06	5.0E-03	2.8E-08	3.5E-11	5.6E-06	7.1E-09
Ethanol	64-17-5	0.013	5.1E-04	6.0E+00	7.7E-07	5.2E-08	1.3E-07	8.6E-09
Ethylene glycol	107-21-1	0.028	9.0E-05	1.5E+01	1.6E-06	1.9E-08	1.1E-07	1.3E-09
Fatty acids, tall-oil, ethoxylated	61791-00-2	0.007	NA	1.0E+00	3.9E-07	NA	3.9E-07	NA
Glutaraldehyde	111-30-8	0.00000005	2.5E-04	4.0E-02	2.9E-12	9.5E-14	7.3E-11	2.4E-12
Guar gum	9000-30-0	2.9	NA	1.3E+01	1.7E-04	NA	1.3E-05	NA
Hydrochloric acid	7647-01-0	1034.7	NA	7.1E+01	6.0E-02	NA	8.4E-04	NA
Hydrotreated light petroleum distillate	64742-47-8	6.6	NA	1.3E+01	3.8E-04	NA	3.0E-05	NA
Lactose	63-42-3	0.24	9.2E-09	1.0E+00	1.4E-05	1.7E-11	1.4E-05	1.7E-11
Methanol	67-56-1	0.0007	3.3E-04	2.0E+00	3.9E-08	1.6E-09	1.9E-08	8.2E-10
Monoethanolamine borate	26038-87-9	1.3	NA	1.0E+00	7.4E-05	NA	7.4E-05	NA
Sodium hydroxide	1310-73-2	269	NA	5.1E+01	1.6E-02	NA	3.1E-04	NA
Sodium persulfate	7775-27-1	14	NA	5.1E+01	8.2E-04	NA	1.6E-05	NA
Sodium Sulfate	7757-82-6	0.013	NA	5.1E+01	7.8E-07	NA	1.5E-08	NA
Tributyl tetradecyl phosphonium chloride	81741-28-8	18	2.4E-04	9.0E-03	1.0E-03	3.2E-05	1.2E-01	3.6E-03
							Hazard Index	1.2E-01

NA and "-" indicates not applicable
$CADD_{derm}$ = dermal chronic average daily dose
$CADD_{oral}$ = oral chronic average daily dose
CAS No. = Chemical Abstracts Service number
Cfrac = concentration in flowback
cm/hr = cenitmetres per hour
mg/l = milligrams per litre
PC = dermal permeability factor
RfDo = oral reference dose

Table 8 Exposure Assumptions - Cattle
Halliburton Hybor (DFS-BCG-H) and Delta (DFS-BGB) Hydraulic Fracturing Fluid Systems

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/day	86
	EF	Exposure frequency	day/yr	15
	ED	Exposure duration	yr	8
	BW	Body weight	kg	454
	AT-NC	Averaging time - noncancer	days	2,920

day/yr = days per year
kg = kilograms
l/day = litres per day
yr = year

Table 9 Exposure Assumptions - Kangaroo
Halliburton Hybor (DFS-BCG-H) and Delta (DFS-BGB) Hydraulic Fracturing Fluid Systems

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/day	3
	EF	Exposure frequency	day/yr	10
	ED	Exposure duration	yr	15
	BW	Body weight	kg	25
	AT-NC	Averaging time - noncancer	days	5,475

day/yr = days per year
kg = kilograms
l/day = litres per day
yr = year

Table 10 Exposure Assumptions - Dingo
Halliburton Hybor (DFS-BCG-H) and Delta (DFS-BGB) Hydraulic Fracturing Fluid Systems

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/day	0.75
	EF	Exposure frequency	day/yr	10
	ED	Exposure duration	yr	15
	BW	Body weight	kg	13
	AT-NC	Averaging time - noncancer	days	5,475

day/yr = days per year
kg = kilograms
l/day = litres per day
yr = year

Table 11 ANZECC Water Quality and PNEC Values
Halliburton Hybor (DFS-BCG-H) and Delta (DFS-BGB) Hydraulic Fracturing Fluid Systems

ANZECC Water Quality Guidelines		
Constituent (CAS No.)	**Substance**	**Freshwater Trigger Value**
Alcohols, C12-15, ethoxylated (68131-39-5)	Alcohol ethoxylates	140 µg/L
Disodium octaborate tetrahydrate (12008-41-2)	Boron	370 µg/L

PNEC Values				
Constituents	**Endpoint**	**E(L)C_{50} or NOEC (mg/L)**	**Assessment Factor**	**$PNEC_{water}$**
Acetic acid (64-19-7)	Acute fish or *Daphnia*	300.82	100	3
Amides, tall oil fatty, N,N-bis(hydroxyethyl) (68155-20-4)	Chronic *Daphnia*	0.07	10	0.007
Butyl alcohol (71-36-3)	Chronic Daphnia	4.1	50	0.08
Cellulase enzyme (9012-54-8)	Acute fish	52.1	1000	0.05
Chlorous acid, sodium salt (7758-19-2)	Acute algae	1	1,000	0.001
Choline chloride (67-48-1)	Chronic *Daphnia*	30	100	0.3
Citric acid (77-92-9)	Acute Daphnia	440	1,000	0.44
Coffee Extract (68916-18-7)	Acute fish, invertebrates, or algae	100 [WAF]	100	1 [WAF]
Crystalline silica (14808-60-7)	[a]	-	-	-
Diethanolamine (111-42-2)	Chronic algae	1.1	50	0.02
Ethanol (64-17-5)	Chronic *Daphnia*	9.6	10	1
Ethylene glycol (107-21-1)	Acute fish	100	10	10
Fatty acids, tall oil, ethoxylated (61791-00-2)	Acute *Daphnia*	12.41 [WAF]	100	0.12 [WAF]
Glutaraldehyde (111-30-8)	Chronic algae	0.025	10	0.0025
Guar gum (9000-30-0)	Acute *Daphnia*	6.2	1,000	0.006
Hydrochloric acid (7647-01-0)	[a]	-	-	-
Hydroxypropyl guar (39421-75-5)	[a]	-	-	-
Hydrotreated light petroleum distillate (64742-47-8)*	[b]	-	-	0.001
Lactose (63-42-3)	Acute *Daphnia*	93,396	1000	93
Methanol (67-56-1)	Acute *Daphnia*	10,000	1,000	10
Monoethanolamine borate (26038-87-9)	Acute algae	26	1000	0.026
Silicon dioxide (112926-00-8)	[a]	-	-	-
Sodium bisulfite (7631-90-5)	Chronic *Daphnia*	8.3	10	0.8
Sodium carbonate (497-19-8)	[a]	-	-	-
Sodium chloride (7647-14-5)	[a]	-	-	-
Sodium hydroxide	[a]	-	-	-
Sodium persulfate (7775-27-1)	Acute algae	116	100	1.2
Sodium polyacrylate (9003-04-7)	Chronic *Daphnia*	12	10	1.2

Table 11 ANZECC Water Quality and PNEC Values
Halliburton Hybor (DFS-BCG-H) and Delta (DFS-BGB) Hydraulic Fracturing Fluid Systems

PNEC Values				
Constituents	**Endpoint**	**E(L)C_{50} or NOEC (mg/L)**	**Assessment Factor**	**$PNEC_{water}$**
Sodium sulfate (7757-82-6)	Chronic *Ceriodaphnia*	1109	100	11
Tributyl tetradecyl phosphonium chloride (81741-28-8)	Acute algae	0.019	1,000	1.9×10^{-5}
Triethanolamine (102-71-6)	Chronic *Daphnia*	16	50	0.32
Ulexite (1319-33-1)	[a]	-	-	-

[a]Not calculated.
[b]Based on QSAR model, PETRORISK v.7.04.
*Read-across from hydrocarbons, C12-C15, n-alkanes, isoalkanes, cyclics, <2% aromatics (CAS No. 869062-45-3).
ANZECC = Australian and New Zealand Environment and Conservation Council
CAS = Chemical Abstracts Service
E(L)C_{50} = effects (lethal) concentration at 50 percent total effect/lethality
mg/L = millgrams per litre
NOEC = no observed effect concentration
PNEC = predicted no-effect concentration
QSAR = quantitative structure - activity relationship
WAF = Water Accommodated Fraction
µg/L = micrograms per litre

Table 12a Risk Estimates for Cattle
Halliburton Hybor (DFS-BCG-H) Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 0

		Day 0	Toxicity	DFS-BCG-H Hydraulic Fracturing Fluid System Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Acetic acid	64-19-7	2.1E+03	NA	1.7E+01	NA
Alcohols, C12-15, ethoxylated	68131-39-5	1.3E+02	8.3E+00	1.0E+00	1.2E-01
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	1.4E+02	NA	1.1E+00	NA
Butyl alcohol	71-36-3	1.4E+02	2.1E+01	1.1E+00	5.2E-02
Chlorous acid, sodium salt	7758-19-2	5.9E+02	6.7E-01	4.6E+00	6.8E+00
Choline Chloride	67-48-1	2.1E+03	6.7E+01	1.6E+01	2.4E-01
Citric acid	77-92-9	6.9E+01	2.0E+02	5.3E-01	2.7E-03
Coffee Extract	68916-18-7	3.7E+00	NA	2.9E-02	NA
Crystalline silica, quartz	14808-60-7	7.5E+01	NA	5.8E-01	NA
Diethanolamine	111-42-2	1.1E+03	2.3E+00	8.8E+00	3.8E+00
Disodium octaborate tetrahydrate	12008-41-2	1.3E+02	1.7E+00	1.0E+00	5.8E-01
Ethanol	64-17-5	2.9E+02	2.9E+02	2.2E+00	7.7E-03
Ethylene glycol	107-21-1	1.1E+03	2.5E+01	8.6E+00	3.4E-01
Fatty acids, tall-oil, ethoxylated	61791-00-2	1.5E+02	1.7E+02	1.1E+00	6.8E-03
Glutaraldehyde	111-30-8	1.1E-01	6.7E-01	8.3E-04	1.2E-03
Hydrochloric acid	7647-01-0	1.9E+02	NA	1.4E+00	NA
Hydrotreated light petroleum distillate	64742-47-8	2.8E+02	2.1E+02	2.2E+00	1.0E-02
Hydroxylpropyl guar	39421-75-5	3.0E+03	8.3E+02	2.3E+01	2.8E-02
Methanol	67-56-1	1.4E+01	8.8E+00	1.1E-01	1.3E-02
Silica dioxide	112926-00-8	2.0E+01	4.2E+02	1.5E-01	3.7E-04
Sodium bisulfite	7631-90-5	4.8E+01	8.7E+01	3.7E-01	4.3E-03
Sodium carbonate	497-19-8	1.7E+01	NA	1.3E-01	NA
Sodium Chloride	7647-14-5	2.0E+03	NA	1.6E+01	NA
Sodium hydroxide	1310-73-2	6.4E+02	NA	5.0E+00	NA
Sodium persulfate	7775-27-1	1.2E+02	NA	9.2E-01	NA
Sodium polyacrylate	9003-04-7	2.3E+02	1.9E+02	1.8E+00	9.7E-03
Sodium Sulfate	7757-82-6	1.1E-01	NA	8.3E-04	NA
Tributyl tetradecyl phosphonium chloride	81741-28-8	3.7E+01	1.4E+00	2.8E-01	2.0E-01
Triethanol amine	102-71-6	2.5E+03	1.7E+02	2.0E+01	1.2E-01
Ulexite	1319-33-1	1.1E+03	NA	8.6E+00	NA
				Hazard Index	1.2E+01

CAS No. = Chemical Abstract Service number
Cfrac = concentration in flowback
mg/l = milligrams per litre
NA = not applicable
TRV = toxicity reference value

Table 12b Risk Estimates for Cattle
Halliburton Delta (DFS-BGB) Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 0

		Day 0	Toxicity	DFS-BGB Hydraulic Fracturing Fluid System Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Acetic acid	64-19-7	2.1E+03	NA	1.7E+01	NA
Alcohols, C12-15, ethoxylated	68131-39-5	6.1E+00	8.3E+00	4.8E-02	5.7E-03
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	6.8E+00	NA	5.3E-02	NA
Butyl alcohol	71-36-3	6.5E+00	2.1E+01	5.1E-02	2.4E-03
Cellulase enzyme	9012-54-8	3.9E+01	1.7E+02	3.0E-01	1.8E-03
Choline Chloride	67-48-1	2.0E+03	6.7E+01	1.5E+01	2.3E-01
Citric acid	77-92-9	3.8E+02	2.0E+02	3.0E+00	1.5E-02
Coffee Extract	68916-18-7	2.1E+01	NA	1.6E-01	NA
Diethanolamine	111-42-2	4.9E-01	2.3E+00	3.8E-03	1.6E-03
Ethanol	64-17-5	1.4E+01	2.9E+02	1.1E-01	3.7E-04
Ethylene glycol	107-21-1	2.9E+01	2.5E+01	2.2E-01	9.0E-03
Fatty acids, tall-oil, ethoxylated	61791-00-2	6.8E+00	1.7E+02	5.3E-02	3.2E-04
Glutaraldehyde	111-30-8	5.1E-05	6.7E-01	4.0E-07	6.0E-07
Guar gum	9000-30-0	2.9E+03	2.1E+02	2.3E+01	1.1E-01
Hydrochloric acid	7647-01-0	1.0E+03	NA	8.1E+00	NA
Hydrotreated light petroleum distillate	64742-47-8	1.3E+01	2.1E+02	1.0E-01	4.9E-04
Lactose	63-42-3	2.5E+02	1.7E+02	1.9E+00	1.2E-02
Methanol	67-56-1	6.8E-01	8.8E+00	5.3E-03	6.0E-04
Monoethanolamine borate	26038-87-9	1.3E+03	1.7E+02	1.0E+01	6.0E-02
Sodium hydroxide	1310-73-2	2.7E+02	NA	2.1E+00	NA
Sodium persulfate	7775-27-1	1.4E+01	NA	1.1E-01	NA
Sodium Sulfate	7757-82-6	1.3E-02	NA	1.0E-04	NA
Tributyl tetradecyl phosphonium chloride	81741-28-8	3.6E+01	1.4E+00	2.8E-01	1.9E-01
				Hazard Index	6.4E-01

CAS No. = Chemical Abstract Service number
Cfrac = concentration in flowback
mg/l = milligrams per litre
NA = not applicable
TRV = toxicity reference value

Table 13a Risk Estimates for Cattle
Halliburton Hybor (DFS-BCG-H) Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 150

		Day 150	Toxicity	DFS-BCG-H Hydraulic Fracturing Fluid System Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Acetic acid	64-19-7	2.1E+00	NA	1.2E-04	NA
Alcohols, C12-15, ethoxylated	68131-39-5	1.3E-01	8.3E+00	7.4E-06	8.9E-07
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	1.4E-01	NA	8.1E-06	NA
Butyl alcohol	71-36-3	1.4E-01	2.1E+01	7.9E-06	3.8E-07
Chlorous acid, sodium salt	7758-19-2	5.7E-01	6.7E-01	3.3E-05	5.0E-05
Choline Chloride	67-48-1	2.0E+00	6.7E+01	1.2E-04	1.7E-06
Citric acid	77-92-9	6.7E-02	2.0E+02	3.9E-06	2.0E-08
Coffee Extract	68916-18-7	1.9E+00	NA	1.1E-04	NA
Crystalline silica, quartz	14808-60-7	7.5E+01	NA	4.4E-03	NA
Diethanolamine	111-42-2	1.1E+00	2.3E+00	6.4E-05	2.8E-05
Disodium octaborate tetrahydrate	12008-41-2	1.3E+02	1.7E+00	7.5E-03	4.4E-03
Ethanol	64-17-5	2.8E-01	2.9E+02	1.6E-05	5.7E-08
Ethylene glycol	107-21-1	1.1E+00	2.5E+01	6.3E-05	2.5E-06
Fatty acids, tall-oil, ethoxylated	61791-00-2	1.4E-01	1.7E+02	8.3E-06	5.0E-08
Glutaraldehyde	111-30-8	1.0E-04	6.7E-01	6.1E-09	9.1E-09
Hydrochloric acid	7647-01-0	1.9E+02	NA	1.1E-02	NA
Hydrotreated light petroleum distillate	64742-47-8	1.4E+02	2.1E+02	8.1E-03	3.9E-05
Hydroxylpropyl guar	39421-75-5	2.9E+00	8.3E+02	1.7E-04	2.0E-07
Methanol	67-56-1	1.4E-02	8.8E+00	8.1E-07	9.2E-08
Silica dioxide	112926-00-8	2.0E+01	4.2E+02	1.2E-03	2.8E-06
Sodium bisulfite	7631-90-5	4.8E+01	8.7E+01	2.8E-03	3.2E-05
Sodium carbonate	497-19-8	1.7E+01	NA	1.0E-03	NA
Sodium Chloride	7647-14-5	2.0E+03	NA	1.2E-01	NA
Sodium hydroxide	1310-73-2	6.4E+02	NA	3.7E-02	NA
Sodium persulfate	7775-27-1	1.2E+02	NA	6.9E-03	NA
Sodium polyacrylate	9003-04-7	2.3E+02	1.9E+02	1.4E-02	7.2E-05
Sodium Sulfate	7757-82-6	1.1E-01	NA	6.2E-06	NA
Tributyl tetradecyl phosphonium chloride	81741-28-8	1.8E+01	1.4E+00	1.1E-03	7.4E-04
Triethanol amine	102-71-6	2.5E+00	1.7E+02	1.4E-04	8.7E-07
Ulexite	1319-33-1	1.1E+03	NA	6.5E-02	NA
				Hazard Index	5.3E-03

CAS No. = Chemical Abstract Service number
Cfrac = concentration in flowback
mg/l = milligrams per litre
NA = not applicable
TRV = toxicity reference value

Table 13b Risk Estimates for Cattle
Halliburton Delta (DFS-BGB) Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 150

		Day 150	Toxicity	DFS-BGB Hydraulic Fracturing Fluid System Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Acetic acid	64-19-7	2.1E+00	NA	1.2E-04	NA
Alcohols, C12-15, ethoxylated	68131-39-5	6.0E-03	8.3E+00	3.5E-07	4.2E-08
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	6.6E-03	NA	3.9E-07	NA
Butyl alcohol	71-36-3	6.4E-03	2.1E+01	3.7E-07	1.8E-08
Cellulase enzyme	9012-54-8	3.8E-02	1.7E+02	2.2E-06	1.3E-08
Choline Chloride	67-48-1	1.9E+00	6.7E+01	1.1E-04	1.7E-06
Citric acid	77-92-9	3.7E-01	2.0E+02	2.2E-05	1.1E-07
Coffee Extract	68916-18-7	1.1E+01	NA	6.1E-04	NA
Diethanolamine	111-42-2	4.8E-04	2.3E+00	2.8E-08	1.2E-08
Ethanol	64-17-5	1.3E-02	2.9E+02	7.7E-07	2.7E-09
Ethylene glycol	107-21-1	2.8E-02	2.5E+01	1.6E-06	6.6E-08
Fatty acids, tall-oil, ethoxylated	61791-00-2	6.6E-03	1.7E+02	3.9E-07	2.3E-09
Glutaraldehyde	111-30-8	5.0E-08	6.7E-01	2.9E-12	4.4E-12
Guar gum	9000-30-0	2.9E+00	2.1E+02	1.7E-04	8.0E-07
Hydrochloric acid	7647-01-0	1.0E+03	NA	6.0E-02	NA
Hydrotreated light petroleum distillate	64742-47-8	6.6E+00	2.1E+02	3.8E-04	1.8E-06
Lactose	63-42-3	2.4E-01	1.7E+02	1.4E-05	8.5E-08
Methanol	67-56-1	6.6E-04	8.8E+00	3.9E-08	4.4E-09
Monoethanolamine borate	26038-87-9	1.3E+00	1.7E+02	7.4E-05	4.4E-07
Sodium hydroxide	1310-73-2	2.7E+02	NA	1.6E-02	NA
Sodium persulfate	7775-27-1	1.4E+01	NA	8.2E-04	NA
Sodium Sulfate	7757-82-6	1.3E-02	NA	7.8E-07	NA
Tributyl tetradecyl phosphonium chloride	81741-28-8	1.8E+01	1.4E+00	1.0E-03	7.2E-04
				Hazard Index	7.3E-04

CAS No. = Chemical Abstract Service number
Cfrac = concentration in flowback
mg/l = milligrams per litre
NA = not applicable
TRV = toxicity reference value

Table 14a Risk Estimates for Kangaroo
Halliburton Hybor (DFS-BCG-H) Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 0

		Day 0	Toxicity	DFS-BCG-H Hydraulic Fracturing Fluid System Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Acetic acid	64-19-7	2.1E+03	NA	7.0E+00	NA
Alcohols, C12-15, ethoxylated	68131-39-5	1.3E+02	1.7E+01	4.3E-01	2.5E-02
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	1.4E+02	NA	4.7E-01	NA
Butyl alcohol	71-36-3	1.4E+02	4.3E+01	4.6E-01	1.1E-02
Chlorous acid, sodium salt	7758-19-2	5.9E+02	1.4E+00	1.9E+00	1.4E+00
Choline Chloride	67-48-1	2.1E+03	1.4E+02	6.8E+00	4.9E-02
Citric acid	77-92-9	6.9E+01	4.1E+02	2.3E-01	5.5E-04
Coffee Extract	68916-18-7	3.7E+00	NA	1.2E-02	NA
Crystalline silica, quartz	14808-60-7	7.5E+01	NA	2.5E-01	NA
Diethanolamine	111-42-2	1.1E+03	4.8E+00	3.7E+00	7.7E-01
Disodium octaborate tetrahydrate	12008-41-2	1.3E+02	3.5E+00	4.2E-01	1.2E-01
Ethanol	64-17-5	2.9E+02	6.0E+02	9.4E-01	1.6E-03
Ethylene glycol	107-21-1	1.1E+03	5.2E+01	3.6E+00	7.0E-02
Fatty acids, tall-oil, ethoxylated	61791-00-2	1.5E+02	3.4E+02	4.8E-01	1.4E-03
Glutaraldehyde	111-30-8	1.1E-01	1.4E+00	3.5E-04	2.5E-04
Hydrochloric acid	7647-01-0	1.9E+02	NA	6.1E-01	NA
Hydrotreated light petroleum distillate	64742-47-8	2.8E+02	4.3E+02	9.2E-01	2.1E-03
Hydroxylpropyl guar	39421-75-5	3.0E+03	1.7E+03	9.8E+00	5.7E-03
Methanol	67-56-1	1.4E+01	1.8E+01	4.7E-02	2.6E-03
Silica dioxide	112926-00-8	2.0E+01	8.6E+02	6.5E-02	7.6E-05
Sodium bisulfite	7631-90-5	4.8E+01	1.8E+02	1.6E-01	8.8E-04
Sodium carbonate	497-19-8	1.7E+01	NA	5.7E-02	NA
Sodium Chloride	7647-14-5	2.0E+03	NA	6.7E+00	NA
Sodium hydroxide	1310-73-2	6.4E+02	NA	2.1E+00	NA
Sodium persulfate	7775-27-1	1.2E+02	NA	3.9E-01	NA
Sodium polyacrylate	9003-04-7	2.3E+02	3.9E+02	7.7E-01	2.0E-03
Sodium Sulfate	7757-82-6	1.1E-01	NA	3.5E-04	NA
Tributyl tetradecyl phosphonium chloride	81741-28-8	3.7E+01	3.0E+00	1.2E-01	4.0E-02
Triethanol amine	102-71-6	2.5E+03	3.4E+02	8.3E+00	2.4E-02
Ulexite	1319-33-1	1.1E+03	NA	3.7E+00	NA
				Hazard Index	2.5E+00

CAS No. = Chemical Abstract Service number
Cfrac = concentration in flowback
mg/l = milligrams per litre
TRV = toxicity reference value
NA = not applicable

Table 14b Risk Estimates for Kangaroo
Halliburton Delta (DFS-BGB) Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 0

		Day 0	Toxicity	DFS-BGB Hydraulic Fracturing Fluid System Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Acetic acid	64-19-7	2.1E+03	NA	7.1E+00	NA
Alcohols, C12-15, ethoxylated	68131-39-5	6.1E+00	1.7E+01	2.0E-02	1.2E-03
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	6.8E+00	NA	2.2E-02	NA
Butyl alcohol	71-36-3	6.5E+00	4.3E+01	2.1E-02	5.0E-04
Cellulase enzyme	9012-54-8	3.9E+01	3.4E+02	1.3E-01	3.7E-04
Choline Chloride	67-48-1	2.0E+03	1.4E+02	6.5E+00	4.7E-02
Citric acid	77-92-9	3.8E+02	4.1E+02	1.3E+00	3.0E-03
Coffee Extract	68916-18-7	2.1E+01	NA	6.9E-02	NA
Diethanolamine	111-42-2	4.9E-01	4.8E+00	1.6E-03	3.4E-04
Ethanol	64-17-5	1.4E+01	6.0E+02	4.5E-02	7.5E-05
Ethylene glycol	107-21-1	2.9E+01	5.2E+01	9.5E-02	1.8E-03
Fatty acids, tall-oil, ethoxylated	61791-00-2	6.8E+00	3.4E+02	2.2E-02	6.5E-05
Glutaraldehyde	111-30-8	5.1E-05	1.4E+00	1.7E-07	1.2E-07
Guar gum	9000-30-0	2.9E+03	4.3E+02	9.6E+00	2.2E-02
Hydrochloric acid	7647-01-0	1.0E+03	NA	3.4E+00	NA
Hydrotreated light petroleum distillate	64742-47-8	1.3E+01	4.3E+02	4.3E-02	1.0E-04
Lactose	63-42-3	2.5E+02	3.4E+02	8.2E-01	2.4E-03
Methanol	67-56-1	6.8E-01	1.8E+01	2.2E-03	1.2E-04
Monoethanolamine borate	26038-87-9	1.3E+03	3.4E+02	4.2E+00	1.2E-02
Sodium hydroxide	1310-73-2	2.7E+02	NA	8.9E-01	NA
Sodium persulfate	7775-27-1	1.4E+01	NA	4.6E-02	NA
Sodium Sulfate	7757-82-6	1.3E-02	NA	4.4E-05	NA
Tributyl tetradecyl phosphonium chloride	81741-28-8	3.6E+01	3.0E+00	1.2E-01	3.9E-02
				Hazard Index	1.3E-01

CAS No. = Chemical Abstract Service number
Cfrac = concentration in flowback
mg/l = milligrams per litre
NA = not applicable
TRV = toxicity reference value

Table 15a Risk Estimates for Kangaroo
Halliburton Hybor (DFS-BCG-H) Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 150

		Day 150	Toxicity	DFS-BCG-H Hydraulic Fracturing Fluid System Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Acetic acid	64-19-7	2.1E+00	NA	6.8E-03	NA
Alcohols, C12-15, ethoxylated	68131-39-5	1.3E-01	1.7E+01	4.2E-04	2.4E-05
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	1.4E-01	NA	4.6E-04	NA
Butyl alcohol	71-36-3	1.4E-01	4.3E+01	4.5E-04	1.0E-05
Chlorous acid, sodium salt	7758-19-2	5.7E-01	1.4E+00	1.9E-03	1.4E-03
Choline Chloride	67-48-1	2.0E+00	1.4E+02	6.6E-03	4.8E-05
Citric acid	77-92-9	6.7E-02	4.1E+02	2.2E-04	5.3E-07
Coffee Extract	68916-18-7	1.9E+00	NA	6.1E-03	NA
Crystalline silica, quartz	14808-60-7	7.5E+01	NA	2.5E-01	NA
Diethanolamine	111-42-2	1.1E+00	4.8E+00	3.6E-03	7.5E-04
Disodium octaborate tetrahydrate	12008-41-2	1.3E+02	3.5E+00	4.2E-01	1.2E-01
Ethanol	64-17-5	2.8E-01	6.0E+02	9.2E-04	1.5E-06
Ethylene glycol	107-21-1	1.1E+00	5.2E+01	3.5E-03	6.9E-05
Fatty acids, tall-oil, ethoxylated	61791-00-2	1.4E-01	3.4E+02	4.7E-04	1.4E-06
Glutaraldehyde	111-30-8	1.0E-04	1.4E+00	3.4E-07	2.5E-07
Hydrochloric acid	7647-01-0	1.9E+02	NA	6.1E-01	NA
Hydrotreated light petroleum distillate	64742-47-8	1.4E+02	4.3E+02	4.6E-01	1.1E-03
Hydroxylpropyl guar	39421-75-5	2.9E+00	1.7E+03	9.6E-03	5.6E-06
Methanol	67-56-1	1.4E-02	1.8E+01	4.6E-05	2.5E-06
Silica dioxide	112926-00-8	2.0E+01	8.6E+02	6.5E-02	7.6E-05
Sodium bisulfite	7631-90-5	4.8E+01	1.8E+02	1.6E-01	8.8E-04
Sodium carbonate	497-19-8	1.7E+01	NA	5.7E-02	NA
Sodium Chloride	7647-14-5	2.0E+03	NA	6.7E+00	NA
Sodium hydroxide	1310-73-2	6.4E+02	NA	2.1E+00	NA
Sodium persulfate	7775-27-1	1.2E+02	NA	3.9E-01	NA
Sodium polyacrylate	9003-04-7	2.3E+02	3.9E+02	7.7E-01	2.0E-03
Sodium Sulfate	7757-82-6	1.1E-01	NA	3.5E-04	NA
Tributyl tetradecyl phosphonium chloride	81741-28-8	1.8E+01	3.0E+00	6.0E-02	2.0E-02
Triethanol amine	102-71-6	2.5E+00	3.4E+02	8.1E-03	2.4E-05
Ulexite	1319-33-1	1.1E+03	NA	3.7E+00	NA
				Hazard Index	1.5E-01

CAS No. = Chemical Abstract Service number
Cfrac = concentration in flowback
mg/l = milligrams per litre
NA = not applicable
TRV = toxicity reference value

Table 15b Risk Estimates for Kangaroo
Halliburton Delta (DFS-BGB) Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 150

		Day 150	Toxicity	DFS-BGB Hydraulic Fracturing Fluid System Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Acetic acid	64-19-7	2.1E+00	NA	6.9E-03	NA
Alcohols, C12-15, ethoxylated	68131-39-5	6.0E-03	1.7E+01	2.0E-05	1.1E-06
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	6.6E-03	NA	2.2E-05	NA
Butyl alcohol	71-36-3	6.4E-03	4.3E+01	2.1E-05	4.9E-07
Cellulase enzyme	9012-54-8	3.8E-02	3.4E+02	1.2E-04	3.6E-07
Choline Chloride	67-48-1	1.9E+00	1.4E+02	6.4E-03	4.6E-05
Citric acid	77-92-9	3.7E-01	4.1E+02	1.2E-03	3.0E-06
Coffee Extract	68916-18-7	1.1E+01	NA	3.5E-02	NA
Diethanolamine	111-42-2	4.8E-04	4.8E+00	1.6E-06	3.3E-07
Ethanol	64-17-5	1.3E-02	6.0E+02	4.4E-05	7.3E-08
Ethylene glycol	107-21-1	2.8E-02	5.2E+01	9.2E-05	1.8E-06
Fatty acids, tall-oil, ethoxylated	61791-00-2	6.6E-03	3.4E+02	2.2E-05	6.3E-08
Glutaraldehyde	111-30-8	5.0E-08	1.4E+00	1.6E-10	1.2E-10
Guar gum	9000-30-0	2.9E+00	4.3E+02	9.4E-03	2.2E-05
Hydrochloric acid	7647-01-0	1.0E+03	NA	3.4E+00	NA
Hydrotreated light petroleum distillate	64742-47-8	6.6E+00	4.3E+02	2.2E-02	5.0E-05
Lactose	63-42-3	2.4E-01	3.4E+02	8.0E-04	2.3E-06
Methanol	67-56-1	6.6E-04	1.8E+01	2.2E-06	1.2E-07
Monoethanolamine borate	26038-87-9	1.3E+00	3.4E+02	4.1E-03	1.2E-05
Sodium hydroxide	1310-73-2	2.7E+02	NA	8.9E-01	NA
Sodium persulfate	7775-27-1	1.4E+01	NA	4.6E-02	NA
Sodium Sulfate	7757-82-6	1.3E-02	NA	4.4E-05	NA
Tributyl tetradecyl phosphonium chloride	81741-28-8	1.8E+01	3.0E+00	5.9E-02	2.0E-02
				Hazard Index	2.0E-02

CAS No. = Chemical Abstract Service number
Cfrac = concentration in flowback
mg/l = milligrams per litre
NA = not applicable
TRV = toxicity reference value

Table 16a Risk Estimates for Dingo
Halliburton Hybor (DFS-BCG-H) Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 0

		Day 0	Toxicity	DFS-BCG-H Hydraulic Fracturing Fluid System Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Acetic acid	64-19-7	2.1E+03	NA	3.4E+00	NA
Alcohols, C12-15, ethoxylated	68131-39-5	1.3E+02	2.0E+01	2.1E-01	1.0E-02
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	1.4E+02	NA	2.3E-01	NA
Butyl alcohol	71-36-3	1.4E+02	5.1E+01	2.2E-01	4.3E-03
Chlorous acid, sodium salt	7758-19-2	5.9E+02	1.6E+00	9.3E-01	5.7E-01
Choline Chloride	67-48-1	2.1E+03	1.6E+02	3.2E+00	2.0E-02
Citric acid	77-92-9	6.9E+01	4.9E+02	1.1E-01	2.2E-04
Coffee Extract	68916-18-7	3.7E+00	NA	5.9E-03	NA
Crystalline silica, quartz	14808-60-7	7.5E+01	NA	1.2E-01	NA
Diethanolamine	111-42-2	1.1E+03	5.7E+00	1.8E+00	3.1E-01
Disodium octaborate tetrahydrate	12008-41-2	1.3E+02	4.2E+00	2.0E-01	4.9E-02
Ethanol	64-17-5	2.9E+02	7.0E+02	4.5E-01	6.5E-04
Ethylene glycol	107-21-1	1.1E+03	6.1E+01	1.7E+00	2.9E-02
Fatty acids, tall-oil, ethoxylated	61791-00-2	1.5E+02	4.1E+02	2.3E-01	5.7E-04
Glutaraldehyde	111-30-8	1.1E-01	1.6E+00	1.7E-04	1.0E-04
Hydrochloric acid	7647-01-0	1.9E+02	NA	2.9E-01	NA
Hydrotreated light petroleum distillate	64742-47-8	2.8E+02	5.1E+02	4.4E-01	8.7E-04
Hydroxylpropyl guar	39421-75-5	3.0E+03	2.0E+03	4.7E+00	2.3E-03
Methanol	67-56-1	1.4E+01	2.1E+01	2.3E-02	1.1E-03
Silica dioxide	112926-00-8	2.0E+01	1.0E+03	3.1E-02	3.1E-05
Sodium bisulfite	7631-90-5	4.8E+01	2.1E+02	7.6E-02	3.6E-04
Sodium carbonate	497-19-8	1.7E+01	NA	2.7E-02	NA
Sodium Chloride	7647-14-5	2.0E+03	NA	3.2E+00	NA
Sodium hydroxide	1310-73-2	6.4E+02	NA	1.0E+00	NA
Sodium persulfate	7775-27-1	1.2E+02	NA	1.9E-01	NA
Sodium polyacrylate	9003-04-7	2.3E+02	4.6E+02	3.7E-01	8.1E-04
Sodium Sulfate	7757-82-6	1.1E-01	NA	1.7E-04	NA
Tributyl tetradecyl phosphonium chloride	81741-28-8	3.7E+01	3.5E+00	5.8E-02	1.6E-02
Triethanol amine	102-71-6	2.5E+03	4.1E+02	4.0E+00	9.9E-03
Ulexite	1319-33-1	1.1E+03	NA	1.8E+00	NA
				Hazard Index	1.0E+00

CAS No. = Chemical Abstract Service number
Cfrac = concentration in flowback
mg/l = milligrams per litre
NA = not applicable
TRV = toxicity reference value

Table 16b Risk Estimates for Dingo
Halliburton Delta (DFS-BGB) Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 0

		Day 0	Toxicity	DFS-BGB Hydraulic Fracturing Fluid System Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Acetic acid	64-19-7	2.1E+03	NA	3.4E+00	NA
Alcohols, C12-15, ethoxylated	68131-39-5	6.1E+00	2.0E+01	9.7E-03	4.8E-04
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	6.8E+00	NA	1.1E-02	NA
Butyl alcohol	71-36-3	6.5E+00	5.1E+01	1.0E-02	2.0E-04
Cellulase enzyme	9012-54-8	3.9E+01	4.1E+02	6.1E-02	1.5E-04
Choline Chloride	67-48-1	2.0E+03	1.6E+02	3.1E+00	1.9E-02
Citric acid	77-92-9	3.8E+02	4.9E+02	6.0E-01	1.2E-03
Coffee Extract	68916-18-7	2.1E+01	NA	3.3E-02	NA
Diethanolamine	111-42-2	4.9E-01	5.7E+00	7.8E-04	1.4E-04
Ethanol	64-17-5	1.4E+01	7.0E+02	2.1E-02	3.1E-05
Ethylene glycol	107-21-1	2.9E+01	6.1E+01	4.6E-02	7.5E-04
Fatty acids, tall-oil, ethoxylated	61791-00-2	6.8E+00	4.1E+02	1.1E-02	2.7E-05
Glutaraldehyde	111-30-8	5.1E-05	1.6E+00	8.1E-08	5.0E-08
Guar gum	9000-30-0	2.9E+03	5.1E+02	4.6E+00	9.2E-03
Hydrochloric acid	7647-01-0	1.0E+03	NA	1.6E+00	NA
Hydrotreated light petroleum distillate	64742-47-8	1.3E+01	5.1E+02	2.1E-02	4.1E-05
Lactose	63-42-3	2.5E+02	4.1E+02	3.9E-01	9.7E-04
Methanol	67-56-1	6.8E-01	2.1E+01	1.1E-03	5.0E-05
Monoethanolamine borate	26038-87-9	1.3E+03	4.1E+02	2.0E+00	5.0E-03
Sodium hydroxide	1310-73-2	2.7E+02	NA	4.3E-01	NA
Sodium persulfate	7775-27-1	1.4E+01	NA	2.2E-02	NA
Sodium Sulfate	7757-82-6	1.3E-02	NA	2.1E-05	NA
Tributyl tetradecyl phosphonium chloride	81741-28-8	3.6E+01	3.5E+00	5.6E-02	1.6E-02
				Hazard Index	5.4E-02

CAS No. = Chemical Abstract Service number
Cfrac = concentration in flowback
mg/l = milligrams per litre
NA = not applicable
TRV = toxicity reference value

Table 17a Risk Estimates for Dingo
Halliburton Hybor (DFS-BCG-H) Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 150

		Day 150	Toxicity	DFS-BCG-H Hydraulic Fracturing Fluid System Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Acetic acid	64-19-7	2.1E+00	NA	3.3E-03	NA
Alcohols, C12-15, ethoxylated	68131-39-5	1.3E-01	2.0E+01	2.0E-04	9.9E-06
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	1.4E-01	NA	2.2E-04	NA
Butyl alcohol	71-36-3	1.4E-01	5.1E+01	2.1E-04	4.2E-06
Chlorous acid, sodium salt	7758-19-2	5.7E-01	1.6E+00	9.0E-04	5.6E-04
Choline Chloride	67-48-1	2.0E+00	1.6E+02	3.2E-03	1.9E-05
Citric acid	77-92-9	6.7E-02	4.9E+02	1.1E-04	2.2E-07
Coffee Extract	68916-18-7	1.9E+00	NA	3.0E-03	NA
Crystalline silica, quartz	14808-60-7	7.5E+01	NA	1.2E-01	NA
Diethanolamine	111-42-2	1.1E+00	5.7E+00	1.7E-03	3.1E-04
Disodium octaborate tetrahydrate	12008-41-2	1.3E+02	4.2E+00	2.0E-01	4.9E-02
Ethanol	64-17-5	2.8E-01	7.0E+02	4.4E-04	6.3E-07
Ethylene glycol	107-21-1	1.1E+00	6.1E+01	1.7E-03	2.8E-05
Fatty acids, tall-oil, ethoxylated	61791-00-2	1.4E-01	4.1E+02	2.2E-04	5.5E-07
Glutaraldehyde	111-30-8	1.0E-04	1.6E+00	1.6E-07	1.0E-07
Hydrochloric acid	7647-01-0	1.9E+02	NA	2.9E-01	NA
Hydrotreated light petroleum distillate	64742-47-8	1.4E+02	5.1E+02	2.2E-01	4.3E-04
Hydroxylpropyl guar	39421-75-5	2.9E+00	2.0E+03	4.6E-03	2.3E-06
Methanol	67-56-1	1.4E-02	2.1E+01	2.2E-05	1.0E-06
Silica dioxide	112926-00-8	2.0E+01	1.0E+03	3.1E-02	3.1E-05
Sodium bisulfite	7631-90-5	4.8E+01	2.1E+02	7.6E-02	3.6E-04
Sodium carbonate	497-19-8	1.7E+01	NA	2.7E-02	NA
Sodium Chloride	7647-14-5	2.0E+03	NA	3.2E+00	NA
Sodium hydroxide	1310-73-2	6.4E+02	NA	1.0E+00	NA
Sodium persulfate	7775-27-1	1.2E+02	NA	1.9E-01	NA
Sodium polyacrylate	9003-04-7	2.3E+02	4.6E+02	3.7E-01	8.1E-04
Sodium Sulfate	7757-82-6	1.1E-01	NA	1.7E-04	NA
Tributyl tetradecyl phosphonium chloride	81741-28-8	1.8E+01	3.5E+00	2.9E-02	8.2E-03
Triethanol amine	102-71-6	2.5E+00	4.1E+02	3.9E-03	9.7E-06
Ulexite	1319-33-1	1.1E+03	NA	1.8E+00	NA
				Hazard Index	6.0E-02

CAS No. = Chemical Abstract Service number
Cfrac = concentration in flowback
mg/l = milligrams per litre
NA = not applicable
TRV = toxicity reference value

Table 17b Risk Estimates for Dingo
Halliburton Delta (DFS-BGB) Hydraulic Fracturing Fluid System
Theoretical Exposure for Day 150

		Day 150	Toxicity	DFS-BGB Hydraulic Fracturing Fluid System Hazard Quotient	
Constituent Name	**CAS No.**	**C_{frac} (mg/l)**	**TRVs**	**Total Intake**	**Incidental Ingestion**
Acetic acid	64-19-7	2.1E+00	NA	3.3E-03	NA
Alcohols, C12-15, ethoxylated	68131-39-5	6.0E-03	2.0E+01	9.5E-06	4.7E-07
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	6.6E-03	NA	1.0E-05	NA
Butyl alcohol	71-36-3	6.4E-03	5.1E+01	1.0E-05	2.0E-07
Cellulase enzyme	9012-54-8	3.8E-02	4.1E+02	5.9E-05	1.5E-07
Choline Chloride	67-48-1	1.9E+00	1.6E+02	3.1E-03	1.9E-05
Citric acid	77-92-9	3.7E-01	4.9E+02	5.9E-04	1.2E-06
Coffee Extract	68916-18-7	1.1E+01	NA	1.7E-02	NA
Diethanolamine	111-42-2	4.8E-04	5.7E+00	7.6E-07	1.3E-07
Ethanol	64-17-5	1.3E-02	7.0E+02	2.1E-05	3.0E-08
Ethylene glycol	107-21-1	2.8E-02	6.1E+01	4.4E-05	7.3E-07
Fatty acids, tall-oil, ethoxylated	61791-00-2	6.6E-03	4.1E+02	1.0E-05	2.6E-08
Glutaraldehyde	111-30-8	5.0E-08	1.6E+00	7.9E-11	4.9E-11
Guar gum	9000-30-0	2.9E+00	5.1E+02	4.5E-03	8.9E-06
Hydrochloric acid	7647-01-0	1.0E+03	NA	1.6E+00	NA
Hydrotreated light petroleum distillate	64742-47-8	6.6E+00	5.1E+02	1.0E-02	2.1E-05
Lactose	63-42-3	2.4E-01	4.1E+02	3.8E-04	9.5E-07
Methanol	67-56-1	6.6E-04	2.1E+01	1.0E-06	4.9E-08
Monoethanolamine borate	26038-87-9	1.3E+00	4.1E+02	2.0E-03	4.9E-06
Sodium hydroxide	1310-73-2	2.7E+02	NA	4.3E-01	NA
Sodium persulfate	7775-27-1	1.4E+01	NA	2.2E-02	NA
Sodium Sulfate	7757-82-6	1.3E-02	NA	2.1E-05	NA
Tributyl tetradecyl phosphonium chloride	81741-28-8	1.8E+01	3.5E+00	2.8E-02	8.1E-03
				Hazard Index	8.1E-03

CAS No. = Chemical Abstract Service number
Cfrac = concentration in flowback
mg/l = milligrams per litre
NA = not applicable
TRV = toxicity reference value

Santos

Appendix C11-1

HALLIBURTON CONFIDENTIAL INFORMATION - ONLY TO BE USED FOR REGULATOR NOTIFICATION (QLD FORMAT)

Comments:
Santos Assessment purpose Fluid: DFS-BCG-H PreJob 350K Gal job

Total injected fluid volume (kiloliters):	1458.298

Comprising of: (Kilograms, liters or kiloliters)		
Base Fluid type (e.g. water)	**Liters**	**% of total volume**
Makeup Water	1333563	91.4%

Proppant type (e.g sand)	**Proppant Size**	**Kilograms**	**Liters**	**% of total volume**
Sand	100 Mesh	14628	5520	0.37853%
Premium	20/40	272566	81121	5.56272%

Any wet chemical constitutes:	**Liters**	**% of total volume**
Water in Products	18000	1.23%
Hydroxylpropyl guar	3263	0.224%
Triethanol amine	2776	0.190%
Acetic acid	2334	0.160%
Choline Chloride	2239	0.154%
Sodium Chloride	2212	0.152%
Diethanolamine	1234	0.0846%
Ulexite	1215	0.0833%
Ethylene glycol	1209	0.0829%
Sodium hydroxide	703	0.0482%
Chlorous acid, sodium salt	640	0.0439%
Ethanol	314	0.0215%
Hydrotreated light petroleum distillate	305	0.0209%
Sodium polyacrylate	257	0.0176%
Hydrochloric acid	202	0.0139%
Fatty acids, tall-oil, ethoxylated	159	0.0109%
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	157	0.0107%
Butyl alcohol	152	0.0104%
Alcohols, C12-15, ethoxylated	143	0.00979%
Disodium octaborate tetrahydrate	141	0.00966%
Sodium persulfate	129	0.00887%
Crystalline silica, quartz	82	0.00563%
Citric acid	75	0.00514%
Sodium bisulfite	52	0.00360%
Tributyl tetradecyl phosphonium chloride	40	0.00274%
Silica dioxide	22	0.00149%
Sodium carbonate	19	0.00130%
Methanol	16	0.00107%
Coffee Extract	4.1	0.00028%
Sodium Sulfate	0.12	0.000008%
Glutaraldehyde	0.12	0.000008%

HALLIBURTON CONFIDENTIAL INFORMATION - ONLY TO BE USED FOR REGULATOR NOTIFICATION (QLD FORMAT)

Comments:
Santos Assessment purpose Fluid: DFS-BGB PreJob 60kgal job

Total injected fluid volume (kiloliters):	261.085

Comprising of: (Kilograms, liters or kiloliters)		
Base Fluid type (e.g. water)	**Liters**	**% of total volume**
Makeup Water	231281	88.6%

Proppant type (e.g sand)	**Proppant Size**	**Kilograms**	**Liters**	**% of total volume**
Sand-Premium Brown	40/70	885	334	0.12784%
Sand-Premium Brown	20/40	68039	25675	9.83397%

Any wet chemical constitutes:	**Liters**	**% of total volume**
Water in Products	1744	0.668%
Guar gum	573	0.220%
Acetic acid	420	0.161%
Choline Chloride	389	0.149%
Monoethanolamine borate	253	0.0969%
Hydrochloric acid	202	0.0776%
Citric acid	75	0.0287%
Sodium hydroxide	53	0.0202%
Lactose	49	0.0186%
Hemicellulase enzyme	7.5	0.00289%
Tributyl tetradecyl phosphonium chloride	7.0	0.00268%
Ethylene glycol	5.6	0.00216%
Coffee Extract	4.1	0.00158%
Sodium persulfate	2.8	0.00105%
Ethanol	2.7	0.00102%
Hydrotreated light petroleum distillate	2.6	0.00099%
Fatty acids, tall-oil, ethoxylated	1.3	0.00051%
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	1.3	0.00051%
Butyl alcohol	1.3	0.00049%
Alcohols, C12-15, ethoxylated	1.2	0.00046%
Methanol	0.13	0.000051%
Diethanolamine	0.096	0.000037%
Sodium Sulfate	0.003	0.000001%
Glutaraldehyde	0.001	0.000000%

Appendix C11-Tables

Table C11-1a Water Quality Data for Theoretical Scenario in Initial Flowback
Halliburton Hybor (DFS-BCG-H) Hydraulic Fracturing Fluid System

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Initial Flowback Concentration = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)			
				Temporal Scenario (days)			
		DFS-BCG-H Fluid System	Half-Life (days)	0	30	150	300
Acetic acid	64-19-7	16000	15	2133	533	2.1	0.002
Alcohols, C12-15, ethoxylated	68131-39-5	979	15	131	33	0.13	0.0001
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	1070	15	143	36	0.14	0.0001
Butyl alcohol	71-36-3	1040	15	139	35	0.14	0.0001
Chlorous acid, sodium salt	7758-19-2	4390	15	585	146	0.6	0.001
Choline Chloride	67-48-1	15400	15	2053	513	2.0	0.002
Citric acid	77-92-9	514	15	69	17	0.07	0.0001
Coffee Extract	68916-18-7	28	150	4	3.3	1.9	0.9
Crystalline silica, quartz	14808-60-7	563	NA	75	75	75.1	75
Diethanolamine	111-42-2	8460	15	1128	282	1.1	0.001
Disodium octaborate tetrahydrate	12008-41-2	966	NA	129	129	128.8	129
Ethanol	64-17-5	2150	15	287	72	0.28	0.0003
Ethylene glycol	107-21-1	8290	15	1105	276	1.1	0.001
Fatty acids, tall-oil, ethoxylated	61791-00-2	1090	15	145	36	0.14	0.0001
Glutaraldehyde	111-30-8	1	15	0.11	0.03	0.0001	0.0000001
Hydrochloric acid	7647-01-0	1390	NA	185	185	185	185
Hydrotreated light petroleum distillate	64742-47-8	2090	150	279	243	139	69.67
Hydroxylpropyl guar	39421-75-5	22400	15	2987	747	2.92	0.00
Methanol	67-56-1	107	15	14	3.6	0.01	0.00001
Silica dioxide	112926-00-8	149	NA	20	20	20	20
Sodium bisulfite	7631-90-5	360	NA	48	48	48	48
Sodium carbonate	497-19-8	130	NA	17	17	17	17
Sodium Chloride	7647-14-5	15200	NA	2027	2027	2027	2027
Sodium hydroxide	1310-73-2	4820	NA	643	643	643	643
Sodium persulfate	7775-27-1	887	NA	118	118	118	118
Sodium polyacrylate	9003-04-7	1760	NA	235	235	235	235
Sodium Sulfate	7757-82-6	1	NA	0.11	0.11	0.11	0.11
Tributyl tetradecyl phosphonium chloride	81741-28-8	274	150	37	32	18	9
Triethanol amine	102-71-6	19000	15	2533	633	2.5	0.002
Ulexite	1319-33-1	8330	NA	1111	1111	1111	1111

CAS No. = chemical abstract service number
mg/L = milligrams per litre
% = percent
FB = flowback
NA = not applicable

Table C11-1b Water Quality Data for Theoretical Scenario in Initial Flowback
Halliburton Delta (DFS-BGB) Hydraulic Fracturing Fluid System

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Initial Flowback Concentration = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)			
				Temporal Scenario (days)			
		DFS-BGB Fluid System	Half-Life (days)	0	30	150	300
Acetic acid	64-19-7	16100	15	2147	537	2.1	0.002
Alcohols, C12-15, ethoxylated	68131-39-5	46	15	6.1	1.5	0.006	0.000006
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	51	15	6.8	1.7	0.007	0.000006
Butyl alcohol	71-36-3	49	15	6.5	1.6	0.006	0.000006
Cellulase enzyme	9012-54-8	289	15	39	9.6	0.04	0.00004
Choline Chloride	67-48-1	14900	15	1987	497	1.9	0.002
Citric acid	77-92-9	2870	15	383	96	0.37	0.0004
Coffee Extract	68916-18-7	158	150	21	18	10.5	5.267
Diethanolamine	111-42-2	4	15	0.49	0.12	0.0005	0.0000005
Ethanol	64-17-5	102	15	14	3.4	0.013	0.00001
Ethylene glycol	107-21-1	216	15	29	7	0.028	0.00003
Fatty acids, tall-oil, ethoxylated	61791-00-2	51	15	6.8	1.7	0.007	0.000006
Glutaraldehyde	111-30-8	0.0004	15	0.00005	0.00001	0.00000005	0.00000000005
Guar gum	9000-30-0	22000	15	2933	733	2.9	0.003
Hydrochloric acid	7647-01-0	7760	NA	1035	1035	1034.7	1035
Hydrotreated light petroleum distillate	64742-47-8	99	150	13	11.5	6.6	3.3
Lactose	63-42-3	1860	15	248	62	0.24	0.000
Methanol	67-56-1	5	15	0.68	0.17	0.0007	0.0000006
Monoethanolamine borate	26038-87-9	9690	15	1292	323	1.3	0.001
Sodium hydroxide	1310-73-2	2020	NA	269	269	269	269
Sodium persulfate	7775-27-1	105	NA	14	14	14	14
Sodium Sulfate	7757-82-6	0	NA	0.013	0.013	0.013	0.013
Tributyl tetradecyl phosphonium chloride	81741-28-8	268	150	36	31	18	8.9

CAS No. = chemical abstract service number
mg/L = milligrams per litre
% = percent
FB = flowback
NA = not applicable

Table C11-2a Comparison of Estimated Theoretical
Halliburton Hybor (DFS-BCG-H) Hydraulic Fracturing Fluid System
Concentrations to Human Health Drinking Water Guidelines

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Initial Flowback Concentration = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)				Drinking Water Guideline (mg/L)	Ratio of COPC Concentrations and Screening Criteria (Ratio greater than one = unacceptable potential risk)			
				Temporal Scenario (days)					Temporal Scenario (days)			
		DFS-BCG-H Fluid System	Half-Life (days)	0	30	150	300		0	30	150	300
Acetic acid	64-19-7	16000	15	2133	533	2.1	0.002	NA	NA	NA	NA	NA
Alcohols, C12-15, ethoxylated	68131-39-5	979	15	131	33	0.13	0.0001	1.8	7.3E+01	1.8E+01	7.1E-02	6.9E-05
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	1070	15	143	36	0.14	0.0001	NA	NA	NA	NA	NA
Butyl alcohol	71-36-3	1040	15	139	35	0.14	0.0001	1.4	9.9E+01	2.5E+01	9.7E-02	9.4E-05
Chlorous acid, sodium salt	7758-19-2	4390	15	585	146	0.6	0.001	0.014	4.2E+04	1.0E+04	4.1E+01	4.0E-02
Choline Chloride	67-48-1	15400	15	2053	513	2.0	0.002	175	1.2E+01	2.9E+00	1.1E-02	1.1E-05
Citric acid	77-92-9	514	15	69	17	0.07	0.0001	42	1.6E+00	4.1E-01	1.6E-03	1.6E-06
Coffee Extract	68916-18-7	28	150	4	3.3	1.9	0.9	100	3.7E-02	3.3E-02	1.9E-02	9.3E-03
Crystalline silica, quartz	14808-60-7	563	NA	75	75	75.1	75	NA	NA	NA	NA	NA
Diethanolamine	111-42-2	8460	15	1128	282	1.1	0.001	0.02	5.6E+04	1.4E+04	5.5E+01	5.4E-02
Disodium octaborate tetrahydrate	12008-41-2	966	NA	129	129	128.8	129	0.7	1.8E+02	1.8E+02	1.8E+02	1.8E+02
Ethanol	64-17-5	2150	15	287	72	0.28	0.0003	20	1.4E+01	3.6E+00	1.4E-02	1.4E-05
Ethylene glycol	107-21-1	8290	15	1105	276	1.1	0.001	53	2.1E+01	5.2E+00	2.0E-02	2.0E-05
Fatty acids, tall-oil, ethoxylated	61791-00-2	1090	15	145	36	0.14	0.0001	3.5	4.2E+01	1.0E+01	4.1E-02	4.0E-05
Glutaraldehyde	111-30-8	0.80	15	0.11	0.03	0.0001	0.0000001	0.14	7.6E-01	1.9E-01	7.4E-04	7.3E-07
Hydrochloric acid	7647-01-0	1390	NA	185	185	185	185	250	7.4E-01	7.4E-01	7.4E-01	7.4E-01
Hydrotreated light petroleum distillate	64742-47-8	2090	150	279	243	139	69.67	46	6.1E+00	5.3E+00	3.0E+00	1.5E+00
Hydroxylpropyl guar	39421-75-5	22400	15	2987	747	2.92	0.00	60	5.0E+01	1.2E+01	4.9E-02	4.7E-05
Methanol	67-56-1	107	15	14	3.6	0.01	0.00001	7	2.0E+00	5.1E-01	2.0E-03	1.9E-06
Silica dioxide	112926-00-8	149	NA	20	20	20	20	88	2.3E-01	2.3E-01	2.3E-01	2.3E-01
Sodium bisulfite	7631-90-5	360	NA	48	48	48	48	18	2.7E+00	2.7E+00	2.7E+00	2.7E+00
Sodium carbonate	497-19-8	130	NA	17	17	17	17	180	9.6E-02	9.6E-02	9.6E-02	9.6E-02
Sodium Chloride	7647-14-5	15200	NA	2027	2027	2027	2027	180	1.1E+01	1.1E+01	1.1E+01	1.1E+01
Sodium hydroxide	1310-73-2	4820	NA	643	643	643	643	180	3.6E+00	3.6E+00	3.6E+00	3.6E+00
Sodium persulfate	7775-27-1	887	NA	118	118	118	118	180	6.6E-01	6.6E-01	6.6E-01	6.6E-01
Sodium polyacrylate	9003-04-7	1760	NA	235	235	235	235	4	5.9E+01	5.9E+01	5.9E+01	5.9E+01
Sodium Sulfate	7757-82-6	0.80	NA	0.11	0.11	0.11	0.11	180	5.9E-04	5.9E-04	5.9E-04	5.9E-04
Tributyl tetradecyl phosphonium chloride	81741-28-8	274	150	37	32	18	9	0.03	1.2E+03	1.1E+03	6.1E+02	3.0E+02
Triethanol amine	102-71-6	19000	15	2533	633	2.5	0.002	3.5	7.2E+02	1.8E+02	7.1E-01	6.9E-04
Ulexite	1319-33-1	8330	NA	1111	1111	1111	1111	NA	NA	NA	NA	NA
								Cumulative Ratio	**1.0E+05**	**2.6E+04**	**9.7E+02**	**5.7E+02**

CAS No. = chemical abstract service number
mg/L = milligrams per litre
% = percent
FB = flowback
NA = not applicable

Table C11-2b Comparison of Estimated Theoretical Halliburton Delta (DFS-BGB) Hydraulic Fracturing Fluid System Concentrations to Human Health Drinking Water Guidelines

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Initial Flowback Concentration = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)				Drinking Water Guideline (mg/L)	Ratio of COPC Concentrations and Screening Criteria (Ratio greater than one = unacceptable potential risk)			
				Temporal Scenario (days)					Temporal Scenario (days)			
		DFS-BGB Fluid System	Half-Life (days)	0	30	150	300		0	30	150	300
Acetic acid	64-19-7	16100	15	2147	537	2.1	0.002	NA	NA	NA	NA	NA
Alcohols, C12-15, ethoxylated	68131-39-5	46	15	6.1	1.5	0.006	0.000006	1.8	3.4E+00	8.5E-01	3.3E-03	3.2E-06
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	51	15	6.8	1.7	0.007	0.000006	NA	NA	NA	NA	NA
Butyl alcohol	71-36-3	49	15	6.5	1.6	0.006	0.000006	1.4	4.7E+00	1.2E+00	4.6E-03	4.5E-06
Cellulase enzyme	9012-54-8	289	15	39	9.6	0.04	0.00004	3.5	1.1E+01	2.8E+00	1.1E-02	1.0E-05
Choline Chloride	67-48-1	14900	15	1987	497	1.9	0.002	175	1.1E+01	2.8E+00	1.1E-02	1.1E-05
Citric acid	77-92-9	2870	15	383	96	0.37	0.0004	42	9.1E+00	2.3E+00	8.9E-03	8.7E-06
Coffee Extract	68916-18-7	158	150	21	18	10.5	5.267	100	2.1E-01	1.8E-01	1.1E-01	5.3E-02
Diethanolamine	111-42-2	3.7	15	0.49	0.12	0.0005	0.0000005	0.02	2.5E+01	6.2E+00	2.4E-02	2.4E-05
Ethanol	64-17-5	102	15	14	3.4	0.013	0.00001	20	6.8E-01	1.7E-01	6.6E-04	6.5E-07
Ethylene glycol	107-21-1	216	15	29	7	0.028	0.00003	53	5.4E-01	1.4E-01	5.3E-04	5.2E-07
Fatty acids, tall-oil, ethoxylated	61791-00-2	51	15	6.8	1.7	0.007	0.000006	3.5	1.9E+00	4.9E-01	1.9E-03	1.9E-06
Glutaraldehyde	111-30-8	0.0004	15	0.00005	0.00001	0.00000005	0.00000000005	0.14	3.6E-04	9.1E-05	3.6E-07	3.5E-10
Guar gum	9000-30-0	22000	15	2933	733	2.9	0.003	46	6.4E+01	1.6E+01	6.2E-02	6.1E-05
Hydrochloric acid	7647-01-0	7760	NA	1035	1035	1034.7	1035	250	4.1E+00	4.1E+00	4.1E+00	4.1E+00
Hydrotreated light petroleum distillate	64742-47-8	99	150	13	11.5	6.6	3.3	46	2.9E-01	2.5E-01	1.4E-01	7.2E-02
Lactose	63-42-3	1860	15	248	62	0.24	0.000	3.5	7.1E+01	1.8E+01	6.9E-02	6.8E-05
Methanol	67-56-1	5.1	15	0.68	0.17	0.0007	0.0000006	7	9.7E-02	2.4E-02	9.5E-05	9.3E-08
Monoethanolamine borate	26038-87-9	9690	15	1292	323	1.3	0.001	3.5	3.7E+02	9.2E+01	3.6E-01	3.5E-04
Sodium hydroxide	1310-73-2	2020	NA	269	269	269	269	180	1.5E+00	1.5E+00	1.5E+00	1.5E+00
Sodium persulfate	7775-27-1	105	NA	14	14	14	14	180	7.8E-02	7.8E-02	7.8E-02	7.8E-02
Sodium Sulfate	7757-82-6	0.1	NA	0.013	0.013	0.013	0.013	180	7.4E-05	7.4E-05	7.4E-05	7.4E-05
Tributyl tetradecyl phosphonium chloride	81741-28-8	268	150	36	31	18	8.9	0.03	1.2E+03	1.0E+03	6.0E+02	3.0E+02
								Cumulative Ratio	**1.8E+03**	**1.2E+03**	**6.0E+02**	**3.0E+02**

CAS No. = chemical abstract service number
mg/L = milligrams per litre
% = percent
FB = flowback
NA = not applicable

Table C11-3a Comparison of Estimated Theoretical
Halliburton Hybor (DFS-BCG-H) Hydraulic Fracturing Fluid System
Concentrations to Aquatic Life Water Guidelines

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Initial Flowback Concentration = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)				PNEC Aquatic	Ratio of COPC Concentrations and Screening Criteria (Ratio greater than one = unacceptable potential risk)			
				Temporal Scenario (days)					Temporal Scenario (days)			
		DFS-BCG-H Fluid System	Half-Life (days)	0	30	150	300	(mg/l)	0	30	150	300
Acetic acid	64-19-7	16000	15	2133	533	2.1	0.002	3	7.1E+02	1.8E+02	6.9E-01	6.8E-04
Alcohols, C12-15, ethoxylated	68131-39-5	979	15	131	33	0.13	0.0001	0.14	9.3E+02	2.3E+02	9.1E-01	8.9E-04
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	1070	15	143	36	0.14	0.0001	0.007	2.0E+04	5.1E+03	2.0E+01	1.9E-02
Butyl alcohol	71-36-3	1040	15	139	35	0.14	0.0001	0.08	1.7E+03	4.3E+02	1.7E+00	1.7E-03
Chlorous acid, sodium salt	7758-19-2	4390	15	585	146	0.6	0.001	0.001	5.9E+05	1.5E+05	5.7E+02	5.6E-01
Choline Chloride	67-48-1	15400	15	2053	513	2.0	0.002	0.3	6.8E+03	1.7E+03	6.7E+00	6.5E-03
Citric acid	77-92-9	514	15	69	17	0.07	0.0001	0.44	1.6E+02	3.9E+01	1.5E-01	1.5E-04
Coffee Extract	68916-18-7	28	150	4	3.3	1.9	0.9	1	3.7E+00	3.3E+00	1.9E+00	9.3E-01
Crystalline silica, quartz	14808-60-7	563	NA	75	75	75.1	75	NA	NA	NA	NA	NA
Diethanolamine	111-42-2	8460	15	1128	282	1.1	0.001	0.02	5.6E+04	1.4E+04	5.5E+01	5.4E-02
Disodium octaborate tetrahydrate	12008-41-2	966	NA	129	129	128.8	129	0.37	3.5E+02	3.5E+02	3.5E+02	3.5E+02
Ethanol	64-17-5	2150	15	287	72	0.28	0.0003	1	2.9E+02	7.2E+01	2.8E-01	2.7E-04
Ethylene glycol	107-21-1	8290	15	1105	276	1.1	0.001	10	1.1E+02	2.8E+01	1.1E-01	1.1E-04
Fatty acids, tall-oil, ethoxylated	61791-00-2	1090	15	145	36	0.14	0.0001	0.12	1.2E+03	3.0E+02	1.2E+00	1.2E-03
Glutaraldehyde	111-30-8	0.8	15	0.11	0.03	0.0001	0.0000001	0.0025	4.3E+01	1.1E+01	4.2E-02	4.1E-05
Hydrochloric acid	7647-01-0	1390	NA	185	185	185	185	NA	NA	NA	NA	NA
Hydrotreated light petroleum distillate	64742-47-8	2090	150	279	243	139	69.67	0.001	2.8E+05	2.4E+05	1.4E+05	7.0E+04
Hydroxylpropyl guar	39421-75-5	22400	15	2987	747	2.92	0.00	NA	NA	NA	NA	NA
Methanol	67-56-1	107	15	14	3.6	0.01	0.00001	10	1.4E+00	3.6E-01	1.4E-03	1.4E-06
Silica dioxide	112926-00-8	149	NA	20	20	20	20	NA	NA	NA	NA	NA
Sodium bisulfite	7631-90-5	360	NA	48	48	48	48	0.8	6.0E+01	6.0E+01	6.0E+01	6.0E+01
Sodium carbonate	497-19-8	130	NA	17	17	17	17	NA	NA	NA	NA	NA
Sodium Chloride	7647-14-5	15200	NA	2027	2027	2027	2027	NA	NA	NA	NA	NA
Sodium hydroxide	1310-73-2	4820	NA	643	643	643	643	NA	NA	NA	NA	NA
Sodium persulfate	7775-27-1	887	NA	118	118	118	118	1.2	9.9E+01	9.9E+01	9.9E+01	9.9E+01
Sodium polyacrylate	9003-04-7	1760	NA	235	235	235	235	1.2	2.0E+02	2.0E+02	2.0E+02	2.0E+02
Sodium Sulfate	7757-82-6	1	NA	0.11	0.11	0.11	0.11	11	9.7E-03	9.7E-03	9.7E-03	9.7E-03
Tributyl tetradecyl phosphonium chloride	81741-28-8	274	150	37	32	18	9	0.000019	1.9E+06	1.7E+06	9.6E+05	4.8E+05
Triethanol amine	102-71-6	19000	15	2533	633	2.5	0.002	0.32	7.9E+03	2.0E+03	7.7E+00	7.5E-03
Ulexite	1319-33-1	8330	NA	1111	1111	1111	1111	NA	NA	NA	NA	NA
								Cumulative Ratio	**2.9E+06**	**2.1E+06**	**1.1E+06**	**5.5E+05**

CAS No. = chemical abstract service number
mg/L = milligrams per litre
% = percent
FB = flowback
NA = not applicable

Table C11-3b Comparison of Estimated Theoretical
Halliburton Delta (DFS-BGB) Hydraulic Fracturing Fluid System
Concentrations to Aquatic Life Water Guidelines

Constituent Name	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Initial Flowback Concentration = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)				PNEC Aquatic	Ratio of COPC Concentrations and Screening Criteria (Ratio greater than one = unacceptable potential risk)			
				Temporal Scenario (days)					Temporal Scenario (days)			
		DFS-BGB Fluid System	Half-Life (days)	0	30	150	300	(mg/l)	0	30	150	300
Acetic acid	64-19-7	16100	15	2147	537	2.1	0.002	3	7.2E+02	1.8E+02	7.0E-01	6.8E-04
Alcohols, C12-15, ethoxylated	68131-39-5	46	15	6.1	1.5	0.006	0.000006	0.14	4.4E+01	1.1E+01	4.3E-02	4.2E-05
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	51	15	6.8	1.7	0.007	0.000006	0.007	9.7E+02	2.4E+02	9.5E-01	9.3E-04
Butyl alcohol	71-36-3	49	15	6.5	1.6	0.006	0.000006	0.08	8.2E+01	2.0E+01	8.0E-02	7.8E-05
Cellulase enzyme	9012-54-8	289	15	39	9.6	0.04	0.00004	0.05	7.7E+02	1.9E+02	7.5E-01	7.3E-04
Choline Chloride	67-48-1	14900	15	1987	497	1.9	0.002	0.3	6.6E+03	1.7E+03	6.5E+00	6.3E-03
Citric acid	77-92-9	2870	15	383	96	0.37	0.0004	0.44	8.7E+02	2.2E+02	8.5E-01	8.3E-04
Coffee Extract	68916-18-7	158	150	21	18	10.5	5.267	1	2.1E+01	1.8E+01	1.1E+01	5.3E+00
Diethanolamine	111-42-2	3.700	15	0.49	0.12	0.0005	0.0000005	0.02	2.5E+01	6.2E+00	2.4E-02	2.4E-05
Ethanol	64-17-5	102	15	14	3.4	0.013	0.00001	1	1.4E+01	3.4E+00	1.3E-02	1.3E-05
Ethylene glycol	107-21-1	216	15	29	7	0.028	0.00003	10	2.9E+00	7.2E-01	2.8E-03	2.7E-06
Fatty acids, tall-oil, ethoxylated	61791-00-2	51	15	6.8	1.7	0.007	0.000006	0.12	5.7E+01	1.4E+01	5.5E-02	5.4E-05
Glutaraldehyde	111-30-8	0.000	15	0.00005	0.00001	0.00000005	0.00000000005	0.0025	2.0E-02	5.1E-03	2.0E-05	1.9E-08
Guar gum	9000-30-0	22000	15	2933	733	2.9	0.003	0.006	4.9E+05	1.2E+05	4.8E+02	4.7E-01
Hydrochloric acid	7647-01-0	7760	NA	1035	1035	1034.7	1035	NA	NA	NA	NA	NA
Hydrotreated light petroleum distillate	64742-47-8	99	150	13	11.5	6.6	3.3	0.001	1.3E+04	1.1E+04	6.6E+03	3.3E+03
Lactose	63-42-3	1860	15	248	62	0.24	0.000	93	2.7E+00	6.7E-01	2.6E-03	2.5E-06
Methanol	67-56-1	5.1	15	0.68	0.17	0.0007	0.0000006	10	6.8E-02	1.7E-02	6.6E-05	6.5E-08
Monoethanolamine borate	26038-87-9	9690	15	1292	323	1.3	0.001	0.026	5.0E+04	1.2E+04	4.9E+01	4.7E-02
Sodium hydroxide	1310-73-2	2020	NA	269	269	269	269	NA	NA	NA	NA	NA
Sodium persulfate	7775-27-1	105	NA	14	14	14	14	1.2	1.2E+01	1.2E+01	1.2E+01	1.2E+01
Sodium Sulfate	7757-82-6	0.1	NA	0.013	0.013	0.013	0.013	11	1.2E-03	1.2E-03	1.2E-03	1.2E-03
Tributyl tetradecyl phosphonium chloride	81741-28-8	268	150	36	31	18	8.9	0.000019	1.9E+06	1.6E+06	9.4E+05	4.7E+05
								Cumulative Ratio	**2.4E+06**	**1.8E+06**	**9.5E+05**	**4.7E+05**

CAS No. = chemical abstract service number
mg/L = milligrams per litre
% = percent
FB = flowback
NA = not applicable

APPENDIX D TIERED FRAMEWORK

APPENDIX D.1 SCREENING FRAMEWORK

Criteria	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
General PBT Assessment Step					
Combined PBT Assessment Category	Not a PBT	Not a PBT	Not a PBT	Identified as a PBT	N/A
Chemical Databases of Concern Assessment Step					
Listed as a chemical of concern on relevant databases	Not listed as a chemical of potential concern on the following databases: - European Union Substance of Very High Concern (EU SVHC). - US National Toxicology Program (US NTP) Report on Carcinogens or International Agency Research on Cancer (IARC) Monographs. - European Commission Endocrine Disruptors Strategy - list of Category 1 substances with endocrine disrupting capacity. - Chemical Substances Control Law of Japan (CSCL) Class I and II Specified Chemical.	Not listed as a chemical of potential concern on the following databases: - European Union Substance of Very High Concern (EU SVHC). - US National Toxicology Program (US NTP) Report on Carcinogens or International Agency Research on Cancer (IARC) Monographs. - European Commission Endocrine Disruptors Strategy - list of Category 1 substances with endocrine disrupting capacity. - Chemical Substances Control Law of Japan (CSCL) Class I and II Specified Chemical.	Listed as a chemical of concern on the following databases: - European Union Substance of Very High Concern (EU SVHC). - US National Toxicology Program (US NTP) Report on Carcinogens or International Agency Research on Cancer (IARC) Monographs. - European Commission Endocrine Disruptors Strategy - list of Category 1 substances with endocrine disrupting capacity. - Chemical Substances Control Law of Japan (CSCL) Class I and II Specified Chemical.	Listed as a chemical of concern on the following databases: - European Union Substance of Very High Concern (EU SVHC). - US National Toxicology Program (US NTP) Report on Carcinogens or International Agency Research on Cancer (IARC) Monographs. - European Commission Endocrine Disruptors Strategy - list of Category 1 substances with endocrine disrupting capacity. - Chemical Substances Control Law of Japan (CSCL) Class I and II Specified Chemical.	Chemicals noted in the Rotterdam Accord including: - octabromodiphenyl ether - pentabromodiphenyl ether - perfluorooctane sulfonic acid - perfluorooctane sulfonates - perfluorooctane sulfonamides - perfluorooctane sulfonyls - polybromated biphenyls - short chain chlorinated paraffins - tetramethyl lead - tributyl tin compounds Chemicals restricted in the State of Queensland including: - Benzene* - Toluene* - Ethylbenzene* - m-&p- and o-Xylene*
Identified as Polymer of Low Concern	Yes (no further assessment required)	No	No	No	N/A
Persistence Assessment Step					
Persistence	Not persistent as defined by: Air - Half life < 2 days Water - Half life < 60 days Soil and Sediment - Half life < 6 months	Not persistent as defined by: Air - Half life < 2 days Water - Half life < 60 days Soil and Sediment - Half life < 6 months	Persistent as defined by: Air - Half life ≥ 2 days Water - Half life ≥ 60 days Soil and Sediment - Half life ≥ 6 months	Persistent as defined by: Air - Half life ≥ 2 days Water - Half life ≥ 60 days Soil and Sediment - Half life ≥ 6 months	N/A
Other Persistence Concerns – Chemical identified as potentially accumulating in soil and posing risks	No potential concerns with accumulation in soil and impacts on flora and fauna	No potential concerns with accumulation in soil and impacts on flora and fauna	Potential concerns with accumulation in soils based on ANZECC assessment b (for example metals such as Cd)	Potential concerns with accumulation in soils based on ANZECC assessment b (for example metals such as Cd)	N/A
Bioaccumulative Assessment Step					
Bioaccumulative	Does not Bioaccumulate as defined by: - Aquatic - BAF < 2000 or BCF < 2000 or log KoW < 4.2 (if BAF and BCF are not available) -Terrestrial - log Koa < 6 and log Kow < 2 - Food Chain Bioaccumulation Potential - BMF < 1	Does not Bioaccumulate as defined by: - Aquatic - BAF < 2000 or BCF < 2000 or log KoW < 4.2 (if BAF and BCF are not available) -Terrestrial - log Koa < 6 and log Kow < 2 - Food Chain Bioaccumulation Potential - BMF < 1	Does not Bioaccumulate as defined by: - Aquatic - BAF < 2000 or BCF < 2000 or log KoW < 4.2 (if BAF and BCF are not available) -Terrestrial - log Koa < 6 and log Kow < 2 - Food Chain Bioaccumulation Potential - BMF < 1	Does Bioaccumulate as defined by: - Aquatic - BAF ≥ 2000 or BCF ≥ 2000 or log KoW ≥ 4.2 (if BAF and BCF are not available) -Terrestrial - log Koa ≥ 6 and log Kow ≥ 2 - Food Chain Bioaccumulation Potential - BMF > 1	N/A
Toxicity Assessment Step					
Toxicity	Acute Toxicity: Fish -96h LC 50 >10 mg/L Invertebrates - 48h EC50 > 10 mg/L Algae and other aquatic plants -72 or 96h ErC50 > 10 mg/L	Acute Toxicity: Fish -96h LC 50 >1 to < 10 mg/L Invertebrates - 48h EC50 >1 to < 10 mg/L Algae and other aquatic plants -72 or 96h ErC50 >1 to < 10 mg/L	Acute Toxicity: Fish -96h LC 50 ≤ 1 mg/L Invertebrates - 48h EC50 ≤ 1 mg/L Algae and other aquatic plants -72 or 96h ErC50 ≤ 1 mg/L	Acute Toxicity: Fish -96h LC 50 ≤ 1 mg/L Invertebrates - 48h EC50 ≤ 1 mg/L Algae and other aquatic plants -72 or 96h ErC50 ≤ 1 mg/L	N/A
	Chronic Toxicity: Fish NOEC or Ecx >1 mg/L Invertebrates NOEC or Ecx > 1 mg/L Algae and other aquatic plants -NOEC or Ecx > 1 mg/L	Chronic Toxicity: Fish NOEC or Ecx >0.1 to < 1 mg/L Invertebrates NOEC or Ecx >0.1 to < 1 mg/L Algae and other aquatic plants - NOEC or Ecx >0.1 to < 1 mg/L	Chronic Toxicity: Fish NOEC or Ecx ≤ 0.1 mg/L Invertebrates NOEC or Ecx ≤ 0.1 mg/L Algae and other aquatic plants - NOEC or Ecx ≤ 0.1 mg/L	Chronic Toxicity: Fish NOEC or Ecx ≤ 0.1 mg/L Invertebrates NOEC or Ecx ≤ 0.1 mg/L Algae and other aquatic plants -NOEC or Ecx ≤ 0.1 mg/L	N/A
Risk Assessment Actions Required					
Risk Assessment Action Required	Hazard Assessment only. Do screening only and note it meets the above criteria. Develop toxicological profile	Hazard Assessment and Qualitative Assessment Only. Do screening only and note it meets the above criteria. Develop toxicological profile and PNECs for water and soil and provide qualitative discussion of risk	Quantitative Risk Assessment: Complete PBT, qualitative and quantitative assessment of risk. Quantitative assessment of risk will consider only Tier 3 chemicals in end use determination.	Quantitative Risk Assessment and Full Life Cycle Assessment Need to demonstrate that the chemical cannot be substituted. If r etained will need to conduct a full life cycle quantitative risk assessment including food chain risk assessment.	Banned from Use on Project. Would require specific assessment process and require extensive consultation prior to assessment.

** Above levels prescribed in the Queensland Environment Protection Regulation 1999*

APPENDIX D.2 CHEMICALS EVALUATED IN TIERED ASSESSMENT APPROACH

Table 1
Summary of Screening Assessment - Hydraulic Stimulation Fluid Systems (Post-2020)

Chemical	CAS No.	Tier[1]	Halliburton Fluid System Assessed					
			DFS-BGL	DFS-BGL Fluid System 1	DFS-BGL Fluid System 2A	DFS-BGL Fluid System 2B	DFS-BGL Fluid System 3	DFS-BCG Fluid System 4
Acetic acid	64-19-7	1	❍	❍	❍	❍	❍	❍
Alcohols, C12-15, ethoxylated	68131-39-5	1						❍
Alcohols, C12-16, ethoxylated	68551-12-2	2						❍
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	2						❍
Amine oxides, cocoalkyldimethyl	61788-90-7	2						❍
Benzaldehyde	100-52-7	2						❍
Butyl alcohol	71-36-3	1						❍
Chlorous acid, sodium salt	7758-19-2	2						❍
Choline Chloride	67-48-1	1	❍	❍			❍	❍
Cinnamaldehyde	104-55-2	1						❍
Citric acid	77-92-9	1		❍	❍	❍	❍	❍
Cocobetaine	61789-40-0	2				❍		
Coffee Extract	68916-18-7	1		❍	❍	❍	❍	
Crystalline silica, quartz	14808-60-7	1						❍
Diethanolamine	111-42-2	1						❍
Diethylene glycol	111-46-6	1						❍
Disodium octaborate tetrahydrate	12008-41-2	1						❍
Ethanol	64-17-5	1						❍
Ethylene glycol	107-21-1	1	❍	❍			❍	❍
Fatty acids, tall-oil, ethoxylated	61791-00-2	1						❍
Glutaraldehyde	111-30-8	3						❍
Glycerine	56-81-5	1				❍	❍	
Guar gum	9000-30-0	1	❍	❍	❍	❍	❍	
Hemicellulase enzyme	9012-54-8	1	❍	❍	❍	❍	❍	
Hydrochloric acid	7647-01-0	3		❍	❍	❍	❍	❍
Hydrotreated light petroleum distillate	64742-47-8	2						❍
Hydroxylpropyl guar	39421-75-5	1						❍
Lactose	63-42-3	1	❍	❍	❍	❍	❍	
Methanol	67-56-1	1					❍	❍
Methyl Acetate	79-20-9	1					❍	
Monoethanolamine borate	26038-87-9	1	❍	❍	❍	❍	❍	
Nitrogen	7727-37-9	1				❍		
Poly(vinyl acetate)-poly(vinyl alcohol) polymer	25213-24-5	1					❍	
Potassium chloride	7447-40-7	1			❍	❍		
Silica dioxide	112926-00-8	1						❍
Sodium Acetate	127-09-3	1					❍	
Sodium carbonate	497-19-8	1						❍
Sodium Chloride	7647-14-5	1				❍		❍
Sodium hydroxide	1310-73-2	1	❍	❍	❍	❍	❍	❍
Sodium iodide	7681-82-5	1						❍
Sodium persulfate	7775-27-1	1	❍	❍	❍	❍	❍	❍
Sodium Sulfate	7757-82-6	1	❍	❍	❍	❍	❍	❍
Sodium Sulfite	7757-83-7	1						❍
Sodium thiosulfate	7772-98-7	1						❍
Tributyl tetradecyl phosphonium chloride	81741-28-8	3	❍	❍	❍	❍	❍	❍
Triethanol amine	102-71-6	1						❍
Ulexite	1319-33-1	1						❍

CAS No. = chemical abstract service number

1 = Categorisation as defined in assessment framework.
Tier 1 - Hazard Assessment Only
Tier 2 - Hazard Assessment and Qualitative Assessment Only. Develop toxicological profile and PNECs for water and soil and provide qualitative discussion of risk.
Tier 3 - Quantitative Risk Assessment: Complete PBT, qualitative and quantitative assessment of risk.

Table 2

Example Screening Assessment - Hydraulic Stimulation Fluid Systems (Pre-2020)

Halliburton Hybor and Delta Hyraulic Fracturing Fluid Systems (DFS-BCG)[1]		
Chemical Name	**CAS No.**	**Tier[2]**
Acetic acid	64-19-7	1
Alcohols, C12-15, ethoxylated	68131-39-5	1
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	2
Butyl alcohol	71-36-3	1
Cellulase enzyme	9012-54-8	1
Choline Chloride	67-48-1	1
Citric acid	77-92-9	1
Coffee Extract	68916-18-7	1
Diethanolamine	111-42-2	1
Ethanol	64-17-5	1
Ethylene glycol	107-21-1	1
Fatty acids, tall-oil, ethoxylated	61791-00-2	1
Glutaraldehyde	111-30-8	3
Guar gum	9000-30-0	1
Hydrotreated light petroleum distillate	64742-47-8	2
Hydrochloric acid	7647-01-0	3
Lactose	63-42-3	1
Methanol	67-56-1	1
Monoethanolamine borate	26038-87-9	1
Sodium hydroxide	1310-73-2	1
Sodium persulfate	7775-27-1	1
Sodium Sulfate	7757-82-6	1
Tributyl tetradecyl phosphonium chloride	81741-28-8	3

CAS No. = chemical abstract service number

1 = Halliburton fluid system assessed in Appendix C11.

2 = Categorisation as defined in assessment framework.

Tier 1 - Hazard Assessment Only

Tier 2 - Hazard Assessment and Qualitative Assessment Only. Develop toxicological profile and PNECs for water and soil and provide qualitative discussion of risk.

Tier 3 - Quantitative Risk Assessment: Complete PBT, qualitative and quantitative assessment of risk.

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APPENDIX D.3 MASS BALANCE EVALUATION

Table 1
Estimated Theoretical Concentrations
Halliburton DFS-BGL Fluid System

Chemical	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)[1]	Fate and Transport Properties	Estimated Initial Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Initial Flowback Concentration = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)			
				Temporal Scenario (days)			
		DFS-BGL Fluid System	Half-Life (days)	0	30	150	300
Acetic acid	64-19-7	4.25E+01	15	5.67E+00	1.42E+00	5.54E-03	5.41E-06
Choline Chloride	67-48-1	1.89E+02	15	2.52E+01	6.30E+00	2.46E-02	2.40E-05
Guar gum	9000-30-0	1.86E+02	15	2.49E+01	6.21E+00	2.43E-02	2.37E-05
Hemicellulase enzyme	9012-54-8	9.83E-01	15	1.31E-01	3.28E-02	1.28E-04	1.25E-07
Lactose	63-42-3	6.32E+00	15	8.43E-01	2.11E-01	8.23E-04	8.04E-07
Monoethanolamine borate	26038-87-9	5.59E+01	15	7.45E+00	1.86E+00	7.27E-03	7.10E-06
Sodium hydroxide	1310-73-2	3.08E+01	NA	3.08E+01	3.08E+01	3.08E+01	3.08E+01
Sodium persulfate	7775-27-1	1.75E+01	NA	1.75E+01	1.75E+01	1.75E+01	1.75E+01
Sodium Sulfate	7757-82-6	1.62E-02	NA	1.62E-02	1.62E-02	1.62E-02	1.62E-02
Tributyl tetradecyl phosphonium chloride	81741-28-8	3.18E+00	150	4.24E-01	3.69E-01	2.12E-01	1.06E-01

CAS No. = chemical abstract service number
mg/L = milligrams per litre
% = percent
FB = flowback
NA = not applicable

1 - Maximum concentration in vendor disclosure forms

Table 2
Estimated Theoretical Concentrations
Halliburton DFS-BGL Fluid System 1

Chemical	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Initial Flowback Concentration = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)			
				Temporal Scenario (days)			
		DFS-BGL Fluid System 1	Half-Life (days)	0	30	150	300
Acetic acid	64-19-7	2.16E+01	15	2.88E+00	7.21E-01	2.82E-03	2.75E-06
Choline Chloride	67-48-1	1.52E+02	15	2.03E+01	5.07E+00	1.98E-02	1.94E-05
Citric acid	77-92-9	4.12E+00	15	5.49E-01	1.37E-01	5.36E-04	5.24E-07
Coffee Extract	68916-18-7	1.87E+00	150	2.49E-01	2.17E-01	1.25E-01	6.23E-02
Ethylene glycol	107-21-1	2.21E+00	15	2.94E-01	7.35E-02	2.87E-04	2.81E-07
Guar gum	9000-30-0	1.87E+02	15	2.50E+01	6.25E+00	2.44E-02	2.38E-05
Hemicellulase enzyme	9012-54-8	4.94E-01	15	6.59E-02	1.65E-02	6.43E-05	6.28E-08
Hydrochloric acid	7647-01-0	1.22E+02	NA	1.22E+02	1.22E+02	1.22E+02	1.22E+02
Lactose	63-42-3	3.18E+00	15	4.23E-01	1.06E-01	4.13E-04	4.04E-07
Monoethanolamine borate	26038-87-9	4.97E+01	15	6.63E+00	1.66E+00	6.47E-03	6.32E-06
Sodium hydroxide	1310-73-2	9.45E+00	NA	9.45E+00	9.45E+00	9.45E+00	9.45E+00
Sodium persulfate	7775-27-1	2.20E+00	NA	2.20E+00	2.20E+00	2.20E+00	2.20E+00
Sodium Sulfate	7757-82-6	2.04E-03	NA	2.04E-03	2.04E-03	2.04E-03	2.04E-03
Tributyl tetradecyl phosphonium chloride	81741-28-8	2.72E+00	150	3.63E-01	3.16E-01	1.81E-01	9.07E-02

CAS No. = chemical abstract service number
mg/L = milligrams per litre
% = percent
FB = flowback
NA = not applicable

Table 3
Estimated Theoretical Concentrations
Halliburton DFS-BGL Fluid System 2A

Chemical	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Initial Flowback Concentration = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)			
				Temporal Scenario (days)			
		DFS-BGL Fluid System 2A	Half-Life (days)	0	30	150	300
Acetic acid	64-19-7	2.17E+01	15	2.90E+00	7.24E-01	2.83E-03	2.76E-06
Citric acid	77-92-9	3.32E+00	15	4.42E-01	1.11E-01	4.32E-04	4.22E-07
Coffee Extract	68916-18-7	1.51E+00	150	2.01E-01	1.75E-01	1.00E-01	5.02E-02
Guar gum	9000-30-0	1.89E+02	15	2.52E+01	6.29E+00	2.46E-02	2.40E-05
Hemicellulase enzyme	9012-54-8	4.97E-01	15	6.63E-02	1.66E-02	6.48E-05	6.32E-08
Hydrochloric acid	7647-01-0	9.86E+01	NA	9.86E+01	9.86E+01	9.86E+01	9.86E+01
Lactose	63-42-3	3.20E+00	15	4.26E-01	1.07E-01	4.16E-04	4.07E-07
Monoethanolamine borate	26038-87-9	5.00E+01	15	6.67E+00	1.67E+00	6.52E-03	6.36E-06
Potassium chloride	7447-40-7	1.89E+03	NA	1.89E+03	1.89E+03	1.89E+03	1.89E+03
Sodium hydroxide	1310-73-2	9.52E+00	NA	9.52E+00	9.52E+00	9.52E+00	9.52E+00
Sodium persulfate	7775-27-1	2.21E+00	NA	2.21E+00	2.21E+00	2.21E+00	2.21E+00
Sodium Sulfate	7757-82-6	2.05E-03	NA	2.05E-03	2.05E-03	2.05E-03	2.05E-03
Tributyl tetradecyl phosphonium chloride	81741-28-8	2.74E+00	150	3.65E-01	3.18E-01	1.83E-01	9.13E-02

CAS No. = chemical abstract service number
mg/L = milligrams per litre
% = percent
FB = flowback
NA = not applicable

Table 4
Estimated Theoretical Concentrations
Halliburton DFS-BGL Fluid System 2B

Chemical	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Initial Flowback Concentration = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)			
				Temporal Scenario (days)			
		DFS-BGL Fluid System 2B	Half-Life (days)	0	30	150	300
Acetic acid	64-19-7	1.90E+01	15	2.53E+00	6.33E-01	2.47E-03	2.41E-06
Citric acid	77-92-9	5.74E+00	15	7.65E-01	1.91E-01	7.47E-04	7.30E-07
Cocobetaine	61789-40-0	9.39E+01	15	1.25E+01	3.13E+00	1.22E-02	1.19E-05
Coffee Extract	68916-18-7	2.61E+00	150	3.47E-01	3.03E-01	1.74E-01	8.69E-02
Glycerine	56-81-5	1.96E+01	15	2.61E+00	6.52E-01	2.55E-03	2.49E-06
Guar gum	9000-30-0	1.63E+02	15	2.18E+01	5.44E+00	2.13E-02	2.08E-05
Hemicellulase enzyme	9012-54-8	4.30E-01	15	5.74E-02	1.43E-02	5.60E-05	5.47E-08
Hydrochloric acid	7647-01-0	1.71E+02	NA	1.71E+02	1.71E+02	1.71E+02	1.71E+02
Lactose	63-42-3	2.77E+00	15	3.69E-01	9.22E-02	3.60E-04	3.52E-07
Monoethanolamine borate	26038-87-9	4.33E+01	15	5.77E+00	1.44E+00	5.64E-03	5.50E-06
Nitrogen	7727-37-9	7.52E+03	NA	7.52E+03	7.52E+03	7.52E+03	7.52E+03
Potassium chloride	7447-40-7	1.64E+03	NA	1.64E+03	1.64E+03	1.64E+03	1.64E+03
Sodium Chloride	7647-14-5	4.54E+01	NA	4.54E+01	4.54E+01	4.54E+01	4.54E+01
Sodium hydroxide	1310-73-2	8.23E+00	NA	8.23E+00	8.23E+00	8.23E+00	8.23E+00
Sodium persulfate	7775-27-1	1.91E+00	NA	1.91E+00	1.91E+00	1.91E+00	1.91E+00
Sodium Sulfate	7757-82-6	1.77E-03	NA	1.77E-03	1.77E-03	1.77E-03	1.77E-03
Tributyl tetradecyl phosphonium chloride	81741-28-8	2.37E+00	150	3.16E-01	2.75E-01	1.58E-01	7.90E-02

CAS No. = chemical abstract service number
mg/L = milligrams per litre
% = percent
FB = flowback
NA = not applicable

Table 5
Estimated Theoretical Concentrations
Halliburton DFS-BGL Fluid System 3

Chemical	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Initial Flowback Concentration = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)			
				Temporal Scenario (days)			
		DFS-BGL Fluid System 3	Half-Life (days)	0	30	150	300
Acetic acid	64-19-7	2.21E+01	15	2.94E+00	7.36E-01	2.88E-03	2.81E-06
Choline Chloride	67-48-1	1.56E+02	15	2.08E+01	5.19E+00	2.03E-02	1.98E-05
Citric acid	77-92-9	3.37E+00	15	4.50E-01	1.12E-01	4.39E-04	4.29E-07
Coffee Extract	68916-18-7	1.53E+00	150	2.04E-01	1.78E-01	1.02E-01	5.10E-02
Ethylene glycol	107-21-1	2.26E+00	15	3.01E-01	7.52E-02	2.94E-04	2.87E-07
Glycerine	56-81-5	3.15E+00	15	4.20E-01	1.05E-01	4.10E-04	4.00E-07
Guar gum	9000-30-0	1.92E+02	15	2.56E+01	6.39E+00	2.50E-02	2.44E-05
Hemicellulase enzyme	9012-54-8	5.05E-01	15	6.74E-02	1.68E-02	6.58E-05	6.43E-08
Hydrochloric acid	7647-01-0	1.00E+02	NA	1.00E+02	1.00E+02	1.00E+02	1.00E+02
Lactose	63-42-3	3.25E+00	15	4.33E-01	1.08E-01	4.23E-04	4.13E-07
Methanol	67-56-1	9.27E-02	15	1.24E-02	3.09E-03	1.21E-05	1.18E-08
Methyl Acetate	79-20-9	7.85E-02	15	1.05E-02	2.62E-03	1.02E-05	9.99E-09
Monoethanolamine borate	26038-87-9	5.09E+01	15	6.78E+00	1.70E+00	6.62E-03	6.47E-06
Poly(vinyl acetate)-poly(vinyl alcohol) polymer	25213-24-5	3.89E+01	NA	3.89E+01	3.89E+01	3.89E+01	3.89E+01
Sodium Acetate	127-09-3	8.77E-01	NA	8.77E-01	8.77E-01	8.77E-01	8.77E-01
Sodium hydroxide	1310-73-2	9.67E+00	NA	9.67E+00	9.67E+00	9.67E+00	9.67E+00
Sodium persulfate	7775-27-1	2.25E+00	NA	2.25E+00	2.25E+00	2.25E+00	2.25E+00
Sodium Sulfate	7757-82-6	2.08E-03	NA	2.08E-03	2.08E-03	2.08E-03	2.08E-03
Tributyl tetradecyl phosphonium chloride	81741-28-8	2.78E+00	150	3.71E-01	3.23E-01	1.86E-01	9.28E-02

CAS No. = chemical abstract service number
mg/L = milligrams per litre
% = percent
FB = flowback
NA = not applicable

Table 6
Estimated Theoretical Concentrations
Halliburton DFS-BCG Fluid System 4

Chemical	CAS No.	Estimated concentration in pre-injection fluid systems (mg/L)	Fate and Transport Properties	Estimated Initial Concentration in flowback (150% of injected fluid volume) per coal seam per 20% of mass returned calculated using equation: Initial Flowback Concentration = FBconcentration (mg/L)/ FB dilution 150% x percent mass returned (mg/L) x Biodegradation (half life)			
				Temporal Scenario (days)			
		DFS-BCG Fluid System 4	Half-Life (days)	0	30	150	300
Acetic acid	64-19-7	2.17E+01	15	2.90E+00	7.25E-01	2.83E-03	2.77E-06
Alcohols, C12-15, ethoxylated	68131-39-5	9.77E+00	15	1.30E+00	3.26E-01	1.27E-03	1.24E-06
Alcohols, C12-16, ethoxylated	68551-12-2	1.51E-01	15	2.02E-02	5.04E-03	1.97E-05	1.92E-08
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	1.07E+01	15	1.43E+00	3.57E-01	1.40E-03	1.36E-06
Amine oxides, cocoalkyldimethyl	61788-90-7	7.88E-01	15	1.05E-01	2.63E-02	1.03E-04	1.00E-07
Benzaldehyde	100-52-7	3.56E-01	15	4.75E-02	1.19E-02	4.64E-05	4.53E-08
Butyl alcohol	71-36-3	1.04E+01	15	1.39E+00	3.47E-01	1.36E-03	1.33E-06
Chlorous acid, sodium salt	7758-19-2	2.21E+01	15	2.94E+00	7.36E-01	2.87E-03	2.81E-06
Choline Chloride	67-48-1	1.54E+02	15	2.06E+01	5.14E+00	2.01E-02	1.96E-05
Cinnamaldehyde	104-55-2	2.54E+00	15	3.39E-01	8.47E-02	3.31E-04	3.23E-07
Citric acid	77-92-9	1.31E+00	15	1.75E-01	4.38E-02	1.71E-04	1.67E-07
Crystalline silica, quartz	14808-60-7	2.52E+00	NA	2.52E+00	2.52E+00	2.52E+00	2.52E+00
Diethanolamine	111-42-2	2.32E+01	15	3.10E+00	7.75E-01	3.03E-03	2.96E-06
Diethylene glycol	111-46-6	2.31E+00	15	3.09E-01	7.72E-02	3.01E-04	2.94E-07
Disodium octaborate tetrahydrate	12008-41-2	3.24E+00	NA	3.24E+00	3.24E+00	3.24E+00	3.24E+00
Ethanol	64-17-5	2.15E+01	15	2.86E+00	7.16E-01	2.80E-03	2.73E-06
Ethylene glycol	107-21-1	3.83E+01	15	5.10E+00	1.28E+00	4.98E-03	4.87E-06
Fatty acids, tall-oil, ethoxylated	61791-00-2	1.09E+01	15	1.45E+00	3.63E-01	1.42E-03	1.38E-06
Glutaraldehyde	111-30-8	7.96E-03	15	1.06E-03	2.65E-04	1.04E-06	1.01E-09
Hydrochloric acid	7647-01-0	3.90E+01	NA	3.90E+01	3.90E+01	3.90E+01	3.90E+01
Hydrotreated light petroleum distillate	64742-47-8	2.08E+01	150	2.78E+00	2.42E+00	1.39E+00	6.95E-01
Hydroxylpropyl guar	39421-75-5	2.25E+02	15	3.00E+01	7.50E+00	2.93E-02	2.86E-05
Methanol	67-56-1	2.01E+00	15	2.67E-01	6.69E-02	2.61E-04	2.55E-07
Silica dioxide	112926-00-8	1.50E+00	NA	1.50E+00	1.50E+00	1.50E+00	1.50E+00
Sodium carbonate	497-19-8	1.31E+00	NA	1.31E+00	1.31E+00	1.31E+00	1.31E+00
Sodium Chloride	7647-14-5	7.63E+01	NA	7.63E+01	7.63E+01	7.63E+01	7.63E+01
Sodium hydroxide	1310-73-2	9.58E+00	NA	9.58E+00	9.58E+00	9.58E+00	9.58E+00
Sodium iodide	7681-82-5	4.04E-02	NA	4.04E-02	4.04E-02	4.04E-02	4.04E-02
Sodium persulfate	7775-27-1	2.23E+00	NA	2.23E+00	2.23E+00	2.23E+00	2.23E+00
Sodium Sulfate	7757-82-6	2.67E+00	NA	2.67E+00	2.67E+00	2.67E+00	2.67E+00
Sodium Sulfite	7757-83-7	1.53E+00	NA	1.53E+00	1.53E+00	1.53E+00	1.53E+00
Sodium thiosulfate	7772-98-7	7.21E+01	NA	7.21E+01	7.21E+01	7.21E+01	7.21E+01
Tributyl tetradecyl phosphonium chloride	81741-28-8	2.76E+00	150	3.68E-01	3.20E-01	1.84E-01	9.20E-02
Triethanol amine	102-71-6	5.10E+01	15	6.80E+00	1.70E+00	6.64E-03	6.49E-06
Ulexite	1319-33-1	3.72E+01	NA	3.72E+01	3.72E+01	3.72E+01	3.72E+01

CAS No. = chemical abstract service number
mg/L = milligrams per litre
% = percent
FB = flowback
NA = not applicable

APPENDIX E GOLDER SUPPORTING CHEMICAL-SPECIFIC PROPERTY INFORMATION

Santos

APPENDIX E.1 SCHLUMBERGER GUAR BASED SYSTEMS

Name	2-Methyl-4-Isothiazolin-3-one
Synonyms	2-Methyl-3(2H)-isothiazolone
CAS number	2682-20-4
Molecular formula	$C_4 H_5 N_1 O_1 S_1$
Product name	M275

Physical Properties	Value	Reference
Phase/state	NA	
Molecular weight	115.15 g/mol	EPISUITE
Melting point	47.48 ^{o}C	EPISUITE
Boiling point	237.75 ^{o}C	EPISUITE
Density/ specific gravity	NA	
Vapour pressure	0.031 mm Hg at 25^{o}C	EPISUITE
Solubility	5.367 x 10^{5} mg/L	EPISUITE
Henrys law constant	4.96 x 10^{-8} atm m^3/mole (BOND Method)	EPISUITE
Organic carbon partition coefficient (koc)	12.08 (MCI Method)	EPISUITE
Log organic carbon partition coefficient (log Koc)	1.082 (MCI Method)	EPISUITE
Log octanol-water partition coefficient (log Kow)	-0.83	EPISUITE

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation	NA	
Aerobic BOD	NA	
Anaerobic BOD	NA	
Biowin7 (Anerobic linear model)	Biodegrades fast	EPISUITE
Fugacity		
Air %	0.519	EPISUITE
Water %	34.1	EPISUITE
Soil %	65.3	EPISUITE
Sediment %	0.0797	EPISUITE
Bioconcentration factor (BCF)	3.162 L/kg wet wt	EPISUITE
Biotransformation half-life	0.02263 days	EPISUITE

Notes: 1 EPI Suite™ v4.0, United States Environmental Protection Agency.

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	Not listed on IARC database.
ANZECC	2000	Stock water	NA	

Aquatic Ecotoxicological Data

Acute toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Oncorhynchus mykiss	Rainbow Trout	LC50	MOR	MORT	4	70	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	2	180	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LC50	MOR	MORT	4	190	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	4	300	ECOTOX

Media Type : Freshwater for acute toxicity data

MOR/ MORT: Mortality

ITX: Intoxication

IMBL: Immobile

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.
ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	5-chloro-2-methyl-4-isothiazolin-3-one
Synonyms	Methylchloroisothiazolinone
CAS number	26172-55-4
Molecular formula	C_4H_4ClNOS
Product name	M275

Physical Properties	Value	Reference
Phase/state	NA	
Molecular weight	149.60 g/mol	EPI SUITE
Melting point	50-55^{o}C	IUCLID, 2000
Boiling point	106.5 ^{o}C	IUCLID, 2000
Density/ specific gravity	1.2556 g/m^3 at 20 ^{o}C	IUCLID, 2000
Vapour pressure	20.8 hPa at 20^{o}C	IUCLID, 2000
Solubility	>5000 mg/l at 20 ^{o}C	IUCLID, 2000
	1.487 x 10^5 mg/L at 25^{o}C	EPI SUITE
Henrys law constant	3.57 x 10^{-8} atm-m^3 /mol at 25^{o}C (Bond method)	EPI SUITE
Organic carbon partition coefficient (Koc)	19.38 (MCI Method)	EPI SUITE
Log organic carbon partition coefficient (log Koc)	1.287 (MCI Method)	EPI SUITE
Log octanol-water partition coefficient (log Kow)	-0.34	EPI SUITE

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation	NA	
Aerobic BOD	97% after 48 hours	IUCLID, 2000
Anaerobic BOD	NA	
Biowin7 (Anerobic linear model)	Biodegrades fast	EPI SUITE
Fugacity		
Air %	0.251	EPI SUITE
Water %	32.4	EPI SUITE
Soil %	67.2	EPI SUITE
Sediment %	0.0918	EPI SUITE
Bioconcentration factor	3.162 L/kg wet wt	EPISUITE
Biotransformation half-life	0.04781 days	EPI SUITE

Notes: 1 EPI Suite™ v4.0, United States Environmental Protection Agency.

2. Schluberger. Material Safety Data Sheet M275. Issue Date:16 July 2003.

3. International Uniform Chemical Information database, 2000 (IUCLID). Eurpoean Chemical Substances Information System Accessed online 14 April 2011 http://ecb.jrc.ec.europa.eu/iuclid-datasheet/26172554.pdf.

NA - not available

Chemical Information Sheet updated June 2011.

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Ecotoxicological Data

Acute toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Oncorhynchus mykiss	Rainbow Trout	LC50	MOR	MORT	14	80	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	2	180	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LC50	MOR	MORT	4	190	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LC50	MOR	MORT	4	253	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	4	300	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	2	840	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	4	960	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	2	1300	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LC50	MOR	MORT	4	1520	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	4	2130	ECOTOX
Ceriodaphnia dubia	Water Flea	EC50	ITX	IMBL	2	13000	ECOTOX
Chronic toxicity data							
Pseudokirchneriella subcapitata	Green Algae	EC50	POP	ABND	5	22	ECOTOX
Pseudokirchneriella subcapitata	Green Algae	EC50	POP	ABND	4	62	ECOTOX
Pseudokirchneriella subcapitata	Green Algae	EC50	POP	ABND	3	130	ECOTOX
Anabaena flosaquae	Blue-Green Algae	EC50	POP	ABND	5	290	ECOTOX
Lemna gibba	Inflated Duckweed	EC50	POP	ABND	14	4500	ECOTOX

Media Type : Freshwater

ITX : Intoxication

IMBL: Immobile

MOR / MORT: Mortality

POP: Population

ABND : Abundance

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.
ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Acetic Acid
Synonyms	Glacial Acetic Acid, ethanoic acid
CAS number	64-19-7
Molecular formula	C2-H4-O2
Product name	Acetic Acid 60%

Physical Properties	Value	Reference
Phase/state	liquid	MSDS, 2010
Molecular weight	60.05 g/mol	HSDB, 2011
Melting point	16.6 ^{o}C	HSDB, 2011
Boiling point	117.9 ^{o}C	HSDB, 2011
Density/ specific gravity	1.05 at 20^{o}C	HSDB, 2011
Vapour pressure	15.7 mm Hg at 25^{o}C /Extrapolated	HSDB, 2011
Solubility	Miscible with water 4.759 x 10^{5} at 25 ^{o}C	HSDB, 2011 EPISUITE
Henrys law constant	1X10^{-7} atm-cu m/mol at 25^{o}C	HSDB, 2011
Log organic carbon partition coefficient (log Koc)	Koc = 1, Log Koc = 0.00 (MCI method)	EPISUITE
Log octanol-water partition coefficient (log Kow)	-0.17 L/kg	HSDB, 2011
pH	1.38	MSDS, 2010

Persistence/ Bioaccumulation	Value	Reference
Biowin7 (Anaerobic Model Prediction)	Biodegrades Fast	EPISUITE
Ready Biodegradability Prediction	Yes	EPISUITE
Fugacity		
Air %	2.66	EPISUITE
Water %	35	EPISUITE
Soil %	62.3	EPISUITE
Sediment %	0.0619	EPISUITE
Bioconcentration factor (BCF)	3.2 (fish) No potential for biological accumulation or food chain contamination	HSDB, 2011 Environment Canada, 1981
Biotransformation half-life	0.0762 days	EPISUITE

Notes: 1 EPI Suite™ v4.0, United States Environmental Protection Agency.

2 Halliburton Material Safety Data Sheet Acetic Acid 60%. Issue Date: 05 January 2010

3. Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line 29 March 2011

4. Environment Canada; Tech Info for Problem Spills: Acetic Acid (Draft) p.1 (1981).

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2008	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Branchiura sowerbyi	Oligochaete	LC50	MOR	MORT	4	14900	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	1	47000	ECOTOX
Cyprinus carpio	Common Carp	LC50*	MOR	MORT	2	49000	ECOTOX
Cyprinus carpio	Common Carp	LC50*	MOR	MORT	1	69000	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	SURV	4	75000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	3	79000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	79000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	3	88000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	88000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	92000	ECOTOX
-	Shrimp	LC50	MOR	MORT	2	100000	Environment Canada
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	106000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	106000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	122000	ECOTOX
Moina micrura	Water Flea	LC50	MOR	MORT	4	163720	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	1	251000	ECOTOX

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	2	251000	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	4	251000	ECOTOX
Oreochromis mossambicus	Mozambique Tilapia	LC50	MOR	MORT	4	272870	ECOTOX
Leuciscus idus ssp. melanotus	Carp	LC50	MOR	MORT	2	410000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	4.2	426000	ECOTOX
Ictalurus punctatus	Channel Catfish	LC50	MOR	MORT	1	446000	ECOTOX
Ictalurus punctatus	Channel Catfish	LC50	MOR	MORT	2	446000	ECOTOX
Ictalurus punctatus	Channel Catfish	LC50	MOR	MORT	3	446000	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	1	100000 to 1000000	ECOTOX
Daphnia magna	Water Flea	EC50			1	6000000	EPA
Chronic toxicity data							
Navicula seminulum	Diatom	EC50	POP	PGRT	4	73400	ECOTOX
Navicula seminulum	Diatom	EC50	POP	PGRT	4	73900	ECOTOX

Media Type: freshwater

MOR/MORT: Mortality

POP:Population

PGRT : Population Growth Rate

SURV : Survival

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.

EPA/Office of Pollution prevention and toxics; High production Volume (HPV) Challenge program's Robust summaries and Test Plans. Availible from: http://www.epa.gov/chemrtk/viewsrch.htm on Acetic acid and Salts (April 2003) as of February 9, 2004.

Environment Canada; Tech Info for Problem Spills: Acetic Acid (Draft) p.76 (1981).

ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Alcohol C6 - C12 ethoxylated
Synonyms	
CAS number	68439-45-2
Molecular formula	C_{18} H_{38} O_6
Product name	

Physical Properties	Value	Reference
Phase/state		
Molecular weight	350.5	EPISUITE
Melting point	149.56 (estimate)	EPISUITE
Boiling point	414.96 (estimate)	EPISUITE
Density/ specific gravity		
Vapour pressure	3.64 x 10^{-9} mm Hg at 25^{o}C (estimate)	EPISUITE
Solubility	1188 mg/L at 25^{o}C (estimate)	EPISUITE
Henrys law constant	1.77 x 10^{-14} atm m^3/mole (estimate)	EPISUITE
Organic carbon partition coefficient (Koc)	13.6 (estimate)	EPISUITE
Log organic carbon partition coefficient (log Koc)	1.14 (estimate)	EPISUITE
Log octanol-water partition coefficient (log Kow)	1.43 (estimate)	EPISUITE

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation	NA	
Aerobic BOD	NA	
Anaerobic BOD	NA	
Biowin7 (Anaerobic Model Prediction)	Readily biodegradable	EPISUITE
Fugacity		
Air %	0.559 (estimate)	EPISUITE
Water %	28.8 (estimate)	EPISUITE
Soil %	71.8 (estimate)	EPISUITE
Sediment %	0.0693 (estimate)	EPISUITE
Bioconcentration factor (BCF)	4.1 L/kg wet wt (estimate)	EPISUITE
Biotransformation half-life	0.03864 days (estimate)	EPISUITE

Notes: 1 EPI Suite™ v4.0, United States Environmental Protection Agency.

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (ug/L)**	**Notes**
ANZECC	2000	Aquatic toxicity	50 (99% protection) 140 (95% protection)	Alcohol ethoxylated surfactants (grouped)
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
-	Daphnid	LC50	ITX	IMBL	2	441534	ECOSAR
-	Fish	LC50	MOR	MORT	4	851412	ECOSAR
-	Mysid shrimp	LC50	MOR	MORT	4	1271957	ECOSAR
Chronic toxicity data							
-	Green Algae	EC50	POP	GPOP	4	163871	ECOSAR
-	Fish	LC50	MOR	MORT	14	853048	ECOSAR

Media Type: freshwater

IMBL: immobile

ABND: abundance

ITX : Intoxicated

MOR/MORT: Mortality

POP: Population

REP: Reproduction

PROG : Progeny Counts

SEXR : Sex ratio

FCND: Fecundity

HTCH : Hatch

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

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ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Ammonium C6 - C10 alcohol ethoxysulfate
Synonyms	Sulfuric acid, mono-C6-10-alkyl esters, ammonium salts
CAS number	68187-17-7
Molecular formula	$H_8N_2O_4S$
Product name	

Physical Properties	Value	Reference
Phase/state	NA	
Molecular weight	132.1395	LookChem 2008
Melting point	NA	
Boiling point	330^{o}C	LookChem 2008
Solubility	NA	

Other Relevant Factors	Value	Reference
Reactivity		
Species & Reaction type		
pH		
acid / alkaline	Salt	LookChem 2008

Notes: 1 EPI Suite™ v4.0, United States Environmental Protection Agency.

2, LookChem 2008. Sulfuric acid, mono-C6-1O-alkyl esters, ammonium salts. Accessed on 9 June 2011. Accessed at : http://www.lookchem.com/cas-681/68187-17-7.html.

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Species Name	Common Name	Endpoint	Effect	Effect Measure	Test Time (Days)	Conc (μg/L)	Reference
Acute toxicity data							
-	Fish	LC50	MOR	MORT	4	525985	Ecosar
-	Daphnid	LC50	ITX	IMBL	2	273740	Ecosar
Chronic toxicity data							
-	Green Algae	EC50	POP	GPOP	4	102661	Ecosar
-	Fish	LC50	MOR	MORT	14	527200	Ecosar

Media Type: freshwater

IMBL: immobile

ABND: abundance

ITX : Intoxicated

MOR/MORT: Mortality

POP: Population

REP: Reproduction

PROG : Progeny Counts

SEXR : Sex ratio

FCND: Fecundity

HTCH : Hatch

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

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ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Boric Acid
Synonyms	Orthoboric acid, boron trihydroxide, trihydroxyborane
CAS number	10043-35-3
Molecular formula	H_3Bo_3
Product name	Crosslinker L10

Physical Properties	Value	Reference
Phase/state	Colourless, transparent crystals or white granules or powder.	HSDB, 2011
Molecular weight	61.833 g/mol	HSDB, 2011
Melting point	170.9^{o}C	HSDB, 2011
Boiling point	300 ^{o}C	IUCLID, 2000
Solubility	4.72% at 20 ^{o}C	HSDB, 2011
	5 x 10^4 g/m^3 at 25^{o}C	HSDB, 2011
	One gram dissolves in 18ml cold water or 4ml boiling water	Merck, 1996

Other Relevant Factors	Value	Reference
Reactivity		
Species & Reaction type	Incompatible /with/ alkali carbonates and hydroxides.	HSDB, 2011
pH	pH at 20 ^{o}C 6.1 (0.1% solution); 5.1 (1.0% solution); 3.7 (4.5% solution)	HSDB, 2011

Notes: 1 EPI Suite™ v4.0, United States Environmental Protection Agency.

2 Schlumberger Material Safety Data Sheet L010. Issue Date: 12 April 2007.

3. Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line : 24 March 2011.

4. The Merck Index. 1996. An Encyclopedia of Chemicals, Drugs and Biologicals. Merck REserach Laboratories. (12th Ed.) Whitehouse station, NJ.

5. International Program on Chemical Saftey (IPCS). Chemical Saftey Information from Intergovernmental Organisations, INCHEM. Accessed on line : 31 March 2011 at http://www.inchem.org/documents/icsc/icsc/eics0991.htm

6. International Uniform Chemical Information database, 2000 (IUCLID). Eurpoean Chemical Substances Information System Accessed online 14 April 2011. http://ecb.jrc.ec.europa.eu/iuclid-datasheet/10043353.pdf

NA - not available

Boron is found in the environment primarily combined with oxygen in compounds called borates. Common borate compounds include boric acid, sodium tetraborates and boron oxide (ATSDR, 2010). In water the dominant form of boron is boric acid, which does not dissociate readily (ADWG, 2004). As little information is available relating to guidelines for boric acid, guidelines for boron have been utilised as a surrogate. This is based on the assumption that boron guidelines account for boric acid as one of the constituents for boron.

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	90 ug/L	Boron used as surrogate for boric acid.
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	4 mg/L	Boron used as surrogate for boric acid.
NZDWS	2008	Drinking water	1.4 mg/L	Boron used as surrogate for boric acid.
WHO	2006	Drinking water	0.3 mg/L	Boron used as surrogate for boric acid.
USEPA	2010	Human Health	16,000 mg/kg	Protective of residential soil. Boron used as surrogate for boric acid.
			23 mg/kg.	Protective of groundwater. Boron used as surrogate for boric acid.
IARC	2006	Carcinogen risk	NA	Boric acid and boron not listed in the IARC database.
ANZECC	2000	Stock water	0.5 mg/L	Boron used as surrogate for boric acid.

Aquatic Ecotoxicological Data

Acute toxicity data							
Species Scientific Name	**Species Common Name**	**Endpoint**	**Effect**	**Effect Measurement**	**Test time (Days)**	**Conc (ug/L)**	**Reference**
Oncorhynchus mykiss	Rainbow Trout	LC50	MOR	MORT	4	79000	ECOTOX
Ceriodaphnia pulchella	Water Flea	EC50	MOR	MORT	1	101200	ECOTOX
Simocephalus vetulus	Water Flea	EC50	MOR	MORT	1	123400	ECOTOX
Catostomus latipinnis	Flannelmouth Sucker	LC50	MOR	MORT	4	125000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	133000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LC50*	MOR	MORT	1	150000	ECOTOX
Carassius auratus	Goldfish	LC50*	MOR	MORT	3	170000	ECOTOX
Carassius auratus	Goldfish	LC50*	MOR	MORT	3	178000	ECOTOX
Ceriodaphnia dubia	Water Flea	EC50	MOR	MORT	1	180600	ECOTOX
Catostomus latipinnis	Flannelmouth Sucker	LC50	MOR	MORT	3	225000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	226000	ECOTOX
Xyrauchen texanus	Razorback Sucker	LC50	MOR	MORT	4	233000	ECOTOX
Daphnia carinata	Water Flea	EC50	MOR	MORT	1	267700	ECOTOX
Ptychocheilus lucius	Colorado Squawfish	LC50	MOR	MORT	4	279000	ECOTOX
Xyrauchen texanus	Razorback Sucker	LC50	MOR	MORT	4	279000	ECOTOX
Gila elegans	Bonytail	LC50	MOR	MORT	4	280000	ECOTOX
Daphnia magna	Water Flea	EC50	MOR	MORT	1	319800	ECOTOX
Catostomus latipinnis	Flannelmouth Sucker	LC50	MOR	MORT	2	337000	ECOTOX
Oncorhynchus kisutch	Coho Salmon,Silver Salmon	LC50	MOR	MORT	4	447000	ECOTOX

Species Scientific Name	Species Common Name	Endpoint	Effect	Effect Measurement	Test time (Days)	Conc (ug/L)	Reference
Ptychocheilus lucius	Colorado Squawfish	LC50	MOR	MORT	4	527000	ECOTOX
Gila elegans	Bonytail	LC50	MOR	MORT	4	552000	ECOTOX
Oncorhynchus tshawytscha	Chinook Salmon	LC50	MOR	MORT	4	566000	ECOTOX
Oncorhynchus tshawytscha	Chinook Salmon	LC50	MOR	MORT	4	600000	ECOTOX
Oncorhynchus tshawytscha	Chinook Salmon	LC50	MOR	MORT	4	600000	ECOTOX
Oncorhynchus tshawytscha	Chinook Salmon	LC50	MOR	MORT	4	725000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LC50	MOR	MORT	4	800000	ECOTOX
Catostomus latipinnis	Flannelmouth Sucker	LC50	MOR	MORT	1	1000000	ECOTOX
Oncorhynchus tshawytscha	Chinook Salmon	LC50	MOR	MORT	4	1000000	ECOTOX
Oncorhynchus tshawytscha	Chinook Salmon	LC50	MOR	MORT	4	1000000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	3	1020000	IUCLID, 2005
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	4	1021000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LC50	MOR	MORT	4	1100000	ECOTOX
Spirostomum ambiguum	Protozoa	LC50	MOR	MORT	2	4871000	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50	MOR	MORT	4	5600000	ECOTOX
Spirostomum ambiguum	Protozoa	LC50	MOR	MORT	1	5825000	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50	MOR	MORT	2	10500000	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50	MOR	MORT	1	18000000	ECOTOX
Ceriodaphnia dubia	Water Flea	EC50	ITX	IMBL	1	101200000	Hickey et al., 1989
Simocephalus vetulus	Water Flea	EC50	ITX	IMBL	1	123400000	Hickey et al., 1989
Ceriodaphnia dubia	Water Flea	EC50	ITX	IMBL	1	167700000	Hickey et al., 1989
Ceriodaphnia dubia	Water Flea	EC50	ITX	IMBL	1	180600000	Hickey et al., 1989
Ceriodaphnia dubia	Water Flea	EC50	ITX	IMBL	1	319800000	Hickey et al., 1989

Chronic toxicity data

Species Scientific Name	Species Common Name	Endpoint	Effect	Effect Measurement	Test time (Days)	Conc 1 (ug/L)	Reference
Chlorella pyrenoidosa	Green Algae	NOEC	POP	GPOP	14	400	ECOTOX
Micropterus salmoides	Largemouth Bass	NOEC	MOR	MORT	11	1390	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	NOEC	MOR	MORT	87	2100	ECOTOX
Daphnia magna	Water Flea	NOEC	REP	GREP	21	6000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	14	10000	ECOTOX
Daphnia magna	Water Flea	NOEC	REP	PROG	14	18000	ECOTOX

Species Scientific Name	Species Common Name	Endpoint	Effect	Effect Measurement	Test time (Days)	Conc 1 (ug/L)	Reference
Oncorhynchus mykiss	Rainbow Trout	LOEC	MOR	MORT	32	100	ECOTOX
Chlorella pyrenoidosa	Green Algae	LOEC	POP	GPOP	14	800	ECOTOX
Daphnia magna	Water Flea	MATC	GRO	GGRO	21	9330	ECOTOX
Daphnia magna	Water Flea	MATC	REP	GREP	21	9330	ECOTOX
Daphnia magna	Water Flea	MATC	REP	GREP	21	9330	ECOTOX
Micropterus salmoides	Largemouth Bass	LOEC	MOR	MORT	11	12170	ECOTOX
Ceriodaphnia dubia	Water Flea	MATC	REP	PROG	14	13400	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	REP	PROG	14	18000	ECOTOX
Daphnia magna	Water Flea	MATC	REP	PROG	14	24000	ECOTOX
Daphnia magna	Water Flea	LOEC	REP	PROG	14	32000	ECOTOX
Elodea canadensis	Waterweed	LC50	MOR	MORT	21	5000	ECOTOX
Myriophyllum alterniflorum	Water-Milfoil	LC50	MOR	MORT	21	5000	ECOTOX
Ranunculus penicillatus	Buttercup	LC50	MOR	MORT	21	10000	ECOTOX
Ictalurus punctatus	Channel Catfish	LC50*	MOR	MORT	9	22000	ECOTOX
Carassius auratus	Goldfish	LC50*	MOR	MORT	7	46000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	21	52200	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	21	53200	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	21	53200	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LC50	MOR	MORT	28	70100	ECOTOX
Carassius auratus	Goldfish	LC50*	MOR	MORT	7	75000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LC50*	MOR	MORT	28	79000	ECOTOX
Micropterus salmoides	Largemouth Bass	LC50	MOR	MORT	11	92000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LC50*	MOR	MORT	24	100000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LC50*	MOR	MORT	28	100000	ECOTOX
Ictalurus punctatus	Channel Catfish	LC50*	MOR	MORT	5	102000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	2	133000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LC50	MOR	MORT	32	138000	ECOTOX
Ictalurus punctatus	Channel Catfish	LC50*	MOR	MORT	9	155000	ECOTOX
Ictalurus punctatus	Channel Catfish	LC50*	MOR	MORT	5	220000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	2	226000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	2	777000	ECOTOX
Ictalurus punctatus	Channel Catfish	LC50	MOR	MORT	5	1260000	IUCLID, 2005
Ictalurus punctatus	Channel Catfish	LC50	MOR	MORT	9	1890000	IUCLID, 2005

Media Type : Freshwater (NR for data from Hickey *et al.*, 1989 and IUCLUD, 2005).

DVP: Development

ITX: Intoxication

REP: Reproduction

DFRM: Deformation

IMBL: Immobile

PROG: Progeny counts

GREP: Reproduction, general

POP: Population

GPOP: Population, general

MOR/MORT : Mortality

Notes:

ATSDR, 2010. Agency for Toxic Substances and Disease Registry, Toxicological Profile for Boron. US Department of Health and Human Services. Accessed at : http://www.atsdr.cdc.gov/ToxProfiles/tp26.pdf.

ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.
Hickey CW; N.Z. J Mar Freshwater Res 23 (1): 131-137 (1989). Available from the ECOTOX database on Boric acid (10043-35-3) at: http://www.epa.gov/cgi-bin/ecotox_quick_search as of May 13, 2005.
European Chemicals Bureau; IUCLID Dataset, Boric acid (10043-35-3) (2000 CD-ROM edition). Available from, as of May 18, 2005: http://ecb.jrc.it/esis/esis.php.
ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Carbonic Acid
Synonyms	sodium sesquicarbonate, trisodium hydrogendicarbonate, sodium monohydrogendicarbonate, sodium salt.
CAS number	533-96-0
Molecular formula	$CH_2O_3.3/2Na$
Product name	

Physical Properties	Value	Reference
Phase/state	White needle shaped crystals	HSDB, 2011
Molecular weight	109.00 g/mol	HSDB, 2011
Melting point	139.9^{o}C (estimate)	EPISUITE
Boiling point	402.8^{o}C (estimate)	EPISUITE
Solubility	5307 mg/L at 25^{o}C (estimate)	EPISUITE

Other Relevant Factors	Value	Reference
Reactivity Species & Reaction type	NA	
pH	Acid	IUCLID 2000

Notes: 1 EPI Suite™ v4.1, United States Environmental Protection Agency.

2. Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line: 9 June 2011.

3. International Uniform Chemical Information database, 2000 (IUCLID). Eurpoean Chemical Substances Information System Accessed online 9 June 2011. http://ecb.jrc.ec.europa.eu/iuclid-datasheet/533960.pdf

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Species Name	Common Name	Endpoint	Effect	Effect Measure	Test Time (Days)	Conc (μg/L)	Reference
Acute toxicity data							
	Daphnid	LC50	ITX	IMBL	2	2.19E+11	ECOSAR
	Fish	LC50	MOR	MORT	4	1.3E+12	ECOSAR
Chronic toxicity data							
	Green Algae	EC50	POP	GPOP	4	2.97E+9	ECOSAR
	Fish	LC50	MOR	MORT	14	1.15E+12	ECOSAR

Media Type: freshwater

IMBL: immobile

ABND: abundance

ITX : Intoxicated

MOR/MORT: Mortality

POP: Population

REP: Reproduction

PROG : Progeny Counts

SEXR : Sex ratio

FCND: Fecundity

HTCH : Hatch

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.

ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Diammonium Peroxidisulphate (Ammonium Persulphate)
Synonyms	Ammonium persulphate
CAS number	7727-54-0
Molecular formula	$H_8N_2O_8S_2$
Product name	Breaker J218 & EB CLEAN J479 LT Encapsulated Breaker

Physical Properties	Value	Reference
Phase/state	White granules	MSDS (Breaker J479), 2010
Molecular weight	228.2 g/mol	IPCS, 2011
Melting point	Decomposition temperature 120^{o}C	MSDS (Breaker J218), 2010
Boiling point	Decomposes	MSDS (Breaker J218), 2010
Solubility	10 - 20 g/L at 20 ^{o}C	MSDS (Breaker J479), 2010
	Freely soluble in water	Merck, 1996
	559 g/l at 20 ^{o}C	IUCLID, 2000

Other Relevant Factors	Value	Reference
Reactivity		
Species	The substance is a strong oxidant and reacts with combustible and reducing materials	IPCS, 2011
Reaction type	Strong oxidising agent	
pH	Typically pH 4 at 1% solution	Merck, 1996
acid / alkaline		MSDS, 2009
pH (10% solution)		

Notes: 1. FMC Material Safety Data Sheet Ammonium Persulphare (revision 11). Issue Date 26 June 2009.

2.Schlumberger Material Safety Data Sheet J134. Issue Date: 18 April 2006.

3. Schlumberger Material Safety Data Sheet J479. Issue Date: 15 April 2010

4. The Merck Index. 1996. An Encyclopedia of Chemicals, Drugs and Biologicals. Merck REserach Laboratories. (12th Ed.) Whitehouse station, NJ.

5. International Program on Chemical Saftey (IPCS). Chemical Saftey Information from Intergovernmental Organisations, INCHEM. Accessed on line : 31 March 2011 at http://www.inchem.org/documents/icsc/icsc/eics0632.htm

6. International Uniform Chemical Information database, 2000 (IUCLID). Eurpoean Chemical Substances Information System Accessed online 14 April 2011. http://ecb.jrc.ec.europa.eu/iuclid-datasheet/7727540.pdf.

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	

Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	Not listed in IARC database.
ANZECC	2000	Stock water	NA	

Aquatic Ecotoxicological Data

Acute toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Cyprinus carpio	Common Carp	LC50	MOR	MORT	2	22000	ECOTOX
Tubificidae	Oligochaete Family	LC50	MOR	MORT	2	33000	ECOTOX
Daphnia pulicaria	Water Flea	LC50	MOR	MORT	2	87000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	101000	ECOTOX
Cyclops strenuus	Cyclopoid Copepod	LC50	MOR	MORT	2	170000	ECOTOX
Cyclops strenuus	Cyclopoid Copepod	LC50	MOR	MORT	2	316000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LC50	MOR	MORT	2	355000	ECOTOX
Tubificidae	Oligochaete Family	LC50	MOR	MORT	2	367000	ECOTOX
Poecilia reticulata	Guppy	LC50	MOR	MORT	2	732000	ECOTOX
Cyprinus carpio	Common Carp	LC50	MOR	MORT	2	1470000	ECOTOX

Media Type : NR

MOR/MORT: Mortality

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.

ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Diatomaceous Earth, calcined
Synonyms	Amorphous Silica, diatomite, kieselgur, biogenic silica.
CAS number	91053-39-3
Molecular formula	O2-Si
Product name	M275

Physical Properties	Value	Reference
Phase/state	Amorphous powder	HSDB, 2011
Molecular weight	60.1 g/mol	HSDB, 2011
Melting point	3,110^{o}C	HSDB, 2011
Boiling point	4,046^{o}C	HSDB, 2011
Solubility	Insoluble	HSDB, 2011

Other Relevant Factors	Value	Reference
Reactivity		
Species	NA	
Reaction type	NA	
pH		
acid / alkaline	pH 5-8	Advanced Minerals, 2007
pH (10% solution)	NA	

Notes: 1.Baker Hughes Material Safety Data Sheet M275. Issue Date: 16 July 2011.

2. Hazardous Substances Data Bank (HSDB) National library of Medicine (amorphous silica) accessed on line : 24 March 2011.

3. Advanced Minerals. Material Safety Data Sheet 3113. Issue Date 2 July 2007.

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Ecotoxicological Data

Chronic toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (%)**	**Reference**
Dicentrarchus labrax**	Sea Bass	LOEL	GRO	GAIN	60	10% v/v	ECOTOX

Note: ECOTOX data is for silica (CASRN 7631-86-9). There were several ECOTOX database entries for this compound and all were in the saltwater environment. Only one entry related to the endpoints considered in this report (mortality, growth, reproduction). This entry is provided in the Table above. The concentration units were reported as 10% v/v, which equates to 100,000 mg/L.

Media Type : sea water

GRO: Growth

GAIN: Weight gain

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7. ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm

Name	Ethanol
Synonyms	Ethyl Alcohol, ethyl hydrate, ethyl hydroxide.
CAS number	64-17-5
Molecular formula	C_2H_6O
Product name	F104

Physical Properties	Value	Reference
Phase/state	Clear, colourless, very mobile liquid	HSDB, 2011
Molecular weight	46.07 g/mol	HSDB, 2011
Melting point	-114.1 ^{o}C	HSDB, 2011
Boiling point	78.5 ^{o}C	HSDB, 2011
Density/ specific gravity	0.789 at 20^{o}C	HSDB, 2011
Vapour pressure	59.3 mm Hg at 25^{o}C	HSDB, 2011
Solubility	Miscible in water	HSDB, 2011
	7.921 x 10^{5} mg/L at 25^{o}C	EPISUITE
Henrys law constant	5 x 10^{-6} atm m^{3}/mole	HSDB, 2011
Organic carbon partition coefficient (Koc)	1	HSDB, 2011
Log organic carbon partition coefficient (log Koc)	0.019 (MCI Method)	EPISUITE
Log octanol-water partition coefficient (log Kow)	-0.31	HSDB, 2011

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation	Biodegradation is expected to occur rapidly in the environment, unlikely to be persistent in the environment. Not expected to adsorb to suspended solids and sediment.	HSDB, 2011
Aerobic BOD	74% BOD in 5 days	HSDB, 2011
Anaerobic BOD	1.5 days under denitrifying conditions, 5 days under iron - reducing conditions.	HSDB, 2011
Biowin7 (Anaerobic Model Prediction)	Biodegrades fast	EPISUITE
Fugacity		
Air %	7.4	EPISUITE
Water %	40.6	EPISUITE
Soil %	51.9	EPISUITE
Sediment %	0.0718	EPISUITE
Bioconcentration factor (BCF)	3 (aquatic organisms)	HSDB, 2011
Biotransformation half-life	0.02866 days	EPISUITE

Notes: 1 EPI Suite™ v4.0, United States Environmental Protection Agency.

2. Halliburton Material Safety Data Sheet GasPerm 1100. Issue Date: 4 March 2010.

3. Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line: 25 March 2011.

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	400	Freshwater guideline (99%) level of protection - % species.
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	1	Carcinogenic to humans.
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Acute Toxicity Data							
Species Scientific Name	**Species Common Name**	**Endpoint**	**Effect**	**Effect Measurement**	**Test time (days)**	**Conc 1 (ug/L)**	**Reference**
Oncorhynchus mykiss	Rainbow Trout	LC50	MOR	MORT	4	42000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	1	100000	ECOTOX
Danio rerio	Zebra Danio	LC50	MOR	MORT	1	100000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	2	100000	ECOTOX
Asellus intermedius	Aquatic Sowbug	LC50	MOR	MORT	4	100000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	4	100000	ECOTOX
Gammarus fasciatus	Scud	LC50	MOR	MORT	4	100000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	100000	ECOTOX
Planorbella trivolvis	Snail, Marsh Rams-Horn	LC50	MOR	MORT	4	100000	ECOTOX
Dugesia tigrina	Turbellarian, Flatworm	LC50	MOR	MORT	4	100000	ECOTOX
Lumbriculus variegatus	Oligochaete, Worm	LC50	MOR	MORT	4	100000	ECOTOX
Oryzias latipes	Medaka, High-Eyes	LC50	MOR	MORT	2	1350000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	3715000	ECOTOX
Oryzias latipes	Medaka, High-Eyes	LC50	MOR	MORT	1	5100000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	5577000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	5680000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	6076000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	6325000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	6386000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	6772000	ECOTOX
Leuciscus idus ssp. melanotus	Carp	LC50	MOR	MORT	2	8140000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	8808000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	9248000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	9268000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	2	9300000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	9300000	ECOTOX

Species Scientific Name	Species Common Name	Endpoint	Effect	Effect Measurement	Test time (days)	Conc 1 (ug/L)	Reference
Daphnia magna	Water Flea	LC50	MOR	MORT	1	9788000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	1	10000000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	1	10000000	ECOTOX
Oryzias latipes	Medaka, High-Eyes	LC50	MOR	MORT	1	10000000	ECOTOX
Oryzias latipes	Medaka, High-Eyes	LC50	MOR	MORT	1	10000000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	2	10000000	ECOTOX
Leuciscus idus ssp. melanotus	Carp	LC50	MOR	MORT	2	10000000	ECOTOX
Oryzias latipes	Medaka, High-Eyes	LC50	MOR	MORT	2	10000000	ECOTOX
Oryzias latipes	Medaka, High-Eyes	LC50	MOR	MORT	2	10000000	ECOTOX
Daphnia obtusa	Water Flea	EC50	ITX	IMBL	2	10600000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	10860000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LC50	MOR	MORT	1	11200000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	11853000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	11967000	ECOTOX
Poecilia reticulata	Guppy	LC50	MOR	MORT	1	12500000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	12720000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	12820000	ECOTOX
Daphnia obtusa	Water Flea	EC50	ITX	IMBL	1	12900000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	13248000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	13470000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	13480000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	3	13480000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	13480000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	14136000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	14200000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	14221000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	1	15800000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	18000000	ECOTOX
Chironomus tentans	Midge	LC50	MOR	MORT	2	25100000	ECOTOX
Streptocephalus rubricaudatus	Fairy Shrimp	LC50	MOR	MORT	1	31700000	ECOTOX
Corbicula manilensis	Asiatic Clam	LC50	MOR	MORT	4	60000000	ECOTOX
Caenorhabditis elegans	Nematode	LC50	MOR	MORT	1	87000000	ECOTOX

Chronic Toxicity Data

Species Scientific Name	Species Common Name	Endpoint	Effect	Effect Measurement	Test time (days)	Conc 1 (ug/L)	Reference
Eutreptialla sp.	Euglenoid	NOEC	POP	ABND	4	14000	ECOTOX
Biomphalaria tenagophila	Snail	NOEL	REP	PROG	56	19800	ECOTOX
Biomphalaria tenagophila	Snail	NOEC	MOR	HTCH	196	19800	ECOTOX
Biomphalaria tenagophila	Snail	NOEC	MOR	MORT	196	19800	ECOTOX
Biomphalaria tenagophila	Snail	NOEC	REP	FCND	196	19800	ECOTOX
Biomphalaria tenagophila	Snail	NOEC	REP	PROG	196	19800	ECOTOX
Biomphalaria tenagophila	Snail	NOEL	REP	PROG	196	19800	ECOTOX

Species Scientific Name	Species Common Name	Endpoint	Effect	Effect Measurement	Test time (days)	Conc 1 (ug/L)	Reference
Prorocentrum minimum	Dinoflagellate	NOEC	POP	ABND	4	20000	ECOTOX
Heterosigma akashiwo	Algae	NOEC	POP	ABND	4	350000	ECOTOX
Biomphalaria tenagophila	Snail	NOEC	MOR	HTCH	10	1980000	ECOTOX
Biomphalaria tenagophila	Snail	NOEL	MOR	MORT	10	1980000	ECOTOX
Biomphalaria tenagophila	Snail	NOEC	REP	PROG	56	1980000	ECOTOX
Biomphalaria tenagophila	Snail	NOEC	REP	PROG	56	1980000	ECOTOX
Chaetoceros calcitrans	Diatom	NOEC	POP	ABND	4	2000000	ECOTOX
Skeletonema costatum	Diatom	NOEC	POP	ABND	4	3600000	ECOTOX
Caenorhabditis elegans	Nematode	NOEL	REP	PROG	3	4000000	ECOTOX
Pavlova lutheri	Chrysophyte	NOEC	POP	ABND	4	4100000	ECOTOX
Isochrysis galbana	Haptophyte	NOEC	POP	ABND	4	7400000	ECOTOX
Dunaliella tertiolecta	Green Algae	NOEC	POP	ABND	4	9600000	ECOTOX
Tetraselmis tetrathele	Green Flagellate	NOEC	POP	ABND	4	10000000	ECOTOX
Biomphalaria tenagophila	Snail	LOEC	MOR	HTCH	196	19800	ECOTOX
Biomphalaria tenagophila	Snail	LOEL	MOR	HTCH	196	19800	ECOTOX
Biomphalaria tenagophila	Snail	LOEL	REP	PROG	56	198000	ECOTOX
Biomphalaria tenagophila	Snail	LOEC	REP	FCND	196	198000	ECOTOX
Biomphalaria tenagophila	Snail	LOEC	REP	PROG	196	198000	ECOTOX
Biomphalaria tenagophila	Snail	LOEL	REP	PROG	196	198000	ECOTOX
Caenorhabditis elegans	Nematode	LOEL	REP	PROG	3	8000000	ECOTOX
Tetrahymena pyriformis	Ciliate	IC50	POP	PGRT	2	11962.81	ECOTOX
Pseudokirchneriella subcapitata	Green Algae	EC50	POP	PGRT	2	29900	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	9	454000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	10	1806000	ECOTOX
Tetrahymena pyriformis	Ciliate	IC50	POP	ABND	1.67	4515000	ECOTOX
Chaetoceros calcitrans	Diatom	EC50	POP	ABND	4	10000000	ECOTOX
Skeletonema costatum	Diatom	EC50	POP	ABND	4	10000000	ECOTOX
Heterosigma akashiwo	Algae	EC50	POP	ABND	4	10000000	ECOTOX
Tetrahymena pyriformis	Ciliate	IC50	POP	PGRT	1.5	12800000	ECOTOX
Caenorhabditis elegans	Nematode	EC50	REP	PROG	3	18000000	ECOTOX
Tetraselmis tetrathele	Green Flagellate	EC50	POP	ABND	4	20000000	ECOTOX

Media Type: freshwater

IMBL: immobile

ABND: abundance

ITX : Intoxicated

MOR/MORT: Mortality

POP: Population

REP: Reproduction

PROG : Progeny Counts

SEXR : Sex ratio

FCND: Fecundity

HTCH : Hatch

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.
ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Ethylene glycol monobutyl ether
Synonyms	2-Butoxyethanol, Butyl Cellosolve® (Union Carbide)
CAS number	111-76-2
Molecular formula	$C_6H_{14}O_2$
Product name	F104

Physical Properties	Value	Reference
Phase/state	Liquid	EPISUITE
Molecular weight	118.2	HSDB 2010
Melting point	-74.8^{o}C	HSDB 2010
Boiling point	168.4^{o}C	HSDB 2010
Vapour pressure	0.88 mm Hg at 25^{o}C	HSDB 2010
Solubility	6.447 x 10^4 mg/L at 25^{o}C	EPISUITE
Henrys law constant	9.79x10^{-8} atm m^3/mole at 25^{o}C	EPISUITE
Organic carbon partition coefficient (Koc)	2.823	EPISUITE
Log organic carbon partition coefficient (log Koc)	0.451	EPISUITE
Log octanol-water partition coefficient (log Kow)	0.83	HSDB 2010

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation		
Aerobic BOD	Readily biodegradable (5-10 days)	HSDB 2010
Anaerobic BOD	NA	HSDB 2010
Ready Biodegradability Prediction	Biodegrades fast	EPISUITE
Fugacity		
Air %	2.4	EPISUITE
Water %	41	EPISUITE
Soil %	57	EPISUITE
Sediment %	0.075	EPISUITE
Bioconcentration factor (BCF)	3	HSDB 2010
Biotransformation half-life	0.054 days	EPISUITE
Soil adsorption coefficient	2.8-7.6 L/kg	EPISUITE

Notes: 1 EPI SuiteTM v4.0, United States Environmental Protection Agency.

2 Chemwatch Material Safety Data Sheet 2369. Issue Date: 26-Oct-2008.

3. Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line 30/6/10

NA - not available

Chemical Information Sheet updated in June 2011

Aquatic ecosystem guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic ecosystem	None	
USEPA	2006	Aquatic ecosystem	None	
Other guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	None	
NZDWS	2005	Drinking water	None	
WHO	2006	Drinking water	None	
USEPA	2009	Human Health	None	
IARC	2006	Carcinogen risk	-	Risk group 3
ANZECC	2000	Stock water	None	

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Leuciscus idus ssp. melanotus	Carp	LC50	MOR	MORT	2	1395000	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	4	1490000	ECOTOX
Leuciscus idus ssp. melanotus	Carp	LC50	MOR	MORT	2	1575000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	1	1700000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	1	1720000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	1	1000000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	2	1000000	ECOTOX
Daphnia magna	Water Flea	NOEC	ITX	IMBL	2	1000000	ECOTOX

Notes:

ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database.

Name	Guar Gum
Synonyms	-
CAS number	9000-30-0
Molecular formula	NA
Product name	Unspecified

Physical Properties	Value	Reference
Phase/state	Solid	Chemwatch, 2005
Molecular weight	220,000	Chemwatch, 2005
Melting point	NA	
Boiling point	NA	
Density/ specific gravity	NA	
Vapour pressure	NA	
Solubility	Soluble Completely soluble in water	Chemwatch, 2005
Henrys law constant	NA	
Log organic carbon partition coefficient (log Koc)	NA	
Log octanol-water partition coefficient (log Kow)	NA	

Persistence/ Bioaccumulation	Value	Reference
Biowin7 (Anaerobic Model Prediction)	NA	
Ready Biodegradability Prediction	NA	
Fugacity		
Air %	NA	
Water %	NA	
Soil %	NA	
Sediment %	NA	
Bioconcentration factor (BCF)	NA	
Biotransformation half-life	NA	

Notes: 1 Chemwatch Material Safety Data Sheet 23354. Issue Date: 14-Jul-2005.

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	

Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2008	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Oncorhynchus mykiss	Rainbow Trout	LC50*	MOR	MORT	4	218000	ECOTOX
Daphnia magna	Water Flea	LC50*	MOR	MORT	2	42000	ECOTOX
Daphnia magna	Water Flea	LC50*	MOR	MORT	4	6200	ECOTOX
Chronic toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Water flea	Daphnia magna	LC50	MOR	MORT	4	6.2	ECOTOX
Rainbow trout	Oncorhynchus	LC50	MOR	MORT	4	218	ECOTOX

Media Type: freshwater

MOR/MORT: Mortality

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7. EPA/Office of Pollution prevention and toxics; High production Volume (HPV) Challenge program's Robust summaries and Test Plans. Availible from: http://www.epa.gov/chemrtk/viewsrch.htm on Acetic acid and Salts (April 2003) as of February 9, 2004.

Environment Canada; Tech Info for Problem Spills: Acetic Acid (Draft) p.76 (1981).
ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Hydrochloric Acid
Synonyms	Anhydrous hydrochloric acid, chlorohydric acid, dilute hydrochloric acid, hydrochloric acid gas, muriatic acid
CAS number	7647-01-0
Molecular formula	HCl
Product name	Hydrochloric acid

Physical Properties	Value	Reference
Phase/state	Liquid	Merck, 1996
Molecular weight	36.46	HSDB, 2011
Melting point	-114.22 ^{o}C	HSDB, 2011
Boiling point	-85.05^{o}C	
Solubility	Soluble	HSDB, 2011

Other relevant properties	Value	Reference
Reactivity		
Species	HCl/Cl^-	Merck 1996
Reaction type	Acid/base	
pH		
Acid/alkaline	Acid	Merck 1996
pH at 0.1N	1.1	Merck 1996

Notes : 1 Merck Index. Twelfth Edition. 1996. Merck & Co., Inc.

2 Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line 30/6/10

Chemical Information Sheet updated in June 2011.

Aquatic ecosystem guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic ecosystem		
USEPA	2006	Aquatic ecosystem		
Other guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water		
NZDWS	2008	Drinking water		
WHO	2006	Drinking water		

Guideline	Year	Type	Value (g/m^3)	Notes
USEPA	2009	Human Health		
IARC	2006	Carcinogen risk		
ANZECC	2000	Stock water		

Estimated acute toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Gambusia affinis	Western Mosquito fish	LC50*	MOR	MORT	1	282000	ECOTOX
Gambusia affinis	Western Mosquito fish	LC50*	MOR	MORT	2	282000	ECOTOX
Gambusia affinis	Western Mosquito fish	LC50*	MOR	MORT	4	282000	ECOTOX
Carcinus maenas	Green Or European Shore Crab	LC50	MOR	MORT	2	240000	ECOTOX
Crangon crangon	Common Shrimp, Sand Shrimp	LC50	MOR	MORT	2	260000	ECOTOX
Estimated chronic toxicity data							
Lemna minor	Duckweed	EC50	GRO	NLEF	10	189600	ECOTOX
Lemna minor	Duckweed	EC50	GRO	WGHT	10	182300	ECOTOX

Notes:

ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines. Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, United States Environmental Protection Agency ECOTOX database.

Name	Isopropanol
Synonyms	Isopropyl alcohol; secondary propyl alcohol; dimethyl carbinol; petrohol; IPA
CAS number	67-63-0
Molecular formula	C_3H_8O
Product name	Unspecified

Physical Properties	Value	Reference
Phase/state	Liquid	HSDB 2010
Molecular weight	60.10	HSDB 2010HSDB 2010
Melting point	-88.5^{o}C	HSDB 2010HSDB 2010
Boiling point	82.5^{o}C	HSDB 2010
Density/ specific gravity	0.78505	HSDB2010
Vapour pressure	45.4 mm Hg at 25^{o}C	EPISUITE
Solubility	1 x 10^{6} at 25^{o}C (units not provided)	EPISUITE
Henrys law constant	7.52 x 10^{-6} atm m^3/mole	EPISUITE
Organic carbon partition coefficient (Koc)	1.53	HSDB 2010
Log organic carbon partition coefficient (log Koc)	0.185	
Log octanol-water partition coefficient (log Kow)	0.05	

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation		
Aerobic BOD	Readily degraded 5-20 days	HSDB 2010
Anaerobic BOD	Readily degraded	HSDB 2010
Ready Biodegradability Prediction	Yes	EPISUITE
Fugacity		
Air %	4.6	EPISUITE
Water %	45	EPISUITE
Soil %	50	EPISUITE
Sediment %	0.086	EPISUITE
Bioconcentration factor (BCF)	3	HSDB 2010
Biotransformation half-life	0.036 days	EPISUITE
Soil adsorption coefficient	1.5-3.5 L/kg	EPISUITE

Notes: 1 Merck Index. Twelfth Edition. 1996. Merck & Co., Inc.

2 EPI Suite™ v4.0, United States Environmental Protection Agency.

3. Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line 30/6/10

NA - not available

Chemical Information Sheet updated June 2011.

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	None	
USEPA	2006	Aquatic toxicity	None	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	None	
NZDWS	2008	Drinking water	None	
WHO	2006	Drinking water	None	
USEPA	2006	Human Health	None	
IARC	2006	Carcinogen risk	-	Risk group 3
ANZECC	2000	Stock water	None	

Acute toxicity data							
Species Scientific Name	**Species Common Name**	**Endpoint**	**Effect**	**Effect Measurement**	**Test time (Days)**	**Conc 1 (ug/L)**	**Ref**
Rasbora heteromorpha	Harlequinfish, Red Rasbora	LC50	MOR	MORT	4	4200000	ECOTOX
Rasbora heteromorpha	Harlequinfish, Red Rasbora	LC50	MOR	MORT	2	4900000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	1	5000000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	6550000	ECOTOX
Rasbora heteromorpha	Harlequinfish, Red Rasbora	LC50	MOR	MORT	1	7100000	ECOTOX
Leuciscus idus ssp. melanotus	Carp	LC50	MOR	MORT	2	8970000	ECOTOX
Leuciscus idus ssp. melanotus	Carp	LC50	MOR	MORT	2	9280000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	9640000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	10400000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	10400000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	10600000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	11130000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	3	11130000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	11130000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	11160000	ECOTOX
Chironomus riparius	Midge	LC50	MOR	MORT	2	12500000	ECOTOX

Chronic toxicity data							
Species Scientific Name	Species Common Name	Endpoint	Effect	Effect Measurement	**Test time (Days)**	Conc 1 (ug/L)	Reference
Tetrahymena thermophila	Ciliate Protozoa	NOEC	POP	PGRT	2	754000	ECOTOX
Tetrahymena	Ciliate Protozoa	EC50	POP	PGRT	2	7462000	ECOTOX

thermophila							
Tetrahymena thermophila	Ciliate Protozoa	EC50	POP	PGRT	2	8130000	ECOTOX

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines. Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, United States Environmental Protection Agency ECOTOX database; and data presented as [1] geometric mean (range), N = 2; [2] geometric mean (range), N = 3.

Name	Magnesium Chloride
Synonyms	Magnesium dichloride
CAS number	7786-30-3
Molecular formula	$MgCl_2$
Product name	M275

Physical Properties	Value	Reference
Phase/state	Thin white to grey granules and / or flakes	HSDB, 2011
Molecular weight	95.21 g/mol (rapid heating)	HSDB, 2011
Melting point	118 ^{o}C (with decomposition)	Merck, 1996
	712 ^{o}C (rapid heating)	HSDB, 2011
Boiling point	1,412^{o}C	HSDB, 2011
Solubility	56.g/100g at 20^{o}C (in water)	HSDB, 2011

Other Relevant Factors	Value	Reference
Reactivity		
Species & Reaction type	Decomposes to magnesium oxichloride and hydrochloric acid. 2MgCl2 + H20 -> Mg20*Cl2 + 2 HCL	IUCLID, 2000
	Magnesium chloride is one of the constituents in a salt mixture that reacts with water giving a moderate heat evolution and an alkaline effect	IUCLID, 2000
pH		
acid / alkaline	NA	
pH (5% solution)	5% in water is neutral to litmus.	JBaker, 2009

Notes: 1. Baker Hughes. Material Safety Data Sheet M275. Issue Date:16 July 2003.

2. Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line: 24 March 2011.

3. The Merck Index. 1996. An Encyclopedia of Chemicals, Drugs and Biologicals. Merck REserach Laboratories. (12th Ed.) Whitehouse station, NJ.

4. JBaker. Material Safety Data Sheet M0156. Issue Date : 16 September 2009.

5. International Uniform Chemical Information database, 2000 (IUCLID). Eurpoean Chemical Substances Information System Accessed online 14 April 2011. http://ecb.jrc.ec.europa.eu/iuclid-datasheet/7786303.pdf.

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	Not listed in IARC database
ANZECC	2000	Stock water	NA	

Aquatic Ecotoxicological Data

Acute toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Daphnia hyalina	Water Flea	LC50	MOR	MORT	2	32000	ECOTOX
Daphnia magna	Water Flea	EC50*	ITX	IMBL	2	140000	ECOTOX
Eudiaptomus padanus ssp. padanus	Calanoid Copepod	EC50*	ITX	IMBL	2	180000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	2.7	190000	ECOTOX
Cyclops abyssorum ssp. prealpinus	Cyclopoid Copepod	EC50*	ITX	IMBL	2	280000	ECOTOX
Daphnia magna	Water Flea	EC50*	ITX	IMBL	2	322000	ECOTOX
Austropotamobius pallipes ssp. pall	Crayfish	LC50*	MOR	MORT	4	480000	ECOTOX
Orconectes limosus	Crayfish	LC50*	MOR	MORT	4	760000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	880000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	1	1270000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	1330000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	1	1560000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	2120000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	2840000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	1.04	3391000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	4.2	3484000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	3520000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2.1	3699000	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	4	4210000	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	2	4530000	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	1	4780000	ECOTOX

Chronic toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Daphnia magna	Water Flea	EC50*	ITX	IMBL	21	190000	ECOTOX
Daphnia magna	Water Flea	EC50*	REP	GREP	21	125000	ECOTOX

Media Type: Freshwater

MOR/MORT: Mortality

SURV : Survival

ITX : Intoxication

IMBL : Immobile

REP: Reproduction

GREP: Reproduction, general

HTCH: Hatch

CEL: Cells

OGNL : Organelle changes

The asterisk (*) denotes several meanings depending upon the field you are viewing. An asterisk can be used in these fields:

- *Concentration:* This means the reported concentration has been recalculated to meet database conformity. For example, the concentration unit was reported as Molar units, but the standard database unit is micrograms per liter. Another example would be if the reported value was as a metal compound and it was recalculated to the ion level. Note: These recalculations are no longer performed.
- *Endpoint*: This denotes the reported endpoint acronym provided was modified to conform to the standard database acronym terminology. For example, if the author reported a TLM, the endpoint was coded as an LC50*.

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.

ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Magnesium nitrate
Synonyms	Magnesium dinitrate
CAS number	10377-60-3
Molecular formula	$Mg(N0_3)_2$
Product name	M275

Physical Properties	Value	Reference
Phase/state	White cubic crystals	HSDB, 2011
Molecular weight	148.31 g/mol	HSDB, 2011
Melting point	95^{o}C	HSDB, 2011
Boiling point	Decomposes below boiling point at 330^{o}C	IPCS, 2011
Solubility	Very soluble in water 71.2 g/100g (water) at 25 deg ^{o}C	HSDB, 2011 HSDB, 2011

Other Relevant Factors	Value	Reference
Reactivity		
Species	$Mg(N0_3)_2$	
Reaction type	NA	
pH		
acid / alkaline	NA	
pH (10% solution)	NA	

Notes: 1. Baker Huges Material Safety Data Sheet M275. Issue Date:16 July 2003.

2. Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line 24 March 2011.

3. International Program on Chemical Saftey (IPCS). Chemical Saftey Information from Intergovernmental Organisations, INCHEM. Accessed on line : 30 March 2011 at http://www.inchem.org/documents/icsc/icsc/eics1041.htm.

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	Not listed in IARC database
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Estimated acute toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
-	Daphnid	LC50	ITX	IMBL	2	8.69E+06	ECOSAR V1.0
-	Fish	LC50	MOR	MORT	4	2.27E+07	ECOSAR V1.0
Caenorhabditis elegans	Nematode	LC50	MOR	MORT	1	3.71E+07	ECOTOX
Estimated chronic toxicity data							
-	Green Algae	EC50	POP	GPOP	4	1.33E+06	ECOSAR V1.0
-	Fish	LC50	MOR	MORT	14	2.20E+06	ECOSAR V1.0

Media Type: Freshwater

MOR/MORT: Mortality

POP: Population

GPOP: Population, general

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.

ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm

Name	Magnesium silicate hydrate (talc)
Synonyms	Magnesium silicate hydrate, talc, talcum
CAS number	14807-96-6
Molecular formula	$H_2O_3Si.3/4Mg$
Product name	

Physical Properties	Value	Reference
Phase/state	White to grayish-white, very fine crystalline powder	HSDB, 2011
Molecular weight	78.10 (estimate)	EPISUITE
Melting point	219.7°C (estimate)	EPISUITE
Boiling point	549.7°C (estimate)	EPISUITE
Solubility	Insoluble in water, cold acids or in alkalis 1 x 10^6 mg/L at 25°C	HSDB, 2011 EPISUITE

Other Relevant Factors	Value	Reference
Reactivity		
Species & Reaction type	Insoluble and not degradable in soil or water	IUCLID, 2000
pH		
acid / alkaline	NA	NA
pH in water	9.0 to 9.5	HSDB, 2011

Notes: 1. Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line: 9 June 2011.

2. International Uniform Chemical Information database, 2000 (IUCLID). European Chemical Substances Information System Accessed online 9 June 2011. http://ecb.jrc.ec.europa.eu/iuclid-datasheet/7786303.pdf.

3. EPI Suite™ v4.0, United States Environmental Protection Agency.

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	1987	Carcinogen risk	NA	Talc containing asbestiform fibres (see Asbestos)
	2010	Carcinogen risk	NA	Talc not containing asbestos or asbestiform fibres
	2010	Carcinogen risk	NA	Talc-based body powder (perineal use of)
ANZECC	2000	Stock water	NA	

Aquatic Ecotoxicological Data

Acute toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
-	Daphnid	LC50	MOR	MORT	2	24387518	Ecosar
-	Fish	LC50	MOR	MORT	4	72574344	Ecosar

Chronic toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
-	Green Algae	EC50	POP	GPOP	4	2530044	Ecosar
-	Fish	LC50	MOR	MORT	14	69353852	Ecosar

Media Type: Freshwater

MOR/MORT: Mortality

SURV : Survival

ITX : Intoxication

IMBL : Immobile

REP: Reproduction

GREP: Reproduction, general

HTCH: Hatch

CEL: Cells

OGNL : Organelle changes

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.

ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Non crystalline silica
Synonyms	Amorphous silica (silicon dioxide), silica gel, diatomaceous earth, silica anhydrous, colloidal silica.
CAS number	NA (7631-86-9 amorphous silica surrogate used for information on chemical information sheet)
Molecular formula	O_2Si
Product name	

Physical Properties	Value	Reference
Phase/state	Amorphous powder.	HSDB, 2011
Molecular weight	60.1 g/mol	HSDB, 2011
Melting point	1710^{o}C	HSDB, 2011
Boiling point	2230^{o}C	HSDB, 2011
Solubility	Insoluble	HSDB, 2011

Other Relevant Factors	Value	Reference
Reactivity		
Species & Reaction type	Vinyl acetate vapour may react vigorously in contact with silica gel.	HSDB, 2011
pH	NA	

Notes: 1 . Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line : 4 July 2011.
NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2010	Human Health	NA	
IARC	2006	Carcinogen risk	3 (unitless)	*Not classifiable as to its carcinogenicity to humans*
ANZECC	2000	Stock water	NA	

Aquatic Ecotoxicological Data

Acute toxicity data							
Species Scientific Name	**Species Common Name**	**Endpoint**	**Effect**	**Effect Measurement**	**Test time (Days)**	**Conc (µg/L)**	**Reference**
Dicentrarchus labrax	Sea Bass	LOEL	GRO	GAIN	60	10%	ECOTOX

SW data only available for non-crystalline silica

Notes:

ATSDR, 2010. Agency for Toxic Substances and Disease Registry, Toxicological Profile for Boron. US Department of Health and Human Services. Accessed at : http://www.atsdr.cdc.gov/ToxProfiles/tp26.pdf.

ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.
Hickey CW; N.Z. J Mar Freshwater Res 23 (1): 131-137 (1989). Available from the ECOTOX database on Boric acid (10043-35-3) at: http://www.epa.gov/cgi-bin/ecotox_quick_search as of May 13, 2005.
European Chemicals Bureau; IUCLID Dataset, Boric acid (10043-35-3) (2000 CD-ROM edition). Available from, as of May 18, 2005: http://ecb.jrc.it/esis/esis.php.
ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Polypropylene glycol
Synonyms	alpha-Hydro-omega-hydroxypoly(oxypropylene), Oxirane, methyl-, homopolymer, poly(oxy(methyl-1,2-ethanediyl)), alpha-hydro-omega-hydroxy-, Poly(propanediols).
CAS number	25322-69-4 (HSDB, 2011)
Molecular formula	$(C_3\text{-}H_6\text{-}O)$ MULT-H_2-O
Product name	

Physical Properties	Value	Reference
Phase/state	Clear, lightly coloured, slightly oily, viscous liquid	HSDB 2011
Molecular weight	76.11	HSDB 2011
Melting point	372.80 (estimate)	EPISUITE
Boiling point	112.61 (estimate)	EPISUITE
Density/ specific gravity	1.002-1.007	HSDB 2011
Vapour pressure	<0.01 mm Hg at 20^{o}C	HSDB 2011
Solubility	1.654 x 10 ^{4} mg/l at 25 ^{o}C (estimate)	EPISUITE
Henrys law constant	3.14 x 10^{-14} atm m^3/mole (estimate)	EPISUITE
Organic carbon partition coefficient (Koc)	10	EPISUITE
Log organic carbon partition coefficient (log Koc)	1	EPISUITE
Log octanol-water partition coefficient (log Kow)	-0.21	EPISUITE

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation	NA	
Aerobic BOD	NA	
Anaerobic BOD	NA	
Biowin7 (Anaerobic Model Prediction)	Not readily biodegradable	EPISUITE
Fugacity		
Air %	1.82 x 10^{-6} (estimate)	EPISUITE
Water %	30.6 (estimate)	EPISUITE
Soil %	69.4 (estimate)	EPISUITE
Sediment %	0.0688 (estimate)	EPISUITE
Bioconcentration factor (BCF)	3.162 L/kg wet wt (estimate)	EPISUITE
Biotransformation half-life	0.006737 days (estimate)	EPISUITE

Notes: 1 EPI Suite™ v4.0, United States Environmental Protection Agency.

2. Hazardous Substances Data Bank (HSDB) National library of Medicine (Calcium chloride) accessed on line : 9 June 2011.

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (μg/L)**	**Reference**
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	4	1700000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LC50	MOR	MORT	4	10000000	ECOTOX

Media Type: freshwater

IMBL: immobile

ABND: abundance

ITX : Intoxicated

MOR/MORT: Mortality

POP: Population

REP: Reproduction

PROG : Progeny Counts

SEXR : Sex ratio

FCND: Fecundity

HTCH : Hatch

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric

mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7. ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Sodium Carbonate
Synonyms	Soda ash, Solvay soda, bisodium carbonate, carbonic acid, crystol carbonate, disodium carbonate, sodium carbonate.
CAS number	497-19-8
Molecular formula	Na_2Co_3
Product name	Soda Ash M3

Physical Properties	Value	Reference
Phase/state	White powder	HSDB, 2011
Molecular weight	105.99 g/mol	HSDB, 2011
Melting point	851°C	HSDB, 2011
Boiling point	Decomposition	IPCS, 2011
Solubility	Soluble in 3.5 parts water 215g/l at 20°C	HSDB, 2011 IPCS, 2011

Other Relevant Factor	Value	Reference
Reactivity		
Species Reaction type	The sodium ion will not adsorb to particulate matter, but remains in the aqueous phase. In water the carbonate ions will re-equilibrate until an equilibrium is established. The main equilibria are: HCO3 - ↔ CO3 2- + H+ pKa = 10.35 CO2 + H2O ↔ HCO3 - + H+ pKa = 6.33 The carbonate will finally be incorporated into the inorganic and organic carbon cycle.	IPCS, 2011
pH		
acid / alkaline	Aqeous solution is strongly alkaline	Merck, 1996
pH (solution)	Strong alkaline compound with a pH of 11.6 for a 0.1M aqeous solution.	IPCS, 2011

Notes: 1. Schlumberger Material Safety Data Sheet M003. Issue Date: 11 January 2006.

2. Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line: 24 March 2011.

3. International Program on Chemical Saftey (IPCS). Chemical Safety Information from Intergovernmental Organisations, INCHEM. Accessed on line : 30 March 2011 at http://www.inchem.org/documents/sids/sids/Naco.pdf.

4. 3. The Merck Index. 1996. An Encyclopedia of Chemicals, Drugs and Biologicals. Merck REserach Laboratories. (12th Ed.) Whitehouse station, NJ.

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	Used to treat drinking water.
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	Not listed in IARC database.
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Acute Toxicity Data							
Species Scientific Name	**Species Common Name**	**Endpoint**	**Effect**	**Effect Measurement**	**Exposure Duration (Days)**	**Conc 1 (µg/L)**	**Reference**
Amphipoda	Scud Order	LC50	MOR	MORT	3	67000	ECOTOX
Amphipoda	Scud Order	LC50	MOR	MORT	4	67000	ECOTOX
Amphipoda	Scud Order	LC50	MOR	MORT	2	176000	ECOTOX
Ceriodaphnia dubia	Water Flea	EC50	ITX	IMBL	2	199820	ECOTOX
Ceriodaphnia dubia	Water Flea	EC50	ITX	IMBL	2	199820	ECOTOX
Ceriodaphnia dubia	Water Flea	EC50	ITX	IMBL	2	226790	ECOTOX
Daphnia magna	Water Flea	LC50*	MOR	MORT	1	265000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	265000	ECOTOX
Daphnia magna	Water Flea	LC50*	MOR	MORT	2	265000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	2.1	280200	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	1	287300	ECOTOX
Poecilia latipinna	Sailfin Molly	LC50	MOR	MORT	2.1	297000	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	4	300000	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	4	300000	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	4	300000	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	SURV	4	320000	ECOTOX
Lepomis macrochirus	Bluegill	LC50*	MOR	MORT	4	320000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	2.1	333200	ECOTOX
Dugesia sp.	Turbellarian, Flatworm	LC50	MOR	MORT	4	341000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	1	347000	ECOTOX
Amphipoda	Scud Order	LC50	MOR	MORT	1	360000	ECOTOX
Dugesia sp.	Turbellarian, Flatworm	LC50	MOR	MORT	2	360000	ECOTOX

Species Scientific Name	Species Common Name	Endpoint	Effect	Effect Measurement	Exposure Duration (Days)	Conc 1 (µg/L)	Reference
Dugesia sp.	Turbellarian, Flatworm	LC50	MOR	MORT	3	360000	ECOTOX
Dugesia sp.	Turbellarian, Flatworm	LC50	MOR	MORT	1	384000	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	1	385000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	1	387500	ECOTOX
Lymnaea sp.	Pond Snail	LC50	MOR	MORT	3	395000	ECOTOX
Lymnaea sp.	Pond Snail	LC50	MOR	MORT	1	4.03E+05	ECOTOX
Lymnaea sp.	Pond Snail	LC50	MOR	MORT	2	403000	ECOTOX
Poecilia latipinna	Sailfin Molly	LC50	MOR	MORT	1	405000	ECOTOX
Lymnaea sp.	Pond Snail	LC50	MOR	MORT	4	411000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	4	524000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	565000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	2.1	565800	ECOTOX
Culex sp.	Mosquito	LC50	MOR	MORT	2	600000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	1	607000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	1	614700	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	4	740000	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	2	840000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	850000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	1020000	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	1	1200000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	1	1420000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	1640000	ECOTOX
Culex sp.	Mosquito	LC50	MOR	MORT	1	1820000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	1	2380000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	2500000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	4850000	ECOTOX

Chronic Toxicity Data

Species Scientific Name	Species Common Name	Endpoint	Effect	Effect Measurement	Exposure Duration (Days)	Conc 1 (ug/L)	
Navicula seminulum	Diatom	EC50	POP	PGRT	4	242000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	4.2	266600	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	4.2	322400	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	4.2	552400	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	4.2	524000	ECOTOX

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.

Name	Sodium Hydroxide
Synonyms	Sodium hydroxide
CAS number	1310-73-2
Molecular formula	NaOH
Product name	Unspecified

Physical Properties	Value	Reference
Phase/state	White orthogonal crystals	HSDB, 2011
Molecular weight	40 g/mol	HSDB, 2011
Melting point	323^{o}C	HSDB, 2011
Boiling point	1388^{o}C	HSDB, 2011
Solubility	1 g dissolves in 0.9 ml water	HSDB, 2011

Other Relevant Factors	Value	Reference
Reactivity		
Species	OH^-/NaOH	
Reaction type	Acid/base	
pH		
acid / alkaline	Alkaline	HSDB, 2011
pH (5% solution)	11	HSDB, 2011

Notes: 1. Halliburton Material Safety Data Sheet M275. Issue Date:16 July 2003.
2. Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line 24 March 2011.
NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	Not listed in IARC database
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Acute Toxicity Data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Ceriodaphnia dubia	Water Flea	EC50	ITX	IMBL	2	40380	ECOTOX
Ceriodaphnia dubia	Water Flea	EC50	ITX	IMBL	2	40380	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	1	125000	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	2	125000	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	4	125000	ECOTOX
Poecilia reticulata	Guppy	LC50	MOR	MORT	1	145000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	1	160000	ECOTOX

Media Type : Freshwater

ITX: Intoxication

IMBL: Immobile

MOR/MORT: Mortality

The asterisk (*) denotes several meanings depending upon the field you are viewing. An asterisk can be used in these fields:

- *Concentration:* This means the reported concentration has been recalculated to meet database conformity. For example, the concentration unit was reported as Molar units, but the standard database unit is micrograms per liter. Another example would be if the reported value was as a metal compound and it was recalculated to the ion level. Note: These recalculations are no longer performed.
- *Endpoint*: This denotes the reported endpoint acronym provided was modified to conform to the standard database acronym terminology. For example, if the author reported a TLM, the endpoint was coded as an LC50*.

Notes:

ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2008: Guidelines for Drinking-water Quality 2008.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points.

ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm

Name	Tetramethylammonium chloride
Synonyms	N,N,N-trimethylmethanaminium chloride
CAS number	75-57-0
Molecular formula	$C_4H_{12}NCl$
Product name	L064

Physical Properties	Value	Reference
Phase/state	Solid	EPISUITE V 4.0
Molecular weight	109.6	EPISUITE v 4.0
Melting point	420^{o}C	EPISUITE V 4.0
Boiling point	NA	
Vapour pressure	1.21 x10^{-8} mm Hg at 25^{o}C	EPISUITE v 4.0
Solubility	1 x 10^{6} mg/Lat 25 deg C	EPISUITE v 4.0
Henrys law constant	1.74x10^{-15} atm m^{3}/mole	EPISUITE v 4.0
Organic carbon partition coefficient (koc)	8.214	EPISUITE v 4.0
Log organic carbon partition coefficient (log Koc)	0.915	EPISUITE v 4.0
Log octanol-water partition coefficient (log Kow)	-4.18	

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation	NA	
Aerobic BOD	NA	
Anaerobic BOD	NA	
Ready Biodegradability Prediction	No	EPISUITE v 4.0
Fugacity		
Air %	0.0012	EPISUITE v 4.0
Water %	32	EPISUITE v 4.0
Soil %	68	EPISUITE v 4.0
Sediment %	0.070	EPISUITE v 4.0
Bioconcentration factor (BCF)	3.2 L/kg (wet weight)	EPISUITE v 4.0
Biotransformation half-life	0.0075 days	EPISUITE v 4.0
Soil adsorption coefficient	0.034-8.2 L/kg	EPISUITE v 4.0

Notes : 1 EPI Suite™ v4.0, United States Environmental Protection Agency.
Product sheet updated in June 2011.

Aquatic ecosystem guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic ecosystem	None	
USEPA	2006	Aquatic ecosystem	None	
Other guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	None	
NZDWS	2008	Drinking water	None	
WHO	2006	Drinking water	None	
USEPA	2006	Human Health	None	
IARC	2006	Carcinogen risk	None	
ANZECC	2000	Stock water	None	

Estimated acute toxicity data							
Species Scientific Name	**Species Common Name**	**Endpoint**	**Effect**	**Effect Measurement**	**Exposure Duration (Days)**	**Conc (ug/L)**	**Reference**
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	462000	ECOTOX

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines. Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, United States Environmental Protection Agency ECOTOX database for alkylbenzyldimethyl quaternary ammonium compounds chlorides (only quaternary ammonium compound in the database with toxicity data for several phyla); and [1] data presented as geometric mean (range), N=4.

Name	Tetrasodium ethylenediaminetetraacetate
Synonyms	Tetrasodium ethylenediaminetetraacetate, Tetrasodium EDTA, Acetic Acid, N,N'-1,2-Ethanediyl bis[N-(carboxymethyl)glycine, sodium salt
CAS number	64-02-8
Molecular formula	$C_{10}H_{16}N_2O_8Na_4$
Product name	Not specified

Physical Properties	Value	Reference
Phase/state	White powder	HSDB, 2011
Molecular weight	380.17 g/mol	HSDB, 2011
Melting point	>300 ^{o}C	HSDB, 2011
Boiling point	572.7 ^{o}C (estimate)	EPISUITE
Density/ specific gravity	6.9 lb/gal apparent density	HSDB 2011
Vapour pressure	1.49 x 10 $^{-12}$ mm Hg at 25 ^{o}C	EPISUITE
Solubility	500 g/L at 20 ^{o}C in water	HSDB, 2011
	1 x 10^{6} at 25 ^{o}C in water	EPISUITE
Henrys law constant	1.18x10 $^{-23}$ atm m^3/mol	HSDB, 2011
Organic carbon partition coefficient (Koc)	312.7	EPISUITE
Log organic carbon partition coefficient (log Koc)	2.495	EPISUITE
Log octanol-water partition coefficient (log Kow)	-13.17*	EPISUITE

*This molar concentration is not possible but results from the extreme Log Kow value predicted by EPISUITE. It has not been relied upon. A measured value for Kow for this compound could not be found.

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation	NA	
Aerobic BOD	NA	
Anaerobic BOD	NA	
Biowin7 (Anaerobic Model Prediction)	Biodegrades fast	EPISUITE
Fugacity		
Air %	1.36 x 10^{-12}	EPISUITE
Water %	18.9	EPISUITE
Soil %	80.9	EPISUITE
Sediment %	0.198	EPISUITE
Bioconcentration factor (BCF)	3.162	EPISUITE
Biotransformation half-life	7.617x 10^{-6}	EPISUITE

Notes: 1 EPI Suite™ v4.1, United States Environmental Protection Agency.

2. Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line: 25 March 2011.

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (μg/L)**	**Reference**
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	4	486000	ECOTOX
Daphnia magna	Water Flea	EC50	MOR	MORT	1	610000	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	4	1030000	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	4	2070000	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	4	3092000	ECOTOX

Media Type: freshwater

IMBL: immobile

ABND: abundance

ITX : Intoxicated

MOR/MORT: Mortality

POP: Population

REP: Reproduction

PROG : Progeny Counts

SEXR : Sex ratio

FCND: Fecundity

HTCH : Hatch

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.
ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Vinylidene Chloride / Methylacrylate
Synonyms	1,1 dichlorothene, 1,1 dichloroethylene, 1,1 DCE, vinylidene dichloride.
CAS number	25038-72-6 (surrogate CAS 75-35-4 (1,1 DCE) used for the information on the chemical information sheet).
Molecular formula	$C_2H_2Cl_2$
Product name	Not specified

Physical Properties	Value	Reference
Phase/state	Colourless liquid	HSDB, 2011
Molecular weight	96.94 g/mol	HSDB, 2011
Melting point	-122.5 ^{o}C	HSDB, 2011
Boiling point	31.7 ^{o}C	HSDB, 2011
Density/ specific gravity	1.2129 at 20^{o}C	HSDB, 2011
Vapour pressure	600 mm Hg at 25^{o}C	HSDB, 2011
Solubility	2,420 mg/L at 25^{o}C	HSDB, 2011
Henrys law constant	2.61 x 10^{-2} atm cu m/mole at 24 ^{o}C	HSDB, 2011
Organic carbon partition coefficient (Koc)	64	HSDB, 2011
Log organic carbon partition coefficient (log Koc)	1.80618	HSDB, 2011
Log octanol-water partition coefficient (log Kow)	2.12	EPISUITE

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation	Biodegradation in water is not expected to be an important fate process, with 1,1-DCE reaching 0% of its theoretical BOD in 4 weeks(11).	HSDB, 2011
Aerobic BOD	1,1-DCE had a biodegradation half-life of 1.25 yrs in ground water from a former manufacturing facility.	HSDB, 2011
Anaerobic BOD	In the microcosms designed to simulate a groundwater environment, 50% of the 1,1-dichloroethylene disappeared in 5-6 months	HSDB, 2011
Biowin7 (Anaerobic Model Prediction)	Does not biodegrades fast	EPISUITE
Fugacity		
Air %	20.8	EPISUITE
Water %	75.1	EPISUITE
Soil %	3.8	EPISUITE
Sediment %	0.257	EPISUITE
Bioconcentration factor (BCF)	11.81	EPISUITE
Biotransformation half-life	0.614 days	EPISUITE

Notes: 1 EPI Suite^{TM} v4.0, United States Environmental Protection Agency.

2. Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line: 04 July 2011.

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	0.38 ug/L	Human consumption of surface water
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	0.03 mg/L	Health guideline value
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	0.03 mg/L	
USEPA	2010	Human Health	2.4×10^2 mg/kg	
IARC	2006	Carcinogen risk	3	Not classifiable as to its carcinogenicity to humans
ANZECC	2000	Stock water	NA	

Surrogate 1,1 DCE 75-35-4 used for aquatic toxicity guidelines.

Aquatic Toxicological Data

Acute Toxicity Data							
Species Scientific Name	**Species Common Name**	**Endpoint**	**Effect**	**Effect Measurement**	**Test time (days)**	**Conc 1 (ug/L)**	**Reference**
Daphnia magna	Water Flea	LC50	MOR	MORT	1	11600	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	11600	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	1	74000	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	4	74000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	79000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	1	98000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	108000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	108000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	116000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	169000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	169000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	175000	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	4	220000	ECOTOX
Chronic Toxicity Data							
Species Scientific Name	**Species Common Name**	**Endpoint**	**Effect**	**Effect Measurement**	**Test time (days)**	**Conc 1 (ug/L)**	**Reference**
Chlamydomonas reinhardtii	Green Algae	EC50	POP	BMAS	3	9120	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	7	29000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	8	29000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	9	29000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	10	29000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	11	29000	ECOTOX

Species Scientific Name	Species Common Name	Endpoint	Effect	Effect Measurement	Test time (days)	Conc 1 (ug/L)	Reference
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	12	29000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	13	29000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	6	74000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	5	97000	ECOTOX
Scenedesmus abundans	Green Algae	EC50	GRO	GGRO	4	410000	ECOTOX
Pseudokirchneriella subcapitata	Green Algae	EC50	POP	ABND	4	560000	ECOTOX

Media Type: freshwater

IMBL: immobile

ABND: abundance

ITX : Intoxicated

MOR/MORT: Mortality

POP: Population

REP: Reproduction

PROG : Progeny Counts

SEXR : Sex ratio

FCND: Fecundity

HTCH : Hatch

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2011: National recommended water quality criteria: 2011. United States Environmental Protection Agency. Accessed at : http://water.epa.gov/scitech/swguidance/standards/current/index.cfm

USEPA 2011: Regional Screening Level Table. United States Environmental Protection Agency Accessed at : http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/pdf/master_sl_table_run_JUN2011.pdf

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.
ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Alkyaryl Sulfonate
Synonyms	Sodium dodecylbenzenesulfonate, benzenesulfonic acid dodecyl sodium salt.
CAS number	25155-30-0
Molecular formula	C18 H30 O3 S.Na
Product name	ClearFRAC LT

Physical Properties	Value	Reference
Phase/state	White to light yellow flakes, granules or powder	HSDB 2012
Molecular weight	348.49	HSDB 2012
Melting point	287.63 ^{o}C	EPISUITE
Boiling point	660.62 ^{o}C	EPISUITE
Density/ specific gravity	1.0 at 20^{o}C for 60% slurry	HSDB 2012
Vapour pressure	2.29 x 10^{-15} mm Hg at 20°C-25^{o}C	EPISUITE
Solubility	8 x 10^{2} mg/L at 25 ^{o}C	HSDB 2012
Henrys law constant	6.27 x 10^{-8} atm m^{3}/mole	HSDB 2012
Log organic carbon partition coefficient (log Koc)	2.04 (calculated from 110.5 Koc)	HSDB, 2012
Organic carbon partition coefficient (Koc)	110.5 (based on solubility of 800 mg/L)	HSDB 2012
Log octanol-water partition coefficient (log Kow)	0.45	HSDB 2012

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation		
Aerobic BOD	appears to be susceptible to aerobic biodegradation with a BOD5/TOC ratio of 0.95	HSDB 2012
Anaerobic BOD	In anaerobic digester sludge assays, strong inhibition was found with 0.69 and 0.1 g/L sodium dodecylbenzenesulfonate	HSDB 2012
Biowin7 (Anaerobic Model Prediction)	Does not biodegrade fast	EPISUITE
Fugacity		
Air %	0.644	EPISUITE
Water %	18.6	EPISUITE
Soil %	74	EPISUITE
Sediment %	6.8	EPISUITE
Bioconcentration factor (BCF)	64 to 130	HSDB 2012
Biotransformation half-life	1.322 days	EPISUITE

Notes: EPI Suite™ v4.0, United States Environmental Protection Agency.

Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line: 12 April 2012.

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Estimated acute toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (ug/L)**	**Reference**
Dugesia japonica	Flatworm	LC50	MOR	MORT	7	230	ECOTOX
Oryzias latipes	Japanese Medaka	LC50	MOR	MORT	2	700	ECOTOX
Cyprinus carpio	Common Carp	LC50	MOR	MORT	1	1000	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	4	1180	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LC50	MOR	MORT	4	1680	ECOTOX
Dunaliella sp.	Green Algae	EC50	BCM	GBCM	1	3300	ECOTOX
Brachionus calyciflorus	Rotifer	EC50	REP	PROG	2	4000	ECOTOX
Phoxinus phoxinus	Minnow	LC50	MOR	MORT	1	4500	ECOTOX
Oncorhynchus kisutch	Coho Salmon,Silver Salmon	LOEC	MOR	MORT	3	5600	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	2	5880	ECOTOX
Phoxinus phoxinus	Minnow	LC50	MOR	MORT	1	6000	ECOTOX
Daphnia magna	Water Flea	EC50	MOR	MORT	2	6300	ECOTOX
Phoxinus phoxinus	Minnow	LC50	MOR	MORT	1	6400	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	4	6500	ECOTOX
Rita rita	Catfish	LC50	MOR	MORT	4	6900	ECOTOX

Estimated acute toxicity data							
Species name	**Common name**	**End point**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (ug/L)**	**Reference**
Rita rita	Catfish	LC50	MOR	MORT	4	6900	ECOTOX
Rita rita	Catfish	LC50	MOR	MORT	4	6926	ECOTOX
Rita rita	Catfish	LC50	MOR	MORT	4	6969	ECOTOX
Rita rita	Catfish	LC50	MOR	MORT	3	7023	ECOTOX
Rita rita	Catfish	LC50	MOR	MORT	4	7079	ECOTOX
Rita rita	Catfish	LC50	MOR	MORT	3	7133	ECOTOX
Rita rita	Catfish	LC50	MOR	MORT	4	7160	ECOTOX
Rita rita	Catfish	LC50	MOR	MORT	2	7286	ECOTOX
Rita rita	Catfish	LC50	MOR	MORT	1	7379	ECOTOX
Rita rita	Catfish	LC50	MOR	MORT	2	7461	ECOTOX
Daphnia magna	Water Flea	EC50	MOR	MORT	2	7500	ECOTOX
Rita rita	Catfish	LC50	MOR	MORT	1	7609	ECOTOX
Ceriodaphnia dubia	Water Flea	EC50	ITX	IMBL	2	7810	ECOTOX
Ceriodaphnia dubia	Water Flea	EC50	ITX	IMBL	2	7810	ECOTOX
Cyprinus carpio	Common Carp	LT50	MOR	MORT	3	8000	ECOTOX
Cyprinus carpio	Common Carp	LT50	MOR	MORT	3	8000	ECOTOX
Cyprinus carpio	Common Carp	LT50	MOR	MORT	3	8000	ECOTOX
Cyprinus carpio	Common Carp	LT50	MOR	MORT	1.666667	8000	ECOTOX
Daphnia magna	Water Flea	EC50	MOR	MORT	2	9500	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	9546	ECOTOX
Daphnia magna	Water Flea	EC50*	ITX	IMBL	1	12000	ECOTOX
Echinogammarus tibaldii	Amphipod	LC50	MOR	MORT	4	14000	ECOTOX
Echinogammarus tibaldii	Amphipod	LC50	MOR	MORT	4	14000	ECOTOX
Echinogammarus tibaldii	Amphipod	LC50	MOR	MORT	4	16000	ECOTOX
Echinogammarus tibaldii	Amphipod	LC50	MOR	MORT	4	16700	ECOTOX
Daphnia magna	Water Flea	EC50*	ITX	IMBL	1	17000	ECOTOX
Cyprinus carpio	Common Carp	LT50	MOR	MORT	1.047	18000	ECOTOX
Cyprinus carpio	Common Carp	LT50	MOR	MORT	1.97	18000	ECOTOX

Estimated acute toxicity data							
Species name	**Common name**	**End point**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (ug/L)**	**Reference**
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	7	19870	ECOTOX
Daphnia pulex	Water Flea	LC50	MOR	MORT	2	19870	ECOTOX
Gammarus italicus	Scud	LC50	MOR	MORT	4	20500	ECOTOX
Gammarus italicus	Scud	LC50	MOR	MORT	1	25000	ECOTOX
Chlorella pyrenoidosa	Green Algae	EC50	POP	GPOP	4	29000	ECOTOX
Oryzias latipes	Japanese Medaka	LC50	MOR	MORT	1	36000	ECOTOX
Oryzias latipes	Japanese Medaka	LC50	MOR	MORT	1	36000	ECOTOX
Oryzias latipes	Japanese Medaka	LC50	MOR	MORT	1	36000	ECOTOX
Oryzias latipes	Japanese Medaka	LC50	MOR	MORT	2	36000	ECOTOX
Oryzias latipes	Japanese Medaka	LC50	MOR	MORT	2	36000	ECOTOX
Oryzias latipes	Japanese Medaka	LC50	MOR	MORT	2	36000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	1	38514	ECOTOX
Pseudokirchneriella subcapitata	Green Algae	EC50	POP	BMAS	4	70270	ECOTOX
Pseudokirchneriella subcapitata	Green Algae	EC50	POP	BMAS	4	171960	ECOTOX

Estimated chronic toxicity data							
Brachionus calyciflorus	Rotifer	NOEC	REP	PROG	2	2500	ECOTOX
Oncorhynchus kisutch	Coho Salmon,Silver Salmon	NOEC	MOR	MORT	3	3100	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	MOR	MORT	7	4000	ECOTOX

Media Type : freshwater

MOR/MORT : Mortality

POP: Population

GPOP: Population changes, general

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.
ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Nitrogen (liquid form)
Synonyms	Nitrogen elemental, liquid nitrogen, diatomic nitrogen, dinitrogen, mol nitrogen.
CAS number	7727-37-9
Molecular formula	N2
Product name	ClearFRAC LT

Physical Properties	Value	Reference
Phase/state	Colourless Gas	HSDB, 2012
Molecular weight	28.013	HSDB, 2012
Melting point	-210.01 ^{o}C	HSDB, 2012
Boiling point	-195.79 ^{o}C	HSDB, 2012
Density/ specific gravity	1.251 g/L at 0^{o}C	HSDB, 2012
Vapour pressure	1 atm @ 77.347 degrees kelvin	HSDB, 2012
Solubility	1.81 x 10^{4} mg/L at 21 ^{o}C	HSDB, 2012
Henrys law constant	1.94 x 10^{-2} atm m^{3}/mole (Bond Method)[1]	EPISUITE
Log organic carbon partition coefficient (log Koc)	1.121 (MCI Method)	EPISUITE
Log octanol-water partition coefficient (log Kow)	0.67	HSDB, 2012

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation	NA	
Aerobic BOD	NA	
Anaerobic BOD	NA	
Biowin7 (Anaerobic Model Prediction)	Does not biodegrade fast	EPISUITE
Fugacity		
Air %	55.4	EPISUITE
Water %	42.2	EPISUITE
Soil %	2.21	EPISUITE
Sediment %	0.101	EPISUITE
Bioconcentration factor (BCF)	3.162 L/kg	EPISUITE
Biotransformation half-life	0.03954 days	EPISUITE

Notes: EPI Suite™ v4.0, United States Environmental Protection Agency.
Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line: 12 April 2012.
NA - not available

[1] Estimated value is outside of estimation domain

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Estimated acute toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Concentration (ug/L)**	**Reference**
Cloeon dipterum	Mayfly	LC50	MOR	MORT	1	>40000	ECOTOX
Cloeon dipterum	Mayfly	LC50	MOR	MORT	2	>40000	ECOTOX

Media Type : freshwater

MOR/MORT : Mortality

POP: Population

GPOP: Population changes, general

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

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Name	Propane 1,2 diol
Synonyms	Methylethylene glycol, propylene glycol, trimethyl glycol
CAS number	57-55-6
Molecular formula	C3-H8-O2
Product name	ClearFRAC LT

Physical Properties	Value	Reference
Phase/state	Colourless viscous liquid	HSDB, 2012
Molecular weight	76.09	HSDB, 2012
Melting point	-60 ^{o}C	HSDB, 2012
Boiling point	187.6 ^{o}C	HSDB, 2012
Density/ specific gravity	1.0361 g/cm^{3} at 20^{o}C	HSDB, 2012
Vapour pressure	0.13 mm Hg at 25^{o}C	HSDB, 2012
Solubility	1 x 10^{6} mg/L at 20 ^{o}C	HSDB ,2012
Henrys law constant	1.3 x 10^{-8} atm m^{3}/mole	HSDB, 2012
Organic carbon partition coefficient (Koc)	1	HSDB, 2012
Log organic carbon partition coefficient (log Koc)	0 (MCI Method)	EPISUITE
Log octanol-water partition coefficient (log Kow)	-0.92	HSDB 2012

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation		
Aerobic BOD	Propylene glycol achieved 64% of its theoretical BOD using a sewage inoculum and a 5 day incubation period	HSDB, 2012
Anaerobic BOD	Using an activated sludge or digester sludge incubated under anaerobic conditions, propylene glycol was completely degraded within 5-9 days	HSDB, 2012
Biowin7 (Anaerobic Model Prediction)	Does biodegrade fast	EPISUITE
Fugacity		
Air %	0.397	EPISUITE
Water %	34.5	EPISUITE
Soil %	65	EPISUITE
Sediment %	0.061	EPISUITE
Bioconcentration factor (BCF)	3	HSDB, 2012
Biotransformation half-life	0.0087 days	EPISUITE

Notes: EPI Suite™ v4.0, United States Environmental Protection Agency.

Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line: 09 May 2012.

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	3.1 x 10^5 ug/L	USEPA tapwater guidelines
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Estimated acute toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Concentration (ug/L)**	**Reference**
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	710000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	790000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	1	1000000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	2	1000000	ECOTOX
Oryzias latipes	Japanese Medaka	LC50	MOR	MORT	1	1000000	ECOTOX
Oryzias latipes	Japanese Medaka	LC50	MOR	MORT	1	1000000	ECOTOX
Oryzias latipes	Japanese Medaka	LC50	MOR	MORT	1	1000000	ECOTOX
Oryzias latipes	Japanese Medaka	LC50	MOR	MORT	2	1000000	ECOTOX
Oryzias latipes	Japanese Medaka	LC50	MOR	MORT	2	1000000	ECOTOX
Oryzias latipes	Japanese Medaka	LC50	MOR	MORT	2	1000000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	1020000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	4919000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	1	5000000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	1	5000000	ECOTOX

Estimated acute toxicity data							
Species name	Common name	Endpoint	Effect	Effect measure	Test time (days)	Concentration (ug/L)	Reference
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	5122000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	1	10000000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	2	10000000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	15052000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	18340000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	34060000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	55770000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	62000000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	MOR	MORT	7	270000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	MOR	MORT	4	600000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	MOR	MORT	2	660000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	MOR	MORT	3	660000	ECOTOX
Daphnia magna	Water Flea	NOEC	ITX	IMBL	2	1000000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	MOR	MORT	7	11530000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	MOR	MORT	2	13020000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	MOR	MORT	3	29000000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	MOR	MORT	4	52930000	ECOTOX

Estimated chronic toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Concentration (ug/L)**	**Reference**
Pimephales promelas	Fathead Minnow	NOEC	GRO	GGRO	7	98000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	GREP	3	600000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	GGRO	7	11530000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	GREP	3	13020000	ECOTOX

Estimated chronic toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Concentration (ug/L)**	**Reference**
Pimephales promelas	Fathead Minnow	IC25	GRO	GGRO	7	112000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC25	REP	GREP	3	640000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC25	REP	GREP	3	640000	ECOTOX
Pimephales promelas	Fathead Minnow	IC25	GRO	GGRO	7	6941000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC25	REP	GREP	3	13470000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC25	REP	GREP	3	13470000	ECOTOX

Media Type : freshwater

MOR/MORT : Mortality

POP: Population

GPOP: Population changes, general

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

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ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Sodium Hypochlorite
Synonyms	Hypochlorous acid, sodium salt; clorox
CAS number	10377-60-3
Molecular formula	NaOCl
Product name	BE-7

Physical Properties	Value	Reference
Phase/state	liquid	2
Molecular weight	74.4 g/mol	2
Melting point	18^{o}C	2
Boiling point	111^{o}C	2
Solubility	29.3 g/100 g (0 deg C) in water	2

Other Relevant Factors	Value	Reference
Reactivity		
Species	$NaOCl + H_2O \leftrightarrow NaOH + HOCl \leftrightarrow Na^+ + OH^- + H^+ + OCl^-$	
Reaction type	Acid/base, saponification, anti-microbial, oxidising agent	2
pH		
acid / alkaline	alkaline	2
pH (5% solution)	11.1 – 11.6	

Notes:
1. Halliburton Material Safety Data Sheet BE-7. Issue Date:04 January 2011
2. Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line 24 March 2011.

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	Not listed in IARC database
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Acute Toxicity Data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Water Flea	Ceriodaphnia dubia	LC50	MOR	MORT	1	5	ECOTOX
Water Flea	Ceriodaphnia dubia	LC50	MOR	MORT	1	6	ECOTOX
Water Flea	Ceriodaphnia dubia	LC50	MOR	MORT	1	35	ECOTOX
Water Flea	Ceriodaphnia dubia	LC50	MOR	MORT	1	48	ECOTOX
Water Flea	Ceriodaphnia dubia	LC50	MOR	MORT	1	80	ECOTOX
Water Flea	Daphnia magna	LC50	MOR	MORT	2	32	ECOTOX
Water Flea	Daphnia magna	LC50	MOR	MORT	2	55	ECOTOX
Isopod	Caecidotea sp.	LC50	MOR	MORT	4	110	ECOTOX
Mucket	Actinonaias ligamentina	EC50	MOR	SURV	1	74	ECOTOX
Mucket	Actinonaias ligamentina	EC50	MOR	SURV	1	74	ECOTOX
Mucket	Actinonaias ligamentina	EC50	MOR	SURV	2	40	ECOTOX
Mucket	Actinonaias ligamentina	EC50	MOR	SURV	2	40	ECOTOX
Mucket	Actinonaias ligamentina	EC50	MOR	SURV	2	48	ECOTOX
Mucket	Actinonaias ligamentina	EC50	MOR	SURV	2	48	ECOTOX
Mucket	Actinonaias ligamentina	EC50	MOR	SURV	2	52	ECOTOX
Mucket	Actinonaias ligamentina	EC50	MOR	SURV	2	52	ECOTOX
Rio Grande Silvery Minnow	Hybognathus amarus	LC50	MOR	MORT	1	126	ECOTOX
Rio Grande Silvery Minnow	Hybognathus amarus	LC50	MOR	MORT	2	126	ECOTOX
Rio Grande Silvery Minnow	Hybognathus amarus	LC50	MOR	MORT	3	115	ECOTOX
Rio Grande Silvery Minnow	Hybognathus amarus	LC50	MOR	MORT	4	115	ECOTOX
Isopod	Caecidotea sp.	LC50	MOR	MORT	4	185	ECOTOX
Water Flea	Ceriodaphnia dubia	LC50	MOR	MORT	1	140	ECOTOX
Aquatic Sowbug	Asellus intermedius	LC50	MOR	MORT	4	32000	ECOTOX
Water Flea	Daphnia magna	LC50	MOR	MORT	4	2100	ECOTOX
Calanoid Copepod	Diacyclops thomasi	LC50*	MOR	MORT	4	69	ECOTOX
Scud	Gammarus fasciatus	LC50	MOR	MORT	4	4000	ECOTOX
Scud	Hyalella azteca	LC50	MOR	MORT	4	78	ECOTOX
Scud	Hyalella azteca	LC50	MOR	MORT	4	301	ECOTOX
Aquatic Sowbug	Lirceus alabamale	LC50	MOR	MORT	4	145	ECOTOX
Aquatic Sowbug	Lirceus alabamale	LC50	MOR	MORT	4	155	ECOTOX
Channel Catfish	Ictalurus punctatus	LC50	MOR	MORT	4	70	ECOTOX
Channel Catfish	Ictalurus punctatus	LC50	MOR	MORT	4	450	ECOTOX
Bluegill	Lepomis macrochirus	LC50	MOR	MORT	1	2100	ECOTOX
Bluegill	Lepomis macrochirus	LC50	MOR	MORT	4	4300	ECOTOX
Bluegill	Lepomis macrochirus	LC50	MOR	MORT	4	5300	ECOTOX
Bluegill	Lepomis macrochirus	LC50	MOR	MORT	4	580	ECOTOX
Bluegill	Lepomis macrochirus	LC50	MOR	MORT	4	1000	ECOTOX
Bluegill	Lepomis macrochirus	LC50	MOR	MORT	4	440	ECOTOX
Bluegill	Lepomis macrochirus	LC50	MOR	MORT	4	910	ECOTOX
Bluegill	Lepomis macrochirus	LC50	MOR	MORT	4	2130	ECOTOX
Bluegill	Lepomis macrochirus	LC50	MOR	MORT	4	2480	ECOTOX
Bluegill	Lepomis macrochirus	LC50	MOR	MORT	4	880	ECOTOX
Common Shiner	Luxilus cornutus	LC50	MOR	MORT	1	1350	ECOTOX
Inland Silverside	Menidia beryllina	LC50	MOR	MORT	4	193	ECOTOX
Golden Shiner	Notemigonus crysoleucas	LC50	MOR	MORT	4	304	ECOTOX
Golden Shiner	Notemigonus crysoleucas	LC50	MOR	MORT	4	572	ECOTOX
Rainbow Trout	Oncorhynchus mykiss	LC50	MOR	MORT	1	430	ECOTOX
Rainbow Trout	Oncorhynchus mykiss	LC50	MOR	MORT	1	1350	ECOTOX

Acute Toxicity Data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Rainbow Trout	Oncorhynchus mykiss	LC50	MOR	MORT	2	350	ECOTOX
Rainbow Trout	Oncorhynchus mykiss	LC50	MOR	MORT	4	59	ECOTOX
Rainbow Trout	Oncorhynchus mykiss	LC50	MOR	MORT	4	90	ECOTOX
Rainbow Trout	Oncorhynchus mykiss	LC50	MOR	MORT	4	374	ECOTOX
Rainbow Trout	Oncorhynchus mykiss	LC50	MOR	MORT	4	30 to 190	ECOTOX
Rainbow Trout	Oncorhynchus mykiss	LC50	MOR	MORT	4	30 to 70	ECOTOX
Rainbow Trout	Oncorhynchus mykiss	LC50	MOR	MORT	4	1940	ECOTOX
Rainbow Trout	Oncorhynchus mykiss	LC50	MOR	MORT	4	200	ECOTOX
Rainbow Trout	Oncorhynchus mykiss	LC50	MOR	MORT	4	4180	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	1	114	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	1	5600	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	1	6300	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	2	114	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	2	5900	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	2	5900	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	3	114	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	114	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	5600*	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	5900	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	5900	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	10000	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	140	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	170	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	350	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	720	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	790	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	80	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	1370	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	1560	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	180	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	390	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	440	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	580	ECOTOX
Yellow Fever Mosquito	Aedes aegypti	LC50	MOR	MORT	1	1070	ECOTOX
Southern House Mosquito	Culex quinquefasciatus	LC50	MOR	MORT	1	710	ECOTOX
Rotifer	Brachionus calyciflorus	LC50	MOR	MORT	1	370	ECOTOX
Mucket	Actinonaias ligamentina	EC50	MOR	SURV	1	100	ECOTOX
Mucket	Actinonaias ligamentina	EC50	MOR	SURV	1	100	ECOTOX
Mucket	Actinonaias ligamentina	EC50	MOR	SURV	1	100	ECOTOX
Mucket	Actinonaias ligamentina	EC50	MOR	SURV	1	100	ECOTOX
Dwarf Wedge Mussel	Alasmidonta heterodon	EC50	MOR	SURV	1	100	ECOTOX
Dwarf Wedge Mussel	Alasmidonta heterodon	EC50	MOR	SURV	2	100	ECOTOX
Oyster Mussel	Epioblasma capsaeformis	EC50	MOR	SURV	10	29	ECOTOX
Oyster Mussel	Epioblasma capsaeformis	EC50	MOR	SURV	2	100	ECOTOX
Oyster Mussel	Epioblasma capsaeformis	EC50	MOR	SURV	4	100	ECOTOX
Wavy-Rayed Lampmussel	Lampsilis fasciola	EC50	MOR	SURV	1	100	ECOTOX
Wavy-Rayed Lampmussel	Lampsilis fasciola	EC50	MOR	SURV	1	100	ECOTOX
Wavy-Rayed Lampmussel	Lampsilis fasciola	EC50	MOR	SURV	2	100	ECOTOX
Wavy-Rayed	Lampsilis fasciola	EC50	MOR	SURV	2	100	ECOTOX

Acute Toxicity Data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Lampmussel							
Neosho Mucket	Lampsilis rafinesqueana	EC50	MOR	SURV	1	100	ECOTOX
Neosho Mucket	Lampsilis rafinesqueana	EC50	MOR	SURV	10	54	ECOTOX
Neosho Mucket	Lampsilis rafinesqueana	EC50	MOR	SURV	2	100	ECOTOX
Neosho Mucket	Lampsilis rafinesqueana	EC50	MOR	SURV	2	53	ECOTOX
Neosho Mucket	Lampsilis rafinesqueana	EC50	MOR	SURV	4	100	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	1	100	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	1	100	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	1	47	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	1	47	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	1	67	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	1	67	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	1	81	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	1	81	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	1	82	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	1	82	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	1	90	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	1	90	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	10	56	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	10	97	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	100	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	100	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	100	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	100	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	34	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	34	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	57	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	57	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	60	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	60	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	70	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	70	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	79	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	79	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	4	100	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	4	100	ECOTOX
Pink Papershell	Potamilus ohiensis	EC50	MOR	SURV	1	58	ECOTOX
Pink Papershell	Potamilus ohiensis	EC50	MOR	SURV	2	25	ECOTOX
Ellipse	Venustaconcha ellipsiformis	EC50	MOR	SURV	1	76	ECOTOX
Ellipse	Venustaconcha ellipsiformis	EC50	MOR	SURV	2	44	ECOTOX
Rainbow	Villosa iris	EC50	MOR	SURV	1	50	ECOTOX
Rainbow	Villosa iris	EC50	MOR	SURV	10	100	ECOTOX
Rainbow	Villosa iris	EC50	MOR	SURV	10	16	ECOTOX
Rainbow	Villosa iris	EC50	MOR	SURV	10	22	ECOTOX
Rainbow	Villosa iris	EC50	MOR	SURV	2	100	ECOTOX
Rainbow	Villosa iris	EC50	MOR	SURV	2	100	ECOTOX
Rainbow	Villosa iris	EC50	MOR	SURV	2	43	ECOTOX
Rainbow	Villosa iris	EC50	MOR	SURV	2	80	ECOTOX
Rainbow	Villosa iris	EC50	MOR	SURV	4	100	ECOTOX
Rainbow	Villosa iris	EC50	MOR	SURV	4	100	ECOTOX
Rainbow	Villosa iris	EC50	MOR	SURV	4	68	ECOTOX
Zebra Mussel	Dreissena polymorpha	LC50	MOR	MORT	9	1130	ECOTOX
Zebra Mussel	Dreissena polymorpha	LC50	MOR	MORT	9	1610	ECOTOX
Zebra Mussel	Dreissena polymorpha	LC50	MOR	MORT	9	1640	ECOTOX

Acute Toxicity Data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Zebra Mussel	Dreissena polymorpha	LC50	MOR	MORT	9	2110	ECOTOX
Liver Elimia, River Snail	Elimia livescens	LC50	MOR	MORT	1	10400	ECOTOX
Liver Elimia, River Snail	Elimia livescens	LC50	MOR	MORT	2	6200	ECOTOX
Pond Snail	Lymnaea emarginata ssp. angulata	LC50	MOR	MORT	1	21800	ECOTOX
Pond Snail	Lymnaea emarginata ssp. angulata	LC50	MOR	MORT	2	13600	ECOTOX
Pouch Snail	Physa integra	LC50	MOR	MORT	1	2000	ECOTOX
Pouch Snail	Physa integra	LC50	MOR	MORT	2	1800	ECOTOX
Snail, Marsh Rams-Horn	Planorbella trivolvis	LC50	MOR	MORT	4	59000	ECOTOX
Turbellarian, Flatworm	Dugesia tigrina	LC50	MOR	MORT	4	32000	ECOTOX
Oligochaete, Worm	Lumbriculus variegatus	LC50	MOR	MORT	4	3200	ECOTOX

Chronic Toxicity Data							
Ceriodaphnia dubia	Water Flea	NOEC	REP	GREP	10	48	ECOTOX
Algae	Algae	MATC	POP	BMAS	28	50	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	REP	GREP	10	66	ECOTOX
Algae	Algae	MATC	POP	BMAS	24	144	ECOTOX
Algae	Algae	MATC	POP	BMAS	28	175	ECOTOX
Algae	Algae	MATC	POP	DVRS	24	144	ECOTOX

Media Type : Freshwater

REP: REporduction

GREP: Reproduction, general,

BMAS: Biomass

DVRS : Diversity

POP: Population

MOR/MORT : Mortality

SURV : Survival

Notes:

ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.
USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.
NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.
WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.

ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Trimethyl -3- [(1-oxooctadecyl) amino] propylammonium methyl sulphate Product sheet based on modelled data
Synonyms	1-Propanaminium, N,N,N-trimethyl-3-[(1-oxooctadecyl)amino]- ,methyl sulphate, 2-(3 aminophenyl) n phenylacetamide, N,N,N - Trimethyl -3-((1-oxooctadecyl) amino) -1- propanaminium methyl sulfate
CAS number	19277-88-4
Molecular formula	C25 H54 N2O5S1
Product name	ClearFRAC LT

Physical Properties	Value	Reference
Phase/state	NA	
Molecular weight	494.78	EPISUITE
Melting point	331.56^{o}C	EPISUITE
Boiling point	754.66 ^{o}C	EPISUITE
Density/ specific gravity	NA	
Vapour pressure	1.89 x 10^{-18} mm Hg at 25^{o}C	EPISUITE
Solubility	0.01494 mg/L at 25 ^{o}C	EPISUITE
Henrys law constant	2.3 x 10^{-20} atm m^{3}/mole (Bond Method)	EPISUITE
Log organic carbon partition coefficient (log Koc)	5.285 (MCI Method)	EPISUITE
Log octanol-water partition coefficient (log Kow)	5.52 (KOWWIN)	EPISUITE

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation	NA	
Aerobic BOD	NA	
Anaerobic BOD	NA	
Biowin7 (Anaerobic Model Prediction)	Does not biodegrade fast	EPISUITE
Fugacity		
Air %	4.66 x 10^{-5}	EPISUITE
Water %	4.56	EPISUITE
Soil %	55.2	EPISUITE
Sediment %	40.2	EPISUITE
Bioconcentration factor (BCF)	70.79 L/kg wet wt	EPISUITE
Biotransformation half-life	1.034 days	EPISUITE

Notes: EPI Suite™ v4.0, United States Environmental Protection Agency.

Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line: 12 April 2012.

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Estimated acute toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Concentration (ug/L)**	**Reference**
-	Fish	LC50	MOR	MORT	4	105	ECOSAR v1.0
-	Green Algae	EC50	MOR	MORT	4	114	ECOSAR v1.0
-	Daphnid	LC50	MOR	MORT	2	199	ECOSAR v1.0
-	Daphnid	LC50	MOR	MORT	2	354	ECOSAR v1.0
-	Fish	LC50	MOR	MORT	4	400	ECOSAR v1.0
-	Green Algae	EC50	MOR	MORT	4	646	ECOSAR v1.0

Media Type : freshwater

MOR/MORT : Mortality

POP: Population

GPOP: Population changes, general

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.
ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Trimethylammonium chloride Assessed based on 593-81-7 Cas No.
Synonyms	Methanamine, N,N dimethyl hydrochloride, trimethylamine hydrochloride, trimethylamine monohydrochloride
CAS number	8030-78-3 (provided by Santos). 593-81-7 listed in HSDB.
Molecular formula	C3-H9-N.Cl-H
Product name	ClearFRAC LT

Physical Properties	Value	Reference
Phase/state	Monoclinic Crystals from Alcohol	HSDB, 2012
Molecular weight	95.57	HSDB, 2012
Melting point	277.5 ^{o}C	HSDB, 2012
Boiling point	Sublimes at 200 ^{o}C	HSDB, 2012
Density/ specific gravity	1.03 g/m^{3} at 20^{o}C	IUCLID 2000
Vapour pressure	1.66 x 10^{-6} mm Hg at 25^{o}C	HSDB, 2012
Solubility	1 x 10^{6} mg/L at 20 ^{o}C	IUCLID 2000
Henrys law constant	2.3 x 10^{-12} atm m^{3}/mole (Bond Method)	EPISUITE
Log organic carbon partition coefficient (log Koc)	1.004 (MCI Method)	EPISUITE
Log octanol-water partition coefficient (log Kow)	-2.73 (MCL Method)	EPISUITE

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation	NA	
Aerobic BOD	NA	
Anaerobic BOD	NA	
Biowin7 (Anaerobic Model Prediction)	Does not biodegrade fast	EPISUITE
Fugacity		
Air %	5.4 x 10^{-5}	EPISUITE
Water %	30.5	EPISUITE
Soil %	69.4	EPISUITE
Sediment %	0.07	EPISUITE
Bioconcentration factor (BCF)	3.162 L/kg wet wt	EPISUITE
Biotransformation half-life	0.01301 days	EPISUITE

Notes: EPI Suite™ v4.0, United States Environmental Protection Agency. (Cas no. 593-81-7).

Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line: 12 April 2012 (Cas no. 593-81-7).

IUCLID (2000) European Commission, European Chemicals Bureau, IUCLID Dataset Trimethylammonium Chloride (593-81-7) accessed on line 13 April 2012.

NA - not available.

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Estimated Chronic toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Concentration (ug/L)**	**Reference**
Microcystis aeruginosa	Blue-Green Algae	EC50	POP	ABND	4	120	ECOTOX
Pseudokirchneriella subcapitata	Green Algae	EC50	POP	ABND	4	190	ECOTOX
Navicula pelliculosa	Diatom	EC50	POP	ABND	4	200	ECOTOX

Cas no. 593-81-7 used for Ecotox data

Media Type : freshwater

MOR/MORT : Mortality

POP: Population

GPOP: Population changes, general

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.

ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

APPENDIX E.2 HALLIBURTON WATER AND GUAR BASED SYSTEMS

Name	1,2-benzisothiazolin-3-one
Synonyms	1,2 benzisothiazol 3 (2H) one, proxel PL
CAS number	2634-33-5
Molecular formula	C_7H_5NOS
Product name	

Physical Properties	Value	Reference
Phase/state	Solid, faintly yellow, forms crystals	Sigma-Aldrich 2007
Molecular weight	151.2 g/mol	Sigma-Aldrich 2007
Melting point	121.6^{o}C (estimate)	EPISUITE
Boiling point	339.5 ^{o}C (estimate)	EPISUITE
Density/ specific gravity	NA	
Vapour pressure	2.57 x 10^{-5} mm Hg at 25^{o}C (estimate)	EPISUITE
Solubility	2.143 x 10^{4}mg/L at 25^{o}C (estimate)	EPISUITE
Henrys law constant	6.92 x 10^{-9} atm m^3/mol (estimate)	EPISUITE
Organic carbon partition coefficient (Koc)	34.48 (MCI Method (estimate))	EPISUITE
Log organic carbon partition coefficient (log Koc)	1.538 (MCI Method) (estimate)	EPISUITE
Log octanol-water partition coefficient (log Kow)	0.64 (estimate)	EPISUITE

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation	NA	
Aerobic BOD	NA	
Anaerobic BOD	NA	
Biowin7 (Anaerobic Model Prediction)	Does not biodegrade fast	EPISUITE
Fugacity		
Air %	0.129 (estimate)	EPISUITE
Water %	24.4 (estimate)	EPISUITE
Soil %	75.4 (estimate)	EPISUITE
Sediment %	0.0796 (estimate)	EPISUITE
Bioconcentration factor (BCF)	3.162 L/kg wet wt (estimate)	EPISUITE
Biotransformation half-life	0.2548 days (estimate)	EPISUITE

Notes: 1 EPI Suite^{TM} v4.0, United States Environmental Protection Agency.

2. Sigma Aldrich (2007). 1,2 benzisothiazolin 3 one Material Safety Data Sheet. Accessed on 7th June 2011. Accessed at : http://www.hopefortruth.com/LBAM_Forms/bensisothiazol%20MSDS.pdf

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	

Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (μg/L)**	**Reference**
Oncorhynchus mykiss	Rainbow Trout	LC50	MOR	MORT	4	1600	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	2	4400	ECOTOX

Media Type: freshwater

IMBL: immobile

ABND: abundance

ITX : Intoxicated

MOR/MORT: Mortality

POP: Population

REP: Reproduction

PROG : Progeny Counts

SEXR : Sex ratio

FCND: Fecundity

HTCH : Hatch

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.
ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Acetic Acid
Synonyms	Glacial Acetic Acid, ethanoic acid
CAS number	64-19-7
Molecular formula	C2-H4-O2
Product name	Acetic Acid 60%

Physical Properties	Value	Reference
Phase/state	liquid	MSDS, 2010
Molecular weight	60.05 g/mol	HSDB, 2011
Melting point	16.6 ^{o}C	HSDB, 2011
Boiling point	117.9 ^{o}C	HSDB, 2011
Density/ specific gravity	1.05 at 20^{o}C	HSDB, 2011
Vapour pressure	15.7 mm Hg at 25^{o}C /Extrapolated	HSDB, 2011
Solubility	Miscible with water 4.759 x 10^{5} at 25 ^{o}C	HSDB, 2011 EPISUITE
Henrys law constant	1X10^{-7} atm-cu m/mol at 25^{o}C	HSDB, 2011
Log organic carbon partition coefficient (log Koc)	Koc = 1, Log Koc = 0.00 (MCI method)	EPISUITE
Log octanol-water partition coefficient (log Kow)	-0.17 L/kg	HSDB, 2011
pH	1.38	MSDS, 2010

Persistence/ Bioaccumulation	Value	Reference
Biowin7 (Anaerobic Model Prediction)	Biodegrades Fast	EPISUITE
Ready Biodegradability Prediction	Yes	EPISUITE
Fugacity		
Air %	2.66	EPISUITE
Water %	35	EPISUITE
Soil %	62.3	EPISUITE
Sediment %	0.0619	EPISUITE
Bioconcentration factor (BCF)	3.2 (fish) No potential for biological accumulation or food chain contamination	HSDB, 2011 Environment Canada, 1981
Biotransformation half-life	0.0762 days	EPISUITE

Notes: 1 EPI Suite™ v4.0, United States Environmental Protection Agency.

2 Halliburton Material Safety Data Sheet Acetic Acid 60%. Issue Date: 05 January 2010

3. Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line 29 March 2011

4. Environment Canada; Tech Info for Problem Spills: Acetic Acid (Draft) p.1 (1981).

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2008	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Branchiura sowerbyi	Oligochaete	LC50	MOR	MORT	4	14900	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	1	47000	ECOTOX
Cyprinus carpio	Common Carp	LC50*	MOR	MORT	2	49000	ECOTOX
Cyprinus carpio	Common Carp	LC50*	MOR	MORT	1	69000	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	SURV	4	75000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	3	79000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	79000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	3	88000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	88000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	92000	ECOTOX
-	Shrimp	LC50	MOR	MORT	2	100000	Environment Canada
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	106000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	106000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	122000	ECOTOX
Moina micrura	Water Flea	LC50	MOR	MORT	4	163720	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	1	251000	ECOTOX

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	2	251000	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	4	251000	ECOTOX
Oreochromis mossambicus	Mozambique Tilapia	LC50	MOR	MORT	4	272870	ECOTOX
Leuciscus idus ssp. melanotus	Carp	LC50	MOR	MORT	2	410000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	4.2	426000	ECOTOX
Ictalurus punctatus	Channel Catfish	LC50	MOR	MORT	1	446000	ECOTOX
Ictalurus punctatus	Channel Catfish	LC50	MOR	MORT	2	446000	ECOTOX
Ictalurus punctatus	Channel Catfish	LC50	MOR	MORT	3	446000	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	1	100000 to 1000000	ECOTOX
Daphnia magna	Water Flea	EC50			1	6000000	EPA
Chronic toxicity data							
Navicula seminulum	Diatom	EC50	POP	PGRT	4	73400	ECOTOX
Navicula seminulum	Diatom	EC50	POP	PGRT	4	73900	ECOTOX

Media Type: freshwater

MOR/MORT: Mortality

POP:Population

PGRT : Population Growth Rate

SURV : Survival

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.

EPA/Office of Pollution prevention and toxics; High production Volume (HPV) Challenge program's Robust summaries and Test Plans. Availible from: http://www.epa.gov/chemrtk/viewsrch.htm on Acetic acid and Salts (April 2003) as of February 9, 2004.

Environment Canada; Tech Info for Problem Spills: Acetic Acid (Draft) p.76 (1981).

ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Alcohol C6 - C12 ethoxylated
Synonyms	
CAS number	68439-45-2
Molecular formula	C_{18} H_{38} O_6
Product name	

Physical Properties	Value	Reference
Phase/state		
Molecular weight	350.5	EPISUITE
Melting point	149.56 (estimate)	EPISUITE
Boiling point	414.96 (estimate)	EPISUITE
Density/ specific gravity		
Vapour pressure	3.64 x 10^{-9} mm Hg at 25^{o}C (estimate)	EPISUITE
Solubility	1188 mg/L at 25^{o}C (estimate)	EPISUITE
Henrys law constant	1.77 x 10^{-14} atm m^3/mole (estimate)	EPISUITE
Organic carbon partition coefficient (Koc)	13.6 (estimate)	EPISUITE
Log organic carbon partition coefficient (log Koc)	1.14 (estimate)	EPISUITE
Log octanol-water partition coefficient (log Kow)	1.43 (estimate)	EPISUITE

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation	NA	
Aerobic BOD	NA	
Anaerobic BOD	NA	
Biowin7 (Anaerobic Model Prediction)	Readily biodegradable	EPISUITE
Fugacity		
Air %	0.559 (estimate)	EPISUITE
Water %	28.8 (estimate)	EPISUITE
Soil %	71.8 (estimate)	EPISUITE
Sediment %	0.0693 (estimate)	EPISUITE
Bioconcentration factor (BCF)	4.1 L/kg wet wt (estimate)	EPISUITE
Biotransformation half-life	0.03864 days (estimate)	EPISUITE

Notes: 1 EPI Suite™ v4.0, United States Environmental Protection Agency.

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (ug/L)**	**Notes**
ANZECC	2000	Aquatic toxicity	50 (99% protection) 140 (95% protection)	Alcohol ethoxylated surfactants (grouped)
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
-	Daphnid	LC50	ITX	IMBL	2	441534	ECOSAR
-	Fish	LC50	MOR	MORT	4	851412	ECOSAR
-	Mysid shrimp	LC50	MOR	MORT	4	1271957	ECOSAR
Chronic toxicity data							
-	Green Algae	EC50	POP	GPOP	4	163871	ECOSAR
-	Fish	LC50	MOR	MORT	14	853048	ECOSAR

Media Type: freshwater

IMBL: immobile

ABND: abundance

ITX : Intoxicated

MOR/MORT: Mortality

POP: Population

REP: Reproduction

PROG : Progeny Counts

SEXR : Sex ratio

FCND: Fecundity

HTCH : Hatch

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

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ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Bentonite
Synonyms	Colloidal clay, montmorillonite, otaylite, trixoton
CAS number	121888-68-4 (1302-78-9 given by HSDB, 2011)*
Molecular formula	$C_6H_{12}N_4O_9$
Product name	

*All EPISUITE data were collected for the chemical 1302-78-9

Physical Properties	Value	Reference
Phase/state	The colour in the massive condition varies from yellowish-white to almost black. The powder is cream to pale brown.	HSDB, 2011
Molecular weight	284.18 g/mol	EPISUITE
Melting point	101.93 (estimate)	EPISUITE
	NA	IUCLID, 2000
Boiling point	344.50 (estimate)	EPISUITE
	NA	IUCLID, 2000
Solubility	Insoluble	HSDB, 2011

Other Relevant Factors	Value	Reference
Reactivity		
Species	NA	
Reaction type	NA	
pH		
acid / alkaline	pH 7-9 at 10 g/L and 20^{oC}	IUCLID, 2000
pH (10% solution)	In prescence of water it forms translucent suspension with a pH of around 9.	HSDB, 2011

Notes: 1 EPI Suite^{TM} v4.0, United States Environmental Protection Agency.

2. Hazardous Substances Data Bank (HSDB) National library of Medicine (bentonite) accessed on line : 7 June 2011.

3.IUCLID dataset (2000). European Commission: European Chemicals Bureau. Accessed on 7 June 2011. Accessed at: http://ecb.jrc.ec.europa.eu/iuclid-datasheet/1302789.pdf

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	

Other water quality guidelines				
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Oncorhynchus mykiss	Rainbow Trout	LC50	MOR	MORT	4	19000000	ECOTOX
Salmo gairdneri	Rainbow trout	LC50	MOR	MORT	4	8000000-19000000	IUCLID, 2000
Oncorhynchus mykiss	Rainbow trout	LC50	MOR	MORT	4	19000000	IPCS 2005
Daphnia pulex	Water flea	LC50	MOR	MORT	1	>1100000	IPCS 2005
Daphnia pulex	Water flea	LC50	MOR	MORT	2	>1100000	IPCS 2005
-	Fish	LC50	MOR	MORT	4	134731	Ecosar
-	Daphnid	LC50	MOR	MORT	2	11719	Ecosar
-	Fish	LC50	MOR	MORT	4	884649	Ecosar
-	Daphnid	LC50	MOR	-	2	468106	Ecosar

Chronic toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
-	Green algae	EC50	POP	-	4	3984	Ecosar
-	Green algae	EC50	POP	-	4	150393	Ecosar

Media Type: freshwater

IMBL: immobile

ABND: abundance

ITX : Intoxicated

MOR/MORT: Mortality

POP: Population

REP: Reproduction

PROG : Progeny Counts

SEXR : Sex ratio

FCND: Fecundity

HTCH : Hatch

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

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ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Calcium chloride
Synonyms	Calcium II chloride, Calcium dichloride
CAS number	10043-52-4
Molecular formula	$CaCl_2$
Product name	

Physical Properties	Value	Reference
Phase/state	Colourless, cubic crystals	HSDB, 2011
Molecular weight	110.99 g/mol	HSDB, 2011
Melting point	772^{o}C	HSDB, 2011
Boiling point	1670 ^{o}C	HSDB, 2011
Solubility	745 g/L at 20^{o}C	INCHEM2002
	Freely soluble in water	HSDB, 2011
	9.797 x 10^4 mg/L at 25^{o}C	EPISUITE

Other Relevant Factors	Value	Reference
Reactivity		
Species & Reaction type	Reacts violently with heat generation in water. Forms flammable gases and evolves hydrogen when reacted with zinc. When heated to decomposition emits toxic fumes of hydrogen chloride.	HSDB, 2011
pH		
acid / alkaline	Salt	HSDB, 2011

Notes: 1 EPI Suite™ v4.0, United States Environmental Protection Agency.

2. Hazardous Substances Data Bank (HSDB) National library of Medicine (Calcium chloride) accessed on line : 7 June 2011.

3. INCHEM (2002) SIDS Initial Assessment Report for Calcium Chloride, UNEP Publications. Accessed on 8 June 2011. Accessed at: http://www.inchem.org/documents/sids/sids/10043524.pdf

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	

Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Rhamdia quelen	Catfish	NOEC	MOR	HTCH	1.5	24950	ECOTOX
Rhamdia quelen	Catfish	LOEC	MOR	SURV	3.5	24950	ECOTOX
Rhamdia quelen	Catfish	LOEC	MOR	HTCH	1.5	62940	ECOTOX
Rhamdia quelen	Catfish	LOEC	MOR	SURV	3.5	62940	ECOTOX
Daphnia magna	Water Flea	MATC	ITX	IMBL	4	920000	ECOTOX
Mesocyclops leuckarti	Cyclopoid Copepod	MATC	ITX	IMBL	4	1440000	ECOTOX
Cyclops vernalis	Cyclopoid	MATC	ITX	IMBL	4	1730000	ECOTOX
Navicula seminulum	Water Flea	EC50*	ITX	IMBL	2	52000	ECOTOX
Nitzschia linearis	Tubificid Worm	EC50	ITX	IMBL	4	281190	ECOTOX
Cyclops abyssorum ssp. prealpinus	Tubificid Worm	EC50	ITX	IMBL	2	389050	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	2.08	445000	ECOTOX
Daphnia magna	Water Flea	EC50*	ITX	IMBL	2	464000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	1	573060	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	590000	ECOTOX
Eudiaptomus padanus ssp. padanus	Water Flea	LC50	MOR	MORT	4.2	649000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	759000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	3	759000	ECOTOX
Daphnia hyalina	Water Flea	LC50*	MOR	MORT	2	759000	ECOTOX
Daphnia magna	Tubificid Worm	EC50	ITX	IMBL	1	814400	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	2.67	920000	ECOTOX
Daphnia magna	Medaka, High-Eyes	LC50	MOR	MORT	1	1000000	ECOTOX
Daphnia magna	Medaka, High-Eyes	LC50	MOR	MORT	1	1000000	ECOTOX
Daphnia magna	Medaka, High-Eyes	LC50	MOR	MORT	1	1000000	ECOTOX
Daphnia magna	Medaka, High-Eyes	LC50	MOR	MORT	2	1000000	ECOTOX
Daphnia magna	Medaka, High-Eyes	LC50	MOR	MORT	2	1000000	ECOTOX
Daphnia magna	Medaka, High-Eyes	LC50	MOR	MORT	2	1000000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	1830000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	1	1838000	ECOTOX
Daphnia magna	Water Flea	LC50*	MOR	MORT	1	1838000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	4.17	2049000	ECOTOX
Daphnia magna	Fathead Minnow	LC50	MOR	MORT	4	2110000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	1	2260000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	2.08	2459000	ECOTOX
Daphnia magna	Pond Snail	LC50	MOR	MORT	4	2573000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	2770000	ECOTOX

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Daphnia magna	Water Flea	LC50	ITX	IMBL	1.04	2820000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	4.17	2824000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	3000000	ECOTOX
Cyprinodon variegatus	Water Flea	LC50	MOR	MORT	2.08	3005000	ECOTOX
Gambusia affinis	Pond Snail	LC50	MOR	MORT	2	3094000	ECOTOX
Gambusia affinis	Diatom	EC50	POP	PGRT	4	3130000	ECOTOX
Gambusia affinis	Diatom	LC50*	MOR	MORT	5	3130000	ECOTOX
Lepomis macrochirus	Water Flea	LC50	MOR	MORT	1	3250000	ECOTOX
Lepomis macrochirus	Pond Snail	LC50	MOR	MORT	3	3308000	ECOTOX
Lepomis macrochirus	Water Flea	LC50	MOR	MORT	1.04	3526000	ECOTOX
Lepomis macrochirus	Water Flea	LC50	ITX	IMBL	2.08	3553000	ECOTOX
Lepomis macrochirus	Water Flea	LC50	ITX	IMBL	4.17	3972000	ECOTOX
Lepomis macrochirus	Calanoid Copepod	EC50*	ITX	IMBL	2	4000000	ECOTOX
Lepomis macrochirus	Water Flea	LC50	ITX	IMBL	1.04	4365000	ECOTOX
Oryzias latipes	Pond Snail	LC50	MOR	MORT	1	4485000	ECOTOX
Oryzias latipes	Water Flea	LC50	ITX	IMBL	1.04	4626000	ECOTOX
Oryzias latipes	Fathead Minnow	LC50	MOR	MORT	4	4630000	ECOTOX
Oryzias latipes	Sheepshead Minnow	LC50	MOR	MORT	4	4970000	ECOTOX
Oryzias latipes	Fathead Minnow	LC50	MOR	MORT	2	6560000	ECOTOX
Oryzias latipes	Fathead Minnow	LC50	MOR	MORT	1	6660000	ECOTOX
Pimephales promelas	Cyclopoid Copepod	EC50*	ITX	IMBL	2	7000000	ECOTOX
Pimephales promelas	Bluegill	LC50	MOR	MORT	1	8350000	ECOTOX
Pimephales promelas	Bluegill	LC50	MOR	MORT	4	9500000	ECOTOX
Pimephales promelas	Bluegill	LC50	MOR	MORT	4	9500000	ECOTOX
Lymnaea sp.	Bluegill	LC50	MOR	SURV	4	10650000	ECOTOX
Lymnaea sp.	Bluegill	LC50*	MOR	MORT	4	10650000	ECOTOX
Lymnaea sp.	Bluegill	LC50*	MOR	MORT	5	10650000	ECOTOX
Lymnaea sp.	Bluegill	LC50	MOR	MORT	4	11300000	ECOTOX
Tubifex tubifex	Western Mosquitofish	LC50*	MOR	MORT	1	13400000	ECOTOX
Tubifex tubifex	Western Mosquitofish	LC50*	MOR	MORT	2	13400000	ECOTOX
Tubifex tubifex	Western Mosquitofish	LC50*	MOR	MORT	4	13400000	ECOTOX
Chronic toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Ceriodaphnia sp.	Water Flea	NOEC	REP	FCND	7	305000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	WGHT	7	1410000	ECOTOX
Ceriodaphnia sp.	Water Flea	LOEC	REP	FCND	7	305000	ECOTOX
Pimephales promelas	Fathead Minnow	LOEC	GRO	WGHT	7	1410000	ECOTOX
Daphnia magna	Water Flea	EC50*	REP	GREP	21	220000	ECOTOX
Daphnia magna	Water Flea	EC50*	ITX	IMBL	21	330000	ECOTOX

Media Type: freshwater

IMBL: immobile

ABND: abundance

ITX : Intoxicated

MOR/MORT: Mortality

POP: Population

REP: Reproduction

PROG : Progeny Counts

SEXR : Sex ratio

FCND: Fecundity

HTCH : Hatch

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.
ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Coco dimethylaminopropyl betaine
Synonyms	COCAMIDOPROPYL BETAINE
CAS number	61789-40-0
Molecular formula	C19H39N2O3
Product name	HC-2A

Physical Properties	Value	Reference
Phase/state	Liquid	IUCLID 2000
Molecular weight	343.53 g/mol	EPISUITE
Melting point	<0 ^{o}C	IUCLID 2000
Boiling point	100 ^{o}C	IUCLID 2000
Density/ specific gravity	1.04 g/cm^{3} at 20^{o}C	IUCLID 2000
Vapour pressure	Not applicable	IUCLID 2000
Solubility	1755 g/m^{3} at 25^{o}C	EPISUITE
Henrys law constant	6.19x10^{-21} atm m^{3}/mole	EPISUITE
Log organic carbon partition coefficient (log Koc)	2.811 (MCI Method)	EPISUITE
Log octanol-water partition coefficient (log Kow)	Not applicable. Substance dissociates in aqueous solution	IUCLID 2000
	0.69 (KOWWIN)	EPISUITE

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation	At 20 mg/L, 100% degraded after 20 days. Readily biodegradable	IUCLID 2000
Aerobic BOD	NA	
Anaerobic BOD	NA	
Biowin 7 (Anaerobic Model Prediction)	Does not biodegrade fast	EPISUITE
Fugacity	5.7x10^{-8}	EPISUITE
Air %	16.5	EPISUITE
Water %	83.1	EPISUITE
Soil %	0.403	EPISUITE
Sediment %		EPISUITE
Bioconcentration factor (BCF)	70.79 L/kg wet-wt	EPISUITE
Biotransformation half-life	0.04856 days	

Notes: 1 EPI Suite™ v4.0, United States Environmental Protection Agency.

2. IMCD. Material Safety Data Sheet HC 2A. Issue Date:October 2008.

3. IUCLID Dataset. Substance ID 617-40-0. Eurpoean Commission European Chemicals Bureau. 18 February 2000.

NA - not available

Aquatic toxicity				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Estimated acute toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
*Lowest acute LC/EC50 values for fish, daphnia and algae		LC/EC50				1300-2000	SIDS 2006
Estimated chronic toxicity data							
*Oncorhynchus mykiss	Fish	NOEC			Chronic test	160	SIDS 2006
*Daphnia magna	Daphnid	NOEC			Chronic test	30	SIDS 2006
*Desmodesmus subspicatus	Green Algae	NOEC			Chronic test	90	SIDS 2006
	*Daphnids	NOEC				932	SIDS 2006
	*Algae	NOEC			3	9860	SIDS 2006
	*Algae	NOEC				3550	SIDS 2006

Aquatic toxicological data is based on cocamidopropyl betaine data cited with the SIDS (2006) alkylamidopropyl betaines document.

* SIDS profile provided does not cite the studies where aquatic ecotoxicological data was sourced. Unable to find full SIDS document at http://www.chem.unep.ch/irptc/sids/OECDSIDS/index1.htm

MOR/ MORT : Mortality

POP: Population

GPOP: Population changes, general

Effect values within the same species (e.g Desmodesmus subspicatus, Daphnia magna) have shown high variability. Recent studies in accordance with OECD TG 211 and 201 have resulted in a lower aquatic toxicity for cocamidapropyl betaine (SIDS, 2006).

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

Name	Ethanol
Synonyms	Ethyl Alcohol, ethyl hydrate, ethyl hydroxide.
CAS number	64-17-5
Molecular formula	C_2H_6O
Product name	GasPerm 1100

Physical Properties	Value	Reference
Phase/state	Clear, colourless, very mobile liquid	HSDB, 2011
Molecular weight	46.07 g/mol	HSDB, 2011
Melting point	-114.1 ^{o}C	HSDB, 2011
Boiling point	78.5 ^{o}C	HSDB, 2011
Density/ specific gravity	0.789 at 20^{o}C	HSDB, 2011
Vapour pressure	59.3 mm Hg at 25^{o}C	HSDB, 2011
Solubility	Miscible in water	HSDB, 2011
	7.921 x 10^5 mg/L at 25^{o}C	EPISUITE
Henrys law constant	5 x 10^{-6} atm m^3/mole	HSDB, 2011
Organic carbon partition coefficient (Koc)	1	HSDB, 2011
Log organic carbon partition coefficient (log Koc)	0.019 (MCI Method)	EPISUITE
Log octanol-water partition coefficient (log Kow)	-0.31	HSDB, 2011

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation	Biodegradation is expected to occur rapidly in the environment, unlikely to be persistent in the environment. Not expected to adsorb to suspended solids and sediment.	HSDB, 2011
Aerobic BOD	74% BOD in 5 days	HSDB, 2011
Anaerobic BOD	1.5 days under denitrifying conditions, 5 days under iron - reducing conditions.	HSDB, 2011
Biowin7 (Anaerobic Model Prediction)	Biodegrades fast	EPISUITE
Fugacity		
Air %	7.4	EPISUITE
Water %	40.6	EPISUITE
Soil %	51.9	EPISUITE
Sediment %	0.0718	EPISUITE
Bioconcentration factor (BCF)	3 (aquatic organisms)	HSDB, 2011
Biotransformation half-life	0.02866 days	EPISUITE

Notes: 1 EPI Suite™ v4.0, United States Environmental Protection Agency.

2. Halliburton Material Safety Data Sheet GasPerm 1100. Issue Date: 4 March 2010.

3. Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line: 25 March 2011.

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	400	Freshwater guideline (99%) level of protection - % species.
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk		1 : Carcinogenic to humans.
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Eutreptialla sp.	Euglenoid	NOEC	POP	ABND	4	14000	ECOTOX
Prorocentrum minimum	Dinoflagellate	NOEC	POP	ABND	4	20000	ECOTOX
Heterosigma akashiwo	Algae	NOEC	POP	ABND	4	350000	ECOTOX
Chaetoceros calcitrans	Diatom	NOEC	POP	ABND	4	2000000	ECOTOX
Skeletonema costatum	Diatom	NOEC	POP	ABND	4	3600000	ECOTOX
Caenorhabditis elegans	Nematode	NOEL	REP	PROG	3	4000000	ECOTOX
Pavlova lutheri	Chrysophyte	NOEC	POP	ABND	4	4100000	ECOTOX
Daphnia magna	Water Flea	NOEC	ITX	IMBL	2	6300000	ECOTOX
Isochrysis galbana	Haptophyte	NOEC	POP	ABND	4	7400000	ECOTOX
Dunaliella tertiolecta	Green Algae	NOEC	POP	ABND	4	9600000	ECOTOX
Tetraselmis tetrathele	Green Flagellate	NOEC	POP	ABND	4	10000000	ECOTOX
Caenorhabditis elegans	Nematode	LOEL	REP	PROG	3	8000000	ECOTOX
Cyclops vernalis	Cyclopoid	MATC	ITX	IMBL	4	12000000	ECOTOX
Daphnia magna	Water Flea	MATC	ITX	IMBL	4	12100000	ECOTOX
Daphnia magna	Water Flea	MATC	ITX	IMBL	4	7800000	ECOTOX
Tetrahymena pyriformis	Ciliate	IC50	POP	PGRT	2	11962.81	ECOTOX
Pseudokirchneriella subcapitata	Green Algae	EC50	POP	PGRT	2	29900	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LC50	MOR	MORT	4	42000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	1	100000	ECOTOX
Danio rerio	Zebra Danio	LC50	MOR	MORT	1	100000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	2	100000	ECOTOX
Asellus intermedius	Aquatic Sowbug	LC50	MOR	MORT	4	100000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	4	100000	ECOTOX
Gammarus fasciatus	Scud	LC50	MOR	MORT	4	100000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	100000	ECOTOX
Planorbella trivolvis	Snail, Marsh Rams-Horn	LC50	MOR	MORT	4	100000	ECOTOX
Dugesia tigrina	Turbellarian, Flatworm	LC50	MOR	MORT	4	100000	ECOTOX
Lumbriculus variegatus	Oligochaete, Worm	LC50	MOR	MORT	4	100000	ECOTOX

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (μg/L)**	**Reference**
Oryzias latipes	Medaka, High-Eyes	LC50	MOR	MORT	2	1350000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	3715000	ECOTOX
Tetrahymena pyriformis	Ciliate	IC50	POP	ABND	1.67	4515000	ECOTOX
Oryzias latipes	Medaka, High-Eyes	LC50	MOR	MORT	1	5100000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	5577000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	5680000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	6076000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	6325000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	6386000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	6772000	ECOTOX
Leuciscus idus ssp. melanotus	Carp	LC50	MOR	MORT	2	8140000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	8808000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	9248000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	9268000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	2	9300000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	9300000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	1	9788000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	1	10000000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	1	10000000	ECOTOX
Oryzias latipes	Medaka, High-Eyes	LC50	MOR	MORT	1	10000000	ECOTOX
Oryzias latipes	Medaka, High-Eyes	LC50	MOR	MORT	1	10000000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	2	10000000	ECOTOX
Leuciscus idus ssp. melanotus	Carp	LC50	MOR	MORT	2	10000000	ECOTOX
Oryzias latipes	Medaka, High-Eyes	LC50	MOR	MORT	2	10000000	ECOTOX
Oryzias latipes	Medaka, High-Eyes	LC50	MOR	MORT	2	10000000	ECOTOX
Chaetoceros calcitrans	Diatom	EC50	POP	ABND	4	10000000	ECOTOX
Skeletonema costatum	Diatom	EC50	POP	ABND	4	10000000	ECOTOX
Heterosigma akashiwo	Algae	EC50	POP	ABND	4	10000000	ECOTOX
Daphnia obtusa	Water Flea	EC50	ITX	IMBL	2	10600000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	10860000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LC50	MOR	MORT	1	11200000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	11853000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	11967000	ECOTOX
Poecilia reticulata	Guppy	LC50	MOR	MORT	1	12500000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	12720000	ECOTOX
Tetrahymena pyriformis	Ciliate	IC50	POP	PGRT	1.5	12800000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	12820000	ECOTOX
Daphnia obtusa	Water Flea	EC50	ITX	IMBL	1	12900000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	13248000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	13470000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	13480000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	3	13480000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	13480000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	14136000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	14200000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	14221000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	1	15800000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	18000000	ECOTOX
Caenorhabditis elegans	Nematode	EC50	REP	PROG	3	18000000	ECOTOX
Tetraselmis tetrathele	Green Flagellate	EC50	POP	ABND	4	20000000	ECOTOX
Chironomus tentans	Midge	LC50	MOR	MORT	2	25100000	ECOTOX
Streptocephalus	Fairy Shrimp	LC50	MOR	MORT	1	31700000	ECOTOX

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
rubricaudatus							
Corbicula manilensis	Asiatic Clam	LC50	MOR	MORT	4	60000000	ECOTOX
Caenorhabditis elegans	Nematode	LC50	MOR	MORT	1	87000000	ECOTOX
Chronic toxicity data							
Biomphalaria tenagophila	Snail	NOEC	MOR	HTCH	10	1980000	ECOTOX
Daphnia magna	Water Flea	NOEL	POP	SEXR	35	8	ECOTOX
Daphnia magna	Water Flea	NOEL	REP	FCND	35	8	ECOTOX
Daphnia magna	Water Flea	NOEL	REP	FCND	35	8	ECOTOX
Biomphalaria tenagophila	Snail	NOEL	REP	PROG	56	19800	ECOTOX
Biomphalaria tenagophila	Snail	NOEC	REP	PROG	56	1980000	ECOTOX
Biomphalaria tenagophila	Snail	NOEC	REP	PROG	56	1980000	ECOTOX
Biomphalaria tenagophila	Snail	NOEC	REP	FCND	196	19800	ECOTOX
Daphnia magna	Water Flea	LOEL	POP	SEXR	35	8	ECOTOX
Biomphalaria tenagophila	Snail	LOEL	REP	PROG	56	198000	ECOTOX
Biomphalaria tenagophila	Snail	LOEC	MOR	HTCH	196	19800	ECOTOX
Biomphalaria tenagophila	Snail	LOEL	MOR	HTCH	196	19800	ECOTOX
Biomphalaria tenagophila	Snail	LOEC	REP	FCND	196	198000	ECOTOX
Biomphalaria tenagophila	Snail	LOEC	REP	PROG	196	198000	ECOTOX
Biomphalaria tenagophila	Snail	LOEL	REP	PROG	196	198000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	9	454000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	10	1806000	ECOTOX

Media Type: freshwater

IMBL: immobile

ABND: abundance

ITX : Intoxicated

MOR/MORT: Mortality

POP: Population

REP: Reproduction

PROG : Progeny Counts

SEXR : Sex ratio

FCND: Fecundity

HTCH : Hatch

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.

ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Guar Gum
Synonyms	-
CAS number	9000-30-0
Molecular formula	NA
Product name	WG-36

Physical Properties	Value	Reference
Phase/state	Solid	Chemwatch, 2005
Molecular weight	220,000	Chemwatch, 2005
Melting point	NA	
Boiling point	NA	
Density/ specific gravity	NA	
Vapour pressure	NA	
Solubility	Soluble Completely soluble in water	Chemwatch, 2005
Henrys law constant	NA	
Log organic carbon partition coefficient (log Koc)	NA	
Log octanol-water partition coefficient (log Kow)	NA	

Persistence/ Bioaccumulation	Value	Reference
Biowin7 (Anaerobic Model Prediction)	NA	
Ready Biodegradability Prediction	NA	
Fugacity		
Air %	NA	
Water %	NA	
Soil %	NA	
Sediment %	NA	
Bioconcentration factor (BCF)	NA	
Biotransformation half-life	NA	

Notes: 1 Chemwatch Material Safety Data Sheet 23354. Issue Date: 14-Jul-2005.

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	

Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2008	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Oncorhynchus mykiss	Rainbow Trout	LC50*	MOR	MORT	4	218000	ECOTOX
Daphnia magna	Water Flea	LC50*	MOR	MORT	2	42000	ECOTOX
Daphnia magna	Water Flea	LC50*	MOR	MORT	4	6200	ECOTOX
Chronic toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Water flea	Daphnia magna	LC50	MOR	MORT	4	6.2	ECOTOX
Rainbow trout	Oncorhynchus	LC50	MOR	MORT	4	218	ECOTOX

Media Type: freshwater

MOR/MORT: Mortality

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7. EPA/Office of Pollution prevention and toxics; High production Volume (HPV) Challenge program's Robust summaries and Test Plans. Availible from: http://www.epa.gov/chemrtk/viewsrch.htm on Acetic acid and Salts (April 2003) as of February 9, 2004.

Environment Canada; Tech Info for Problem Spills: Acetic Acid (Draft) p.76 (1981).
ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Polyethylene glycol oleate ester (surrogate Cremophor El Castor Oil)
Synonyms	
CAS number	Surrogate 61791-12-6 Cremophor El Castor Oil used for chemical information sheet
Molecular formula	$(C_2\text{-}H_3\text{-}O)MULT\ C_{18}\text{-}H_{36}\text{-}O_2$
Product name	

Physical Properties	Value	Reference
Phase/state	Oily, light yellow*	BASF 2008
Molecular weight	4^oC*	BASF 2008
Melting point	$>100^oC$* 1.05-1.06 g/cm^3	BASF 2008
Boiling point	100 g/L	BASF 2008
Density/ specific gravity	NA	BASF 2008
Vapour pressure	NA	
Solubility	NA	
Henrys law constant	NA	
Organic carbon partition coefficient (Koc)	NA	
Log organic carbon partition coefficient (log Koc)	NA	
Log octanol-water partition coefficient (log Kow)	NA	

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation	NA	
Aerobic BOD	NA	
Anaerobic BOD	NA	
Biowin7 (Anerobic linear model)	Not readily biodegradable	BASF 2008
Fugacity		
Air %	NA	
Water %	NA	
Soil %	NA	
Sediment %	NA	
Bioconcentration factor	NA	
Biotransformation half-life	NA	

Notes: Data refers to Cremophor El Caster Oil unless otherwise stated

1 BASF 2008, The Chemical Company Safety Data Sheet Cremophor El Caster Oil Ref : 30035153/MDS/GEN/CA/EN rev 1.1. dated 22/05/2008.

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Ecotoxicological Data

Acute toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Golden orfe	Fish	LC50			2	448000	BASF 2008
Daphnia magna	Daphnid	LC50			2	>100000	BASF 2008
Chronic toxicity data							
	Green Algae	EC50			3	93000	BASF 2008

Media Type : Freshwater

ITX : Intoxication

IMBL: Immobile

MOR / MORT: Mortality
POP: Population

ABND : Abundance

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.
ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Sodium Chloride
Synonyms	Salt
CAS number	7647-14-5
Molecular formula	NaCl
Product name	HpH Breaker

Physical Properties	Value	Reference
Phase/state	Colourless transparent crystals or white crystalline powder.	HSDB, 2011
Molecular weight	58.44 g/mol	HSDB, 2011
Melting point	801 ^{o}C	HSDB, 2011
Boiling point	1 mm Hg at 865^{o}C	HSDB, 2011
Solubility	3.57 x 10 ^{5} g/m^{3} at 25^{o}C	HSDB, 2011
	35.7 g/100 ml of water at 0^{o}C	HSDB, 2011
	One gram dissolves in 2.8ml of water at 25^{o}C	Merck, 1996

Other Relevant Factors	Value	Reference
Reactivity	zero	MSDS, 2010
Species	NA	
Reaction type	NA	
pH		
acid / alkaline	In aqueous solution is neutral	HSDB, 2011
pH (10% solution)	6.7 to 7.3	HSDB, 2011

Notes: 1. Haliburton Material Safety Data Sheet HPH Breaker. Issue Date:4 January 2010.

2. Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line: 24 March 2011.

3. The Merck Index. 1996. An Encyclopedia of Chemicals, Drugs and Biologicals. Merck REserach Laboratories. (12th Ed.) Whitehouse station, NJ.

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^{3})**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^{3})**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	Not listed on IARC Database
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Acute Toxicity Data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Ceriodaphnia dubia	Water Flea	NOEC	MOR	SURV	7	300000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	MOR	SURV	7	300000	ECOTOX
Daphnia ambigua	Water Flea	NOEC	MOR	SURV	10	440000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	MOR	SURV	7	500000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	MOR	SURV	7	500000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	MOR	SURV	7	620000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	NOEC	MOR	SURV	90	643000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEL	MOR	SURV	4	860000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	MOR	SURV	7	900000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	MOR	SURV	7	1250000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	MOR	SURV	7	1250000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	MOR	SURV	7	1500000	ECOTOX
Ictalurus punctatus	Channel Catfish	NOEC	MOR	SURV	7	2000000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEL	MOR	SURV	7	2000000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	MOR	SURV	7	2500000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	MOR	SURV	7	2500000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	MOR	MORT	7	4000000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	MOR	MORT	7	4000000	ECOTOX
Metynnis orinocensis	Characid	NOEC	MOR	MORT	4	5000000	ECOTOX
Metynnis orinocensis	Characid	NOEC	MOR	MORT	4	5000000	ECOTOX
Caenorhabditis elegans	Nematode	NOEL	MOR	MORT	1	15460000	ECOTOX
Caenorhabditis elegans	Nematode	NOEL	MOR	MORT	4	15500000	ECOTOX
Caenorhabditis elegans	Nematode	NOEL	MOR	MORT	1	20500000	ECOTOX
Caenorhabditis elegans	Nematode	NOEL	MOR	MORT	4	20950000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	NOEL	MOR	MORT	14	35200000	ECOTOX
Pimephales promelas	Fathead Minnow	LOEL	MOR	SURV	7	210000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	MOR	SURV	7	300000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	MOR	SURV	7	500000	ECOTOX
Daphnia ambigua	Water Flea	LOEC	MOR	SURV	10	850000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	MOR	SURV	7	900000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	MOR	SURV	7	900000	ECOTOX
Pimephales promelas	Fathead Minnow	LOEL	MOR	SURV	4	1140000	ECOTOX
Lemna minor	Duckweed	MATC	POP	ABND	4	1340000	ECOTOX
Lemna minor	Duckweed	MATC	POP	ABND	4	1340000	ECOTOX
Lemna minor	Duckweed	MATC	POP	CHLO	4	1340000	ECOTOX
Lemna minor	Duckweed	MATC	POP	CHLO	4	1340000	ECOTOX
Lemna minor	Duckweed	MATC	POP	ABND	4	1410000	ECOTOX
Lemna minor	Duckweed	MATC	POP	ABND	4	1410000	ECOTOX
Lemna minor	Duckweed	MATC	POP	CHLO	4	1410000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	MOR	SURV	7	1500000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	MOR	SURV	7	2200000	ECOTOX
Pimephales promelas	Fathead Minnow	LOEL	MOR	SURV	7	2200000	ECOTOX
Pimephales promelas	Fathead Minnow	LOEC	MOR	SURV	7	2250000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	MOR	SURV	7	2500000	ECOTOX
Pimephales promelas	Fathead Minnow	LOEC	MOR	SURV	7	2500000	ECOTOX
Lemna minor	Duckweed	MATC	POP	ABND	4	2690000	ECOTOX

Acute Toxicity Data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Lemna minor	Duckweed	MATC	POP	ABND	4	2690000	ECOTOX
Lemna minor	Duckweed	MATC	POP	CHLO	4	2690000	ECOTOX
Lemna minor	Duckweed	MATC	POP	CHLO	4	2690000	ECOTOX
Lemna minor	Duckweed	MATC	POP	CHLO	4	2828000	ECOTOX
Cyclops vernalis	Cyclopoid	MATC	ITX	IMBL	4	3030000	ECOTOX
Ceriodaphnia sp.	Water Flea	LOEC	MOR	SURV	7	3300000	ECOTOX
Daphnia magna	Water Flea	MATC	ITX	IMBL	4	3700000	ECOTOX
Leptodora kindtii	Water Flea	MATC	ITX	IMBL	4	3700000	ECOTOX
Ictalurus punctatus	Channel Catfish	LOEC	MOR	SURV	7	4000000	ECOTOX
Daphnia magna	Water Flea	LETC	ITX	IMBL	2	4200000	ECOTOX
Daphnia magna	Water Flea	MATC	ITX	IMBL	4	4600000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	MOR	SURV	7	5000000	ECOTOX
Pimephales promelas	Fathead Minnow	LOEC	MOR	SURV	7	5000000	ECOTOX
Baetis tricaudatus	Mayfly	LOEC	ITX	IMBL	2	6000000	ECOTOX
Baetis tricaudatus	Mayfly	LOEC	ITX	IMBL	2	6000000	ECOTOX
Cyclops vernalis	Cyclopoid	MATC	ITX	IMBL	4	6100000	ECOTOX
Baetis tricaudatus	Mayfly	LOEC	ITX	IMBL	1	8000000	ECOTOX
Baetis tricaudatus	Mayfly	LOEC	ITX	IMBL	1	8000000	ECOTOX
Baetis tricaudatus	Mayfly	LOEC	ITX	IMBL	1	8000000	ECOTOX
Pimephales promelas	Fathead Minnow	LOEC	MOR	MORT	7	8000000	ECOTOX
Metynnis orinocensis	Characid	LOEC	MOR	MORT	4	10000000	ECOTOX
Metynnis orinocensis	Characid	LOEC	MOR	MORT	4	10000000	ECOTOX
Caenorhabditis elegans	Nematode	LOEL	MOR	MORT	1	15500000	ECOTOX
Caenorhabditis elegans	Nematode	LOEL	MOR	MORT	4	15550000	ECOTOX
Caenorhabditis elegans	Nematode	LOEL	MOR	MORT	1	20550000	ECOTOX
Caenorhabditis elegans	Nematode	LOEL	MOR	MORT	4	21000000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	7	280000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	7	330000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	1	402600	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	2	402600	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	9	467000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	10	467000	ECOTOX
Lampsilis siliquoidea	Lamp-Mussel	EC50	MOR	SURV	1	550000	ECOTOX
Tubifex tubifex	Tubificid Worm	EC50	ITX	IMBL	4	781000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	7	910000	ECOTOX
Morone saxatilis	Striped Bass	LC50	MOR	MORT	3	1000000	ECOTOX
Morone saxatilis	Striped Bass	LC50	MOR	MORT	4	1000000	ECOTOX
Morone saxatilis	Striped Bass	LC50	MOR	MORT	4	1000000	ECOTOX
Tubifex tubifex	Tubificid Worm	EC50	ITX	IMBL	2	1016000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	1042000	ECOTOX
Ceriodaphnia reticulata	Water Flea	LC50	MOR	MORT	2	1100000	ECOTOX
Sphaerium sp.	Orb Cockle, Fingernail Clam	LC50	MOR	MORT	4	1150000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	7	1170000	ECOTOX
Tubifex tubifex	Tubificid Worm	EC50	ITX	IMBL	1	1250000	ECOTOX
Sphaerium sp.	Orb Cockle,	LC50	MOR	MORT	3	1250000	ECOTOX

Acute Toxicity Data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
	Fingernail Clam						
Sphaerium sp.	Orb Cockle, Fingernail Clam	LC50	MOR	MORT	3	1250000	ECOTOX
Lepomis macrochirus	Bluegill	LC50*	MOR	MORT	4	1294600	ECOTOX
Morone saxatilis	Striped Bass	LC50	MOR	MORT	1	1400000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	7	1430000	ECOTOX
Daphnia pulex	Water Flea	LC50	MOR	SURV	2	1470000	ECOTOX
Morone saxatilis	Striped Bass	LC50	MOR	MORT	2	1500000	ECOTOX
Sphaerium sp.	Orb Cockle, Fingernail Clam	LC50	MOR	MORT	2	1550000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	1590000	ECOTOX
Morone saxatilis	Striped Bass	LC50	MOR	MORT	1	1600000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	7	1640000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	1661000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	7	1710000	ECOTOX
Lampsilis fasciola	Wavy-Rayed Lampmussel	EC50	MOR	SURV	2	1740000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	7	1740000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	7	1830000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	7	1940000	ECOTOX
Sphaerium sp.	Orb Cockle, Fingernail Clam	LC50	MOR	MORT	2	1950000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	1960000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	SURV	2	2000000	ECOTOX
Daphnia ambigua	Water Flea	LC50	MOR	MORT	2	2000000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	SURV	8	2000000	ECOTOX
Ceriodaphnia dubia	Water Flea	EC50	ITX	IMBL	2	2122550	ECOTOX
Ceriodaphnia dubia	Water Flea	EC50	ITX	IMBL	2	2122550	ECOTOX
Tricorythus sp.	Mayfly	LC50	MOR	MORT	4	2200000	ECOTOX
Elliptio complanata	Mussel, Eastern Elliptio	EC50	MOR	SURV	2	2230000	ECOTOX
Sphaerium sp.	Orb Cockle, Fingernail Clam	LC50	MOR	MORT	1	2250000	ECOTOX
Sphaerium sp.	Orb Cockle, Fingernail Clam	LC50	MOR	MORT	1	2400000	ECOTOX
Nitzschia linearis	Diatom	LC50*	MOR	MORT	5	2430000	ECOTOX
Stenonema rubrum	Mayfly	LC50	MOR	MORT	2	2500000	ECOTOX
Physa gyrina	Pouch Snail	LC50	MOR	SURV	4	2540000	ECOTOX
Nais variabilis	Oligochaete	LC50*	MOR	MORT	2	2569000	ECOTOX
Villosa constricta	Notched Rainbow	EC50	MOR	SURV	2	2590000	ECOTOX
Rana sylvatica	Wood Frog	LC50	MOR	MORT	4	2636500	ECOTOX
Lirceus fontinalis	Aquatic Sowbug	LC50	MOR	SURV	4	2970000	ECOTOX
Morone saxatilis	Striped Bass	LC50	MOR	MORT	1	3000000	ECOTOX
Daphnia pulex	Water Flea	LC50	MOR	SURV	2	3050000	ECOTOX
Streptocephalus rubricaudatus	Fairy Shrimp	LC50	MOR	MORT	1	3070000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	4.2	3114000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	3136000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	3137000	ECOTOX
Gyraulus circumstriatus	Flatly Coiled Gyraulus	LC50	MOR	MORT	4	3200000	ECOTOX
Gyraulus	Flatly Coiled	LC50	MOR	MORT	5	3200000	ECOTOX

Acute Toxicity Data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
circumstriatus	Gyraulus						
Daphnia magna	Water Flea	LC50	MOR	MORT	2	3222000	ECOTOX
Villosa delumbis	Eastern Creekshell	EC50	MOR	SURV	1	3310000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	3310000	ECOTOX
Daphnia magna	Water Flea	LC50*	MOR	MORT	2	3318000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	1	3380000	ECOTOX
Lymnaea sp.	Pond Snail	LC50	MOR	MORT	2	3388000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	1	3412000	ECOTOX
Lymnaea sp.	Pond Snail	LC50	MOR	MORT	1	3412000	ECOTOX
Daphnia magna	Water Flea	LC50*	MOR	MORT	1	3412000	ECOTOX
Physa heterostropha	Pond Snail, Pneumonate Snail	LC50	MOR	MORT	3	3500000	ECOTOX
Physa heterostropha	Pond Snail, Pneumonate Snail	LC50	MOR	MORT	4	3500000	ECOTOX
Pycnopsyche guttifer	Caddisfly	LC50	MOR	MORT	4	3526000	ECOTOX
Pycnopsyche lepida	Northern Caddisfly	LC50	MOR	MORT	4	3526000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	2.7	3680000	ECOTOX
Physa heterostropha	Pond Snail, Pneumonate Snail	LC50	MOR	MORT	2	3700000	ECOTOX
Gyraulus circumstriatus	Flatly Coiled Gyraulus	LC50	MOR	MORT	3	3700000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	2.1	3807000	ECOTOX
Lampsilis fasciola	Wavy-Rayed Lampmussel	EC50	MOR	SURV	4	3980000	ECOTOX
Physa heterostropha	Pond Snail, Pneumonate Snail	LC50	MOR	MORT	4	4100000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	2.1	4105000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	1.041666667	4106000	ECOTOX
Physa heterostropha	Pond Snail, Pneumonate Snail	LC50	MOR	MORT	1	4200000	ECOTOX
Physa heterostropha	Pond Snail, Pneumonate Snail	LC50	MOR	MORT	2	4250000	ECOTOX
Physa heterostropha	Pond Snail, Pneumonate Snail	LC50	MOR	MORT	3	4250000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	10	4324000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	4400000	ECOTOX
Lampsilis siliquoidea	Lamp-Mussel	EC50	MOR	SURV	4	4560000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	4571000	ECOTOX
Baetis tricaudatus	Mayfly	EC50	ITX	IMBL	2	4740000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	1.041666667	4756000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	4770000	ECOTOX
Physa heterostropha	Pond Snail, Pneumonate Snail	LC50	MOR	MORT	1	4800000	ECOTOX
Lemna minor	Duckweed	EC50			7	4880000	Buckley et al.,
Morone saxatilis	Striped Bass	LC50	MOR	MORT	2	5000000	ECOTOX
Morone saxatilis	Striped Bass	LC50	MOR	MORT	3	5000000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	5000000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	5000000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	5000000	ECOTOX
Morone saxatilis	Striped Bass	LC50	MOR	MORT	4	5000000	ECOTOX

Acute Toxicity Data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Morone saxatilis	Striped Bass	LC50	MOR	MORT	4	5000000	ECOTOX
Callibaetis fluctuans	Mayfly	LC50	MOR	MORT	4	5000000	ECOTOX
Callibaetis fluctuans	Mayfly	LC50	MOR	MORT	4	5000000	ECOTOX
Callibaetis fluctuans	Mayfly	LC50	MOR	MORT	4	5000000	ECOTOX
Callibaetis fluctuans	Mayfly	LC50	MOR	MORT	4	5000000	ECOTOX
Chaoborus americanus	Midge	LC50	MOR	MORT	4	5000000	ECOTOX
Chaoborus americanus	Midge	LC50	MOR	MORT	4	5000000	ECOTOX
Chaoborus americanus	Midge	LC50	MOR	MORT	4	5000000	ECOTOX
Physella integra	Snail, Ashy Physa	LC50	MOR	MORT	4	5000000	ECOTOX
Physella integra	Snail, Ashy Physa	LC50	MOR	MORT	4	5000000	ECOTOX
Physella integra	Snail, Ashy Physa	LC50	MOR	MORT	4	5000000	ECOTOX
Physella integra	Snail, Ashy Physa	LC50	MOR	MORT	4	5000000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	5020000	ECOTOX
Asellus communis	Aquatic Sowbug	LC50	MOR	MORT	3	5100000	ECOTOX
Asellus communis	Aquatic Sowbug	LC50	MOR	MORT	4	5100000	ECOTOX
Physa heterostropha	Pond Snail, Pneumonate Snail	LC50	MOR	MORT	4	5100000	ECOTOX
Physa heterostropha	Pond Snail, Pneumonate Snail	LC50	MOR	MORT	5	5100000	ECOTOX
Rana sylvatica	Wood Frog	LC50	MOR	MORT	4	5109200	ECOTOX
Villosa delumbis	Eastern Creekshell	EC50	MOR	SURV	4	5230000	ECOTOX
Baetis tricaudatus	Mayfly	EC50	ITX	IMBL	2	5330000	ECOTOX
Baetis tricaudatus	Mayfly	EC50	ITX	IMBL	2	5440000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	5480000	ECOTOX
Asellus communis	Aquatic Sowbug	LC50	MOR	MORT	1	5600000	ECOTOX
Physa heterostropha	Pond Snail, Pneumonate Snail	LC50	MOR	MORT	1	5600000	ECOTOX
Asellus communis	Aquatic Sowbug	LC50	MOR	MORT	2	5600000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	5600000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	5600000	ECOTOX
Physa heterostropha	Pond Snail, Pneumonate Snail	LC50	MOR	MORT	2	5600000	ECOTOX
Physa heterostropha	Pond Snail, Pneumonate Snail	LC50	MOR	MORT	3	5600000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	2.1	5709000	ECOTOX
Limnodrilus hoffmeisteri	Tubificid Worm, Oligochaete	LC50	MOR	MORT	6	5800000	ECOTOX
Limnodrilus hoffmeisteri	Tubificid Worm, Oligochaete	LC50	MOR	MORT	7	5800000	ECOTOX
Limnodrilus hoffmeisteri	Tubificid Worm, Oligochaete	LC50	MOR	MORT	10.875	5800000	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	SURV	4	5840000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2.1	5874000	ECOTOX
Baetis tricaudatus	Mayfly	EC50	ITX	IMBL	2	6000000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	6027000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	6027000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LC50	MOR	MORT	4	6094000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LC50	MOR	MORT	4	6094000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	2.1	6111000	ECOTOX

Acute Toxicity Data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Planorbella campanulata	Snail, Bellmouth Rams-Horn	LC50	MOR	MORT	3	6150000	ECOTOX
Planorbella campanulata	Snail, Bellmouth Rams-Horn	LC50	MOR	MORT	4	6150000	ECOTOX
Planorbella campanulata	Snail, Bellmouth Rams-Horn	LC50	MOR	MORT	5	6150000	ECOTOX
Asellus communis	Aquatic Sowbug	LC50	MOR	MORT	7	6150000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	4	6170000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	4	6180000	ECOTOX
Physa heterostropha	Pond Snail, Pneumonate Snail	LC50	MOR	MORT	3	6200000	ECOTOX
Physa heterostropha	Pond Snail, Pneumonate Snail	LC50	MOR	MORT	4	6200000	ECOTOX
Limnodrilus hoffmeisteri	Tubificid Worm, Oligochaete	LC50	MOR	MORT	4	6200000	ECOTOX
Limnodrilus hoffmeisteri	Tubificid Worm, Oligochaete	LC50	MOR	MORT	5	6200000	ECOTOX
Cricotopus trifasciatus	Midge	LC50*	MOR	MORT	2	6221000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	1	6380000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	6390000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	1.041666667	6447000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	6500000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	6510000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	SURV	4	6570000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	1.041666667	6575000	ECOTOX
Hydroptila angusta	Caddisfly	LC50*	MOR	MORT	2	6621000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	2	6800000	ECOTOX
Limnodrilus hoffmeisteri	Tubificid Worm, Oligochaete	LC50	MOR	MORT	3	6800000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	4	6800000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	4	6800000	ECOTOX
Asellus communis	Aquatic Sowbug	LC50	MOR	MORT	6	6800000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	2	6950000	ECOTOX
Physa heterostropha	Pond Snail, Pneumonate Snail	LC50	MOR	MORT	2	6950000	ECOTOX
Limnodrilus hoffmeisteri	Tubificid Worm, Oligochaete	LC50	MOR	MORT	2	6950000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	4	6950000	ECOTOX
Morone saxatilis	Striped Bass	LC50	MOR	MORT	1	7000000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	4	7000000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	7050000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	4	7050000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	7050000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	7100000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	2	7150000	ECOTOX
Baetis tricaudatus	Mayfly	EC50	ITX	IMBL	1	7180000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	7200000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	2	7200000	ECOTOX

Acute Toxicity Data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	7200000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	4	7200000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	4	7200000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	7200000	ECOTOX
Asellus communis	Aquatic Sowbug	LC50	MOR	MORT	5	7200000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	1.041666667	7212000	ECOTOX
Baetis tricaudatus	Mayfly	EC50	ITX	IMBL	1	7260000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	7300000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	4	7300000	ECOTOX
Baetis tricaudatus	Mayfly	EC50	ITX	IMBL	1	7330000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	4	7341000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	2	7350000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	3	7388000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	7400000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	2	7400000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	2	7400000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	7400000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	7400000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	7400000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LC50	MOR	MORT	4	7461000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LC50	MOR	MORT	4	7461000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	7500000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	7500000	ECOTOX
Physa heterostropha	Pond Snail, Pneumonate Snail	LC50	MOR	MORT	1	7500000	ECOTOX
Limnodrilus hoffmeisteri	Tubificid Worm, Oligochaete	LC50	MOR	MORT	1	7500000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	7500000	ECOTOX
Planorbella campanulata	Snail, Bellmouth Rams-Horn	LC50	MOR	MORT	2	7500000	ECOTOX
Erpobdella punctata	Red Leech	LC50	MOR	MORT	2	7500000	ECOTOX
Erpobdella punctata	Red Leech	LC50	MOR	MORT	3	7500000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	7500000	ECOTOX
Erpobdella punctata	Red Leech	LC50	MOR	MORT	4	7500000	ECOTOX
Erpobdella punctata	Red Leech	LC50	MOR	MORT	5	7500000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	2	7550000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	7550000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	7600000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	4	7600000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	7650000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	7650000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	3	7650000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	4	7650000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	7650000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	7650000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	7650000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	7700000	ECOTOX
Gammarus pseudolimnaeus	Scud	LC50	MOR	MORT	4	7700000	ECOTOX

Acute Toxicity Data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	7750000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	7750000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	7800000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	7800000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	2	7850000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	2	7900000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	2	7900000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	4	7900000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	2	7950000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	7950000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	4	7950000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	4	7950000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	7950000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	4	8050000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	8100000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	8150000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	8150000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	2	8200000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	8200000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	8200000	ECOTOX
Asellus communis	Aquatic Sowbug	LC50	MOR	MORT	3	8250000	ECOTOX
Asellus communis	Aquatic Sowbug	LC50	MOR	MORT	4	8250000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	8280000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	8300000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	8300000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	8300000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	8300000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	1	8350000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	2	8400000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	8400000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	2	8500000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	8700000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	1	8800000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	8800000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	8800000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	2	8800000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	9000000	ECOTOX
Hydropsyche sp.	Caddisfly	LC50	MOR	MORT	2	9000000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	1	9270000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	1	9600000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	1	9750000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	1	9800000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	1	9850000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	1	9900000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	1	9950000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	1	9980000	ECOTOX
Asellus communis	Aquatic Sowbug	LC50	MOR	MORT	1	10000000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	1	10000000	ECOTOX
Gyraulus circumstriatus	Flatly Coiled Gyraulus	LC50	MOR	MORT	1	10000000	ECOTOX

Acute Toxicity Data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Planorbella campanulata	Snail, Bellmouth Rams-Horn	LC50	MOR	MORT	1	10000000	ECOTOX
Erpobdella punctata	Red Leech	LC50	MOR	MORT	1	10000000	ECOTOX
Asellus communis	Aquatic Sowbug	LC50	MOR	MORT	2	10000000	ECOTOX
Gyraulus circumstriatus	Flatly Coiled Gyraulus	LC50	MOR	MORT	2	10000000	ECOTOX
Acroneuria abnormis	Common Stonefly	LC50	MOR	MORT	4	10000000	ECOTOX
Agnetina capitata	Stonefly	LC50	MOR	MORT	4	10000000	ECOTOX
Tipula abdominalis	Crane Fly	LC50	MOR	MORT	4	10000000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	1	10100000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	1	10200000	ECOTOX
Culex sp.	Mosquito	LC50	MOR	MORT	2	10200000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	1	10270000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	1	10400000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	1	10450000	ECOTOX
Culex sp.	Mosquito	LC50	MOR	MORT	1	10500000	ECOTOX
Metynnis orinocensis	Characid	LC50	MOR	MORT	4	10500000	ECOTOX
Metynnis orinocensis	Characid	LC50	MOR	MORT	4	10800000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	1	11050000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	1	11050000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	11400000	ECOTOX
Gambusia holbrooki	Eastern Mosquitofish	LC50	MOR	MORT	4	11540000	ECOTOX
Channa punctata	Snake-Head Catfish	LC50	MOR	MORT	4	12000000	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	SURV	4	12946000	ECOTOX
Lepomis macrochirus	Bluegill	LC50*	MOR	MORT	4	12946000	ECOTOX
Carassius carassius	Crucian Carp	LC50	MOR	MORT	1	13750000	ECOTOX
Clarias batrachus	Walking Catfish	LC50	MOR	MORT	2	14040000	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	1	14125000	ECOTOX
Caenorhabditis elegans	Nematode	LC50	MOR	MORT	2	14899000	ECOTOX
Caenorhabditis elegans	Nematode	LC50	MOR	MORT	1	16439000	ECOTOX
Poecilia latipinna	Sailfin Molly	LC50	MOR	MORT	2	16595000	ECOTOX
Caenorhabditis elegans	Nematode	LC50	MOR	MORT	1	17008000	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	4	17550000	ECOTOX
Anguilla rostrata	American Eel	LC50	MOR	MORT	4	17880000	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	1	18100000	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	2	18100000	ECOTOX
Poecilia latipinna	Sailfin Molly	LC50	MOR	MORT	1.041666667	18735000	ECOTOX
Poecilia reticulata	Guppy	LC50	MOR	MORT	1	20000000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LC50	MOR	MORT	4	20380000	ECOTOX
Anguilla rostrata	American Eel	LC50	MOR	MORT	4	21450000	ECOTOX
Caenorhabditis elegans	Nematode	LC50	MOR	MORT	2	22457000	ECOTOX
Argia sp.	Damselfly	LC50	MOR	MORT	3	23000000	ECOTOX
Caenorhabditis	Nematode	LC50	MOR	MORT	1	23817000	ECOTOX

Acute Toxicity Data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
elegans							
Argia sp.	Damselfly	LC50	MOR	MORT	3	24000000	ECOTOX
Argia sp.	Damselfly	LC50	MOR	MORT	4	24000000	ECOTOX
Caenorhabditis elegans	Nematode	LC50	MOR	MORT	2	24829000	ECOTOX
Caenorhabditis elegans	Nematode	LC50	MOR	MORT	1	25064000	ECOTOX
Caenorhabditis elegans	Nematode	LC50	MOR	MORT	1	25190000	ECOTOX
Caenorhabditis elegans	Nematode	LC50	MOR	MORT	1	25786000	ECOTOX
Argia sp.	Damselfly	LC50	MOR	MORT	2	26000000	ECOTOX
Argia sp.	Damselfly	LC50	MOR	MORT	3	26000000	ECOTOX
Argia sp.	Damselfly	LC50	MOR	MORT	1	32000000	ECOTOX
Argia sp.	Damselfly	LC50	MOR	MORT	1	32000000	ECOTOX
Argia sp.	Damselfly	LC50	MOR	MORT	2	32000000	ECOTOX

Note that two LC50 values for fathead minnows were removed as they appeared to be outliers in the large LC50 dataset and could not be verified. The LC50 values were 5440 and 6280 µg/L. The reference is Brenda Mines Sulphate and Molybdenum Toxicity Testing Proj.Rep.No.2-11-825/826, Prepared for Noranda Mining and Exploration Inc., Brenda Mines Div., B.C.(): -

Chronic Toxicity Data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Stenonema modestum	Mayfly	NOEC	MOR	MORT	14	2700	ECOTOX
Stenonema modestum	Mayfly	NOEC	GRO	GGRO	14	2700	ECOTOX
Stenonema modestum	Mayfly	NOEC	GRO	GGRO	14	4000	ECOTOX
Stenonema modestum	Mayfly	NOEC	MOR	MORT	14	5600	ECOTOX
Stenonema modestum	Mayfly	NOEC	GRO	GGRO	14	7000	ECOTOX
Stenonema modestum	Mayfly	NOEC	GRO	GGRO	14	7000	ECOTOX
Gambusia holbrooki	Eastern Mosquitofish	NOEC	MOR	SURV	5	100000	ECOTOX
Gambusia holbrooki	Eastern Mosquitofish	NOEC	GRO	GAIN	28	100000	ECOTOX
Gambusia holbrooki	Eastern Mosquitofish	NOEC	GRO	SPGR	28	100000	ECOTOX
Gambusia holbrooki	Eastern Mosquitofish	NOEC	REP	BMAS	56	100000	ECOTOX
Gambusia holbrooki	Eastern Mosquitofish	NOEC	REP	FCND	56	100000	ECOTOX
Eulimnogammarus toletanus	Sand Shrimp	NOEC	GRO	LGTH	7	108000	ECOTOX
Polycelis felina	Turbellarian	NOEC	GRO	LGTH	7	108000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	130000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEL	GRO	BMAS	7	210000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	250000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	REPO	7	250000	ECOTOX

Chronic Toxicity Data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Ceriodaphnia dubia	Water Flea	NOEC	REP	REPO	7	250000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	REPO	7	250000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	REPO	7	250000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	REPO	7	250000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	REPO	7	250000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	MOR	SURV	33	252000	ECOTOX
Pseudacris regilla	Pacific Chorus Frog	NOEC	GRO	LGTH	10	284000	ECOTOX
Pseudacris regilla	Pacific Chorus Frog	NOEC	GRO	WGHT	10	284000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	300000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	300000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	300000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	310000	ECOTOX
Daphnia pulex	Water Flea	NOEC	GRO	LGTH	21	314000	ECOTOX
Daphnia pulex	Water Flea	NOEC	REP	FCND	21	314000	ECOTOX
Daphnia pulex	Water Flea	NOEC	REP	PROG	21	314000	ECOTOX
Kirchneriella sp.	Green Algae	NOEL	POP	DBLT	91.32	400000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	440000	ECOTOX
Daphnia ambigua	Water Flea	NOEC	REP	PROG	10	440000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEL	REP	PROG	9	467000	ECOTOX
Daphnia magna	Water Flea	NOEL	REP	PROG	10	467000	ECOTOX
Argulus japonicus	Japanese Fishlouse	NOEL	MOR	TLET	4.5	500000	ECOTOX
Argulus japonicus	Japanese Fishlouse	NOEL	REP	PROG	4.5	500000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	500000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	WGHT	7	500000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	REPO	7	500000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	REPO	7	500000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	REPO	7	500000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	REPO	7	500000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	REPO	7	500000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	REPO	7	500000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	500000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	500000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	500000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	500000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	500000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	500000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	500000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	500000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	500000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	620000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	620000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	620000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	620000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	620000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	620000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	620000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	620000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	620000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	620000	ECOTOX

Chronic Toxicity Data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	620000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	620000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	620000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	620000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	620000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	620000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	620000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	NOEC	GRO	WGHT	56	643000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEL	GRO	BMAS	7	860000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	900000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	900000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	NOEC	GRO	WGHT	56	955000	ECOTOX
Spirulina platensis	Blue-Green Algae	NOEL	POP	ABND	10	1000000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1000000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1000000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1000000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1000000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1000000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1000000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1000000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1000000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1000000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1000000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1000000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	1000000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	1000000	ECOTOX
Paramecium caudatum	Ciliate	NOEL	POP	ABND	15	1000000	ECOTOX
Pacifastacus leniusculus	Signal Crayfish	NOEL	MOR	SURV	71	1000000	ECOTOX
Pacifastacus leniusculus	Signal Crayfish	NOEL	MOR	SURV	71	1000000	ECOTOX
Ceriodaphnia sp.	Water Flea	NOEC	REP	FCND	7	1155000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1250000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1250000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1250000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1250000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1250000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1250000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1250000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1250000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1250000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1250000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1250000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1250000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1250000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1250000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1250000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1250000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1250000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1250000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1250000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	1250000	ECOTOX

Chronic Toxicity Data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	1250000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	1250000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	1250000	ECOTOX
Caridina nilotica	Shrimp	NOEC	GRO	DWGT	80	1300000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	NOEC	MOR	SURV	56	1324000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	NOEC	GRO	WGHT	90	1324000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	1500000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	1500000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	1500000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	1500000	ECOTOX
Ceriodaphnia sp.	Water Flea	NOEC	REP	PROG	7	1650000	ECOTOX
Pseudoplatystoma corruscans	Pintado	NOEC	GRO	WGHT	1	1700000	ECOTOX
Caridina nilotica	Shrimp	NOEC	GRO	LGTH	80	1900000	ECOTOX
Caridina nilotica	Shrimp	NOEC	MOR	MORT	80	1900000	ECOTOX
Caridina nilotica	Shrimp	NOEC	REP	PREG	80	1900000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	NOEC	MOR	SURV	56	1924000	ECOTOX
Ictalurus punctatus	Channel Catfish	NOEC	GRO	GAIN	5	2000000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEL	GRO	BMAS	7	2000000	ECOTOX
Schistosoma mansoni	Trematode Parasite	NOEC	REP	PROG	98	2000000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	2500000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	2500000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	2500000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	2500000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	2500000	ECOTOX
Caridina nilotica	Shrimp	NOEC	GRO	LGTH	80	2500000	ECOTOX
Ictalurus punctatus	Channel Catfish	NOEC	GRO	WGHT	5	4000000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	GGRO	7	4000000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	GGRO	7	4000000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	GGRO	7	4000000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	GGRO	7	4000000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	GGRO	7	4000000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	GGRO	7	4000000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	NOEL	GRO	WGHT	14	4560000	ECOTOX
Metynnis orinocensis	Characid	NOEL	GRO	WGHT	4	5000000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	5000000	ECOTOX
Stuckenia pectinata	Sago Pondweed	NOEL	MOR	SURV	15	6000000	ECOTOX
Stuckenia pectinata	Sago Pondweed	NOEL	MOR	SURV	15	9000000	ECOTOX
Stuckenia pectinata	Sago Pondweed	NOEL	GRO	NROT	35	9000000	ECOTOX
Metynnis orinocensis	Characid	NOEL	GRO	WGHT	4	10000000	ECOTOX
Stuckenia pectinata	Sago Pondweed	NOEL	MOR	SURV	15	12000000	ECOTOX
Stuckenia pectinata	Sago Pondweed	NOEL	MOR	SURV	15	12000000	ECOTOX
Stuckenia pectinata	Sago Pondweed	NOEL	REP	TUPR	35	12000000	ECOTOX
Stuckenia pectinata	Sago Pondweed	NOEL	REP	TUPR	35	12000000	ECOTOX
Caridina nilotica	Shrimp	NOEC	GRO	DWGT	80	16000000	ECOTOX
Caridina nilotica	Shrimp	NOEC	GRO	GRRT	80	16000000	ECOTOX
Caridina nilotica	Shrimp	NOEC	GRO	LGTH	80	16000000	ECOTOX
Caridina nilotica	Shrimp	NOEC	REP	GMET	80	16000000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	NOEL	MOR	HTCH	14	32900000	ECOTOX
Stenonema modestum	Mayfly	LOEC	MOR	MORT	14	3500	ECOTOX

Chronic Toxicity Data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Stenonema modestum	Mayfly	LOEC	GRO	GGRO	14	3500	ECOTOX
Stenonema modestum	Mayfly	LOEC	MOR	MORT	14	7000	ECOTOX
Stenonema modestum	Mayfly	LOEC	GRO	GGRO	14	7000	ECOTOX
Stenonema modestum	Mayfly	LOEC	GRO	GGRO	14	7000	ECOTOX
Stenonema modestum	Mayfly	LOEC	GRO	GGRO	14	7000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	REP	REPO	7	250000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	REP	REPO	7	250000	ECOTOX
Pimephales promelas	Fathead Minnow	MATC	MOR	SURV	33	298000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	REP	PROG	7	300000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	REP	PROG	7	300000	ECOTOX
Pimephales promelas	Fathead Minnow	LOEC	MOR	SURV	33	352000	ECOTOX
Daphnia pulex	Water Flea	MATC	GRO	LGTH	21	372000	ECOTOX
Daphnia pulex	Water Flea	MATC	REP	FCND	21	372000	ECOTOX
Daphnia pulex	Water Flea	MATC	REP	PROG	21	372000	ECOTOX
Daphnia pulex	Water Flea	LOEC	GRO	LGTH	21	441000	ECOTOX
Daphnia pulex	Water Flea	LOEC	REP	FCND	21	441000	ECOTOX
Daphnia pulex	Water Flea	LOEC	REP	PROG	21	441000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	REP	REPO	7	500000	ECOTOX
Daphnia ambigua	Water Flea	LOEC	REP	PROG	10	850000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	REP	PROG	7	900000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	REP	PROG	7	900000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	MATC	MOR	SURV	90	923000	ECOTOX
Schistosoma mansoni	Trematode Parasite	LOEC	REP	PROG	98	1000000	ECOTOX
Pimephales promelas	Fathead Minnow	LOEC	GRO	WGHT	7	1000000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	REP	REPO	7	1000000	ECOTOX
Pimephales promelas	Fathead Minnow	LOEL	GRO	BMAS	7	1140000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	REP	PROG	7	1250000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	REP	PROG	7	1250000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LOEC	GRO	WGHT	56	1324000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LOEC	MOR	SURV	90	1324000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	MATC	GRO	WGHT	56	1356000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	REP	PROG	7	1500000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	REP	PROG	7	1500000	ECOTOX
Ceriodaphnia sp.	Water Flea	LOEC	REP	FCND	7	1650000	ECOTOX
Ceriodaphnia sp.	Water Flea	LOEC	REP	PROG	7	1650000	ECOTOX
Kirchneriella sp.	Green Algae	LOEL	POP	DBLT	91.32	1900000	ECOTOX
Caridina nilotica	Shrimp	LOEC	GRO	DWGT	80	1900000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LOEC	GRO	WGHT	56	1924000	ECOTOX
Stuckenia pectinata	Sago Pondweed	LOEL	REP	GERM	25	2000000	ECOTOX
Caridina nilotica	Shrimp	LOEC	GRO	LGTH	80	2200000	ECOTOX
Pimephales promelas	Fathead Minnow	LOEL	GRO	BMAS	7	2200000	ECOTOX
Pimephales promelas	Fathead Minnow	LOEC	GRO	BMAS	7	2500000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	REP	PROG	7	2500000	ECOTOX
Caridina nilotica	Shrimp	LOEC	REP	PREG	80	2700000	ECOTOX
Caridina nilotica	Shrimp	LOEC	MOR	MORT	80	2700000	ECOTOX

Chronic Toxicity Data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Caridina nilotica	Shrimp	LOEC	GRO	LGTH	80	2700000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LOEC	MOR	SURV	56	2740000	ECOTOX
Stuckenia pectinata	Sago Pondweed	LOEL	GRO	WGHT	35	3000000	ECOTOX
Stuckenia pectinata	Sago Pondweed	LOEL	GRO	WGHT	35	3000000	ECOTOX
Stuckenia pectinata	Sago Pondweed	LOEL	REP	GERM	25	3000000	ECOTOX
Pseudoplatystoma corruscans	Pintado	LOEC	GRO	WGHT	1	3300000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LOEC	MOR	SURV	56	3917000	ECOTOX
Ictalurus punctatus	Channel Catfish	LOEC	GRO	GAIN	5	4000000	ECOTOX
Stuckenia pectinata	Sago Pondweed	LOEL	GRO	NROT	20	4000000	ECOTOX
Stuckenia pectinata	Sago Pondweed	LOEL	REP	GERM	25	5000000	ECOTOX
Pimephales promelas	Fathead Minnow	LOEC	GRO	BMAS	7	5000000	ECOTOX
Stuckenia pectinata	Sago Pondweed	LOEL	MOR	SURV	15	9000000	ECOTOX
Paramecium caudatum	Ciliate	LOEL	POP	ABND	15	10000000	ECOTOX
Pimephales promelas	Fathead Minnow	LOEC	GRO	BMAS	7	10000000	ECOTOX
Stuckenia pectinata	Sago Pondweed	LOEL	GRO	NROT	35	12000000	ECOTOX
Stuckenia pectinata	Sago Pondweed	LOEL	MOR	SURV	15	12000000	ECOTOX
Stuckenia pectinata	Sago Pondweed	LOEL	MOR	SURV	15	15000000	ECOTOX
Stuckenia pectinata	Sago Pondweed	LOEL	MOR	SURV	15	15000000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	PROG	7	300000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	PROG	7	330000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	PROG	7	330000	ECOTOX
Ceriodaphnia dubia	Water Flea	EC50	REP	PROG	9	467000	ECOTOX
Daphnia magna	Water Flea	EC50	REP	PROG	10	467000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	REPO	7	570000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	PROG	7	600000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	REPO	7	610000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	PROG	7	650000	ECOTOX
Daphnia ambigua	Water Flea	EC50	REP	PROG	10	650000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	REPO	7	670000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	REPO	7	680000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	REPO	7	710000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	REPO	7	720000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	PROG	7	720000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	PROG	7	730000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	PROG	7	740000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	REPO	7	750000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	REPO	7	920000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	REPO	7	960000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	REPO	7	980000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	REPO	7	1100000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	REPO	7	1130000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	PROG	3	1245610	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	PROG	7	1290000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	PROG	7	1340000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	PROG	7	1340000	ECOTOX
Ceriodaphnia dubia	Water Flea	EC50	REP	PROG	7	1350000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	PROG	7	1390000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	PROG	3	1450250	ECOTOX
Ceriodaphnia dubia	Water Flea	EC50	REP	PROG	8	1500000	ECOTOX

Chronic Toxicity Data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Ceriodaphnia dubia	Water Flea	IC50	REP	PROG	7	1510000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	PROG	7	1600000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	PROG	7	1690000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	PROG	7	1760000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	PROG	7	1900000	ECOTOX
Caridina nilotica	Shrimp	LC50	MOR	MORT	80	2420000	ECOTOX
Navicula seminulum	Diatom	EC50	POP	PGRT	4	2430000	ECOTOX
Caridina nilotica	Shrimp	LC50	MOR	MORT	80	2670000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	4.2	3170000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	4.2	3448000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	4.2	4178000	ECOTOX
Lemna minor	Duckweed	EC50	POP	BMAS	7	4880000	ECOTOX
Lemna minor	Duckweed	EC50	POP	BMAS	7	5000000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	4.2	5093000	ECOTOX
Lemna minor	Duckweed	EC50	POP	BMAS	7	5390000	ECOTOX
Lemna minor	Duckweed	EC50	POP	BMAS	7	5500000	ECOTOX
Myriophyllum spicatum	Eurasian Watermilfoil	EC50	POP	BMAS	32	5962000	ECOTOX
Myriophyllum spicatum	Eurasian Watermilfoil	EC50	GRO	GGRO	32	7423000	ECOTOX
Myriophyllum spicatum	Eurasian Watermilfoil	EC50	GRO	GGRO	32	8008000	ECOTOX
Myriophyllum spicatum	Eurasian Watermilfoil	EC50	POP	BMAS	32	8183000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LT50	MOR	MORT	30	10000000	ECOTOX
Caridina nilotica	Shrimp	LC50	MOR	MORT	80	22640000	ECOTOX

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.

Name	Sodium Hydroxide
Synonyms	Sodium hydroxide
CAS number	1310-73-2
Molecular formula	NaOH
Product name	BE-7

Physical Properties	Value	Reference
Phase/state	White orthogonal crystals	HSDB, 2011
Molecular weight	40 g/mol	HSDB, 2011
Melting point	323^{o}C	HSDB, 2011
Boiling point	1388^{o}C	HSDB, 2011
Solubility	1 g dissolves in 0.9 ml water	HSDB, 2011

Other Relevant Factors	Value	Reference
Reactivity		
Species	OH^-/NaOH	
Reaction type	Acid/base	
pH		
acid / alkaline	Alkaline	HSDB, 2011
pH (5% solution)	11	HSDB, 2011

Notes: 1. Halliburton Material Safety Data Sheet M275. Issue Date:16 July 2003.
2. Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line 24 March 2011.
NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	Not listed in IARC database
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Acute Toxicity Data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Ceriodaphnia dubia	Water Flea	EC50	ITX	IMBL	2	40380	ECOTOX
Ceriodaphnia dubia	Water Flea	EC50	ITX	IMBL	2	40380	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	1	125000	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	2	125000	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	4	125000	ECOTOX
Poecilia reticulata	Guppy	LC50	MOR	MORT	1	145000	ECOTOX
Carassius auratus	Goldfish	LC50	MOR	MORT	1	160000	ECOTOX

Media Type : Freshwater

ITX: Intoxication

IMBL: Immobile

MOR/MORT: Mortality

Notes:

ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2008: Guidelines for Drinking-water Quality 2008.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points.

ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm

Name	Sodium Hypochlorite
Synonyms	Hypochlorous acid, sodium salt; clorox
CAS number	10377-60-3
Molecular formula	NaOCl
Product name	BE-7

Physical Properties	Value	Reference
Phase/state	liquid	2
Molecular weight	74.4 g/mol	2
Melting point	18^{o}C	2
Boiling point	111^{o}C	2
Solubility	29.3 g/100 g (0 deg C) in water	2

Other Relevant Factors	Value	Reference
Reactivity		
Species	$NaOCl + H_2O \leftrightarrow NaOH + HOCl \leftrightarrow Na^+ + OH^- + H^+ + OCl^-$	
Reaction type	Acid/base, saponification, anti-microbial, oxidising agent	2
pH		
acid / alkaline	alkaline	2
pH (5% solution)	11.1 – 11.6	

Notes:
1. Halliburton Material Safety Data Sheet BE-7. Issue Date:04 January 2011
2. Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line 24 March 2011.

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	Not listed in IARC database
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Acute Toxicity Data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Water Flea	Ceriodaphnia dubia	LC50	MOR	MORT	1	5	ECOTOX
Water Flea	Ceriodaphnia dubia	LC50	MOR	MORT	1	6	ECOTOX
Water Flea	Ceriodaphnia dubia	LC50	MOR	MORT	1	35	ECOTOX
Water Flea	Ceriodaphnia dubia	LC50	MOR	MORT	1	48	ECOTOX
Water Flea	Ceriodaphnia dubia	LC50	MOR	MORT	1	80	ECOTOX
Water Flea	Daphnia magna	LC50	MOR	MORT	2	32	ECOTOX
Water Flea	Daphnia magna	LC50	MOR	MORT	2	55	ECOTOX
Isopod	Caecidotea sp.	LC50	MOR	MORT	4	110	ECOTOX
Mucket	Actinonaias ligamentina	EC50	MOR	SURV	1	74	ECOTOX
Mucket	Actinonaias ligamentina	EC50	MOR	SURV	1	74	ECOTOX
Mucket	Actinonaias ligamentina	EC50	MOR	SURV	2	40	ECOTOX
Mucket	Actinonaias ligamentina	EC50	MOR	SURV	2	40	ECOTOX
Mucket	Actinonaias ligamentina	EC50	MOR	SURV	2	48	ECOTOX
Mucket	Actinonaias ligamentina	EC50	MOR	SURV	2	48	ECOTOX
Mucket	Actinonaias ligamentina	EC50	MOR	SURV	2	52	ECOTOX
Mucket	Actinonaias ligamentina	EC50	MOR	SURV	2	52	ECOTOX
Rio Grande Silvery Minnow	Hybognathus amarus	LC50	MOR	MORT	1	126	ECOTOX
Rio Grande Silvery Minnow	Hybognathus amarus	LC50	MOR	MORT	2	126	ECOTOX
Rio Grande Silvery Minnow	Hybognathus amarus	LC50	MOR	MORT	3	115	ECOTOX
Rio Grande Silvery Minnow	Hybognathus amarus	LC50	MOR	MORT	4	115	ECOTOX
Isopod	Caecidotea sp.	LC50	MOR	MORT	4	185	ECOTOX
Water Flea	Ceriodaphnia dubia	LC50	MOR	MORT	1	140	ECOTOX
Aquatic Sowbug	Asellus intermedius	LC50	MOR	MORT	4	32000	ECOTOX
Water Flea	Daphnia magna	LC50	MOR	MORT	4	2100	ECOTOX
Calanoid Copepod	Diacyclops thomasi	LC50*	MOR	MORT	4	69	ECOTOX
Scud	Gammarus fasciatus	LC50	MOR	MORT	4	4000	ECOTOX
Scud	Hyalella azteca	LC50	MOR	MORT	4	78	ECOTOX
Scud	Hyalella azteca	LC50	MOR	MORT	4	301	ECOTOX
Aquatic Sowbug	Lirceus alabamale	LC50	MOR	MORT	4	145	ECOTOX
Aquatic Sowbug	Lirceus alabamale	LC50	MOR	MORT	4	155	ECOTOX
Channel Catfish	Ictalurus punctatus	LC50	MOR	MORT	4	70	ECOTOX
Channel Catfish	Ictalurus punctatus	LC50	MOR	MORT	4	450	ECOTOX
Bluegill	Lepomis macrochirus	LC50	MOR	MORT	1	2100	ECOTOX
Bluegill	Lepomis macrochirus	LC50	MOR	MORT	4	4300	ECOTOX
Bluegill	Lepomis macrochirus	LC50	MOR	MORT	4	5300	ECOTOX
Bluegill	Lepomis macrochirus	LC50	MOR	MORT	4	580	ECOTOX
Bluegill	Lepomis macrochirus	LC50	MOR	MORT	4	1000	ECOTOX
Bluegill	Lepomis macrochirus	LC50	MOR	MORT	4	440	ECOTOX
Bluegill	Lepomis macrochirus	LC50	MOR	MORT	4	910	ECOTOX
Bluegill	Lepomis macrochirus	LC50	MOR	MORT	4	2130	ECOTOX
Bluegill	Lepomis macrochirus	LC50	MOR	MORT	4	2480	ECOTOX
Bluegill	Lepomis macrochirus	LC50	MOR	MORT	4	880	ECOTOX
Common Shiner	Luxilus cornutus	LC50	MOR	MORT	1	1350	ECOTOX
Inland Silverside	Menidia beryllina	LC50	MOR	MORT	4	193	ECOTOX
Golden Shiner	Notemigonus crysoleucas	LC50	MOR	MORT	4	304	ECOTOX
Golden Shiner	Notemigonus crysoleucas	LC50	MOR	MORT	4	572	ECOTOX
Rainbow Trout	Oncorhynchus mykiss	LC50	MOR	MORT	1	430	ECOTOX
Rainbow Trout	Oncorhynchus mykiss	LC50	MOR	MORT	1	1350	ECOTOX

Acute Toxicity Data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Rainbow Trout	Oncorhynchus mykiss	LC50	MOR	MORT	2	350	ECOTOX
Rainbow Trout	Oncorhynchus mykiss	LC50	MOR	MORT	4	59	ECOTOX
Rainbow Trout	Oncorhynchus mykiss	LC50	MOR	MORT	4	90	ECOTOX
Rainbow Trout	Oncorhynchus mykiss	LC50	MOR	MORT	4	374	ECOTOX
Rainbow Trout	Oncorhynchus mykiss	LC50	MOR	MORT	4	30 to 190	ECOTOX
Rainbow Trout	Oncorhynchus mykiss	LC50	MOR	MORT	4	30 to 70	ECOTOX
Rainbow Trout	Oncorhynchus mykiss	LC50	MOR	MORT	4	1940	ECOTOX
Rainbow Trout	Oncorhynchus mykiss	LC50	MOR	MORT	4	200	ECOTOX
Rainbow Trout	Oncorhynchus mykiss	LC50	MOR	MORT	4	4180	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	1	114	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	1	5600	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	1	6300	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	2	114	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	2	5900	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	2	5900	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	3	114	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	114	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	5600*	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	5900	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	5900	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	10000	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	140	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	170	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	350	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	720	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	790	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	80	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	1370	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	1560	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	180	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	390	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	440	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	580	ECOTOX
Yellow Fever Mosquito	Aedes aegypti	LC50	MOR	MORT	1	1070	ECOTOX
Southern House Mosquito	Culex quinquefasciatus	LC50	MOR	MORT	1	710	ECOTOX
Rotifer	Brachionus calyciflorus	LC50	MOR	MORT	1	370	ECOTOX
Mucket	Actinonaias ligamentina	EC50	MOR	SURV	1	100	ECOTOX
Mucket	Actinonaias ligamentina	EC50	MOR	SURV	1	100	ECOTOX
Mucket	Actinonaias ligamentina	EC50	MOR	SURV	1	100	ECOTOX
Mucket	Actinonaias ligamentina	EC50	MOR	SURV	1	100	ECOTOX
Dwarf Wedge Mussel	Alasmidonta heterodon	EC50	MOR	SURV	1	100	ECOTOX
Dwarf Wedge Mussel	Alasmidonta heterodon	EC50	MOR	SURV	2	100	ECOTOX
Oyster Mussel	Epioblasma capsaeformis	EC50	MOR	SURV	10	29	ECOTOX
Oyster Mussel	Epioblasma capsaeformis	EC50	MOR	SURV	2	100	ECOTOX
Oyster Mussel	Epioblasma capsaeformis	EC50	MOR	SURV	4	100	ECOTOX
Wavy-Rayed Lampmussel	Lampsilis fasciola	EC50	MOR	SURV	1	100	ECOTOX
Wavy-Rayed Lampmussel	Lampsilis fasciola	EC50	MOR	SURV	1	100	ECOTOX
Wavy-Rayed Lampmussel	Lampsilis fasciola	EC50	MOR	SURV	2	100	ECOTOX
Wavy-Rayed	Lampsilis fasciola	EC50	MOR	SURV	2	100	ECOTOX

Acute Toxicity Data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Lampmussel							
Neosho Mucket	Lampsilis rafinesqueana	EC50	MOR	SURV	1	100	ECOTOX
Neosho Mucket	Lampsilis rafinesqueana	EC50	MOR	SURV	10	54	ECOTOX
Neosho Mucket	Lampsilis rafinesqueana	EC50	MOR	SURV	2	100	ECOTOX
Neosho Mucket	Lampsilis rafinesqueana	EC50	MOR	SURV	2	53	ECOTOX
Neosho Mucket	Lampsilis rafinesqueana	EC50	MOR	SURV	4	100	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	1	100	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	1	100	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	1	47	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	1	47	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	1	67	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	1	67	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	1	81	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	1	81	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	1	82	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	1	82	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	1	90	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	1	90	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	10	56	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	10	97	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	100	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	100	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	100	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	100	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	34	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	34	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	57	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	57	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	60	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	60	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	70	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	70	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	79	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	2	79	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	4	100	ECOTOX
Lamp-Mussel	Lampsilis siliquoidea	EC50	MOR	SURV	4	100	ECOTOX
Pink Papershell	Potamilus ohiensis	EC50	MOR	SURV	1	58	ECOTOX
Pink Papershell	Potamilus ohiensis	EC50	MOR	SURV	2	25	ECOTOX
Ellipse	Venustaconcha ellipsiformis	EC50	MOR	SURV	1	76	ECOTOX
Ellipse	Venustaconcha ellipsiformis	EC50	MOR	SURV	2	44	ECOTOX
Rainbow	Villosa iris	EC50	MOR	SURV	1	50	ECOTOX
Rainbow	Villosa iris	EC50	MOR	SURV	10	100	ECOTOX
Rainbow	Villosa iris	EC50	MOR	SURV	10	16	ECOTOX
Rainbow	Villosa iris	EC50	MOR	SURV	10	22	ECOTOX
Rainbow	Villosa iris	EC50	MOR	SURV	2	100	ECOTOX
Rainbow	Villosa iris	EC50	MOR	SURV	2	100	ECOTOX
Rainbow	Villosa iris	EC50	MOR	SURV	2	43	ECOTOX
Rainbow	Villosa iris	EC50	MOR	SURV	2	80	ECOTOX
Rainbow	Villosa iris	EC50	MOR	SURV	4	100	ECOTOX
Rainbow	Villosa iris	EC50	MOR	SURV	4	100	ECOTOX
Rainbow	Villosa iris	EC50	MOR	SURV	4	68	ECOTOX
Zebra Mussel	Dreissena polymorpha	LC50	MOR	MORT	9	1130	ECOTOX
Zebra Mussel	Dreissena polymorpha	LC50	MOR	MORT	9	1610	ECOTOX
Zebra Mussel	Dreissena polymorpha	LC50	MOR	MORT	9	1640	ECOTOX

Acute Toxicity Data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Zebra Mussel	Dreissena polymorpha	LC50	MOR	MORT	9	2110	ECOTOX
Liver Elimia, River Snail	Elimia livescens	LC50	MOR	MORT	1	10400	ECOTOX
Liver Elimia, River Snail	Elimia livescens	LC50	MOR	MORT	2	6200	ECOTOX
Pond Snail	Lymnaea emarginata ssp. angulata	LC50	MOR	MORT	1	21800	ECOTOX
Pond Snail	Lymnaea emarginata ssp. angulata	LC50	MOR	MORT	2	13600	ECOTOX
Pouch Snail	Physa integra	LC50	MOR	MORT	1	2000	ECOTOX
Pouch Snail	Physa integra	LC50	MOR	MORT	2	1800	ECOTOX
Snail, Marsh Rams-Horn	Planorbella trivolvis	LC50	MOR	MORT	4	59000	ECOTOX
Turbellarian, Flatworm	Dugesia tigrina	LC50	MOR	MORT	4	32000	ECOTOX
Oligochaete, Worm	Lumbriculus variegatus	LC50	MOR	MORT	4	3200	ECOTOX

Chronic Toxicity Data							
Ceriodaphnia dubia	Water Flea	NOEC	REP	GREP	10	48	ECOTOX
Algae	Algae	MATC	POP	BMAS	28	50	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	REP	GREP	10	66	ECOTOX
Algae	Algae	MATC	POP	BMAS	24	144	ECOTOX
Algae	Algae	MATC	POP	BMAS	28	175	ECOTOX
Algae	Algae	MATC	POP	DVRS	24	144	ECOTOX

Media Type : Freshwater

REP: REporduction

GREP: Reproduction, general,

BMAS: Biomass

DVRS : Diversity

POP: Population

MOR/MORT : Mortality

SURV : Survival

Notes:

ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.
USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.
NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.
WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.

ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Silica Gel
Synonyms	
CAS number	NA (7631-86-9 amorphous silica surrogate used for information on chemical information sheet)
Molecular formula	O_2Si
Product name	

Physical Properties	Value	Reference
Phase/state	Amorphous powder.	HSDB, 2011
Molecular weight	60.1 g/mol	HSDB, 2011
Melting point	1710^{o}C	HSDB, 2011
Boiling point	2230^{o}C	HSDB, 2011
Solubility	Insoluble	HSDB, 2011

Other Relevant Factors	Value	Reference
Reactivity		
Species & Reaction type	Vinyl acetate vapour may react vigorously in contact with silica gel.	HSDB, 2011
pH	NA	

Notes: 1 . Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line : 4 July 2011.

NA - not available

Surrogate amorphous silica used for silica gel for physical, guideline and aquatic toxicity data.

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2010	Human Health	NA	
IARC	2006	Carcinogen risk	3 (unitless)	*Not classifiable as to its carcinogenicity to humans*
ANZECC	2000	Stock water	NA	

Aquatic Ecotoxicological Data

Acute toxicity data							
Species Scientific Name	**Species Common Name**	**Endpoint**	**Effect**	**Effect Measurement**	**Test time (Days)**	**Conc (µg/L)**	**Reference**
Dicentrarchus labrax	Sea Bass	LOEL	GRO	GAIN	60	10%	ECOTOX

SW data only available for amorphous silica.

Notes:

ATSDR, 2010. Agency for Toxic Substances and Disease Registry, Toxicological Profile for Boron. US Department of Health and Human Services. Accessed at : http://www.atsdr.cdc.gov/ToxProfiles/tp26.pdf.

ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.
Hickey CW; N.Z. J Mar Freshwater Res 23 (1): 131-137 (1989). Available from the ECOTOX database on Boric acid (10043-35-3) at: http://www.epa.gov/cgi-bin/ecotox_quick_search as of May 13, 2005.
European Chemicals Bureau; IUCLID Dataset, Boric acid (10043-35-3) (2000 CD-ROM edition). Available from, as of May 18, 2005: http://ecb.jrc.it/esis/esis.php.
ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Sodium sulfate
Synonyms	Bisodium sulphate, disodium monosulfate, disodium sulphate,
CAS number	7757-82-6
Molecular formula	$H_2O_4S_2Na$
Product name	

Physical Properties	Value	Reference
Phase/state	White powder or orthorhombic bipyramid crystals	HSDB, 2011
Molecular weight	142.06 g/mol	HSDB, 2011
Melting point	888 ^oC	HSDB, 2011
Boiling point	>890 ^oC	IUCLID, 2000
Solubility	Soluble in 3.6 parts water at 33^oC	HSDB, 2011

Other Relevant Factors	Value	Reference
Reactivity		
Species	NA	
Reaction type	NA	
pH		
acid / alkaline	Sodium salt of sulphuric acid	IUCLID, 2000

Notes: 1 EPI Suite™ v4.0, United States Environmental Protection Agency.

2. Hazardous Substances Data Bank (HSDB) National library of Medicine (sodium sulfate) accessed on line : 7 June 2011.

3. IUCLID, 2000. European Commission: European Chemicals Bureau. Accessed on 7 June 2011. Accessed at : http://ecb.jrc.ec.europa.eu/iuclid-datasheet/7757826.pdf

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Pimephales promelas	Fathead Minnow	NOEC	MOR	MORT	7	510000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	MOR	SURV	7	510000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	MOR	MORT	3	1060000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	MOR	MORT	7	1060000	ECOTOX
Hyalella azteca	Scud	NOEC	MOR	MORT	4	1060000	ECOTOX
Hyalella azteca	Scud	NOEC	MOR	SURV	4	1060000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	MOR	SURV	7	1300900	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	MOR	SURV	7	1300900	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	MOR	SURV	7	1381000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	MOR	MORT	7	1381000	ECOTOX
Hyalella azteca	Scud	NOEC	MOR	SURV	2	1460000	ECOTOX
Hyalella azteca	Scud	NOEC	MOR	SURV	3	1460000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	MOR	SURV	7	1727000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	MOR	SURV	7	2264000	ECOTOX
Caridina nilotica	Shrimp	NOEC	MOR	MORT	80	1900000	ECOTOX
Ceriodaphnia sp.	Water Flea	NOEC	MOR	SURV	7	2970000	ECOTOX
Daphnia magna	Water Flea	NOEC	MOR	MORT	2	3650000	ECOTOX
Daphnia magna	Water Flea	NOEC	MOR	MORT	2	3650000	ECOTOX
Pimephales promelas	Fathead Minnow	LOEC	MOR	MORT	7	1060000	ECOTOX
Pimephales promelas	Fathead Minnow	LOEC	MOR	SURV	7	1060000	ECOTOX
Hyalella azteca	Scud	LOEC	MOR	SURV	2	1460000	ECOTOX
Hyalella azteca	Scud	LOEC	MOR	SURV	2	1460000	ECOTOX
Hyalella azteca	Scud	LOEC	MOR	SURV	3	1460000	ECOTOX
Hyalella azteca	Scud	LOEC	MOR	SURV	3	1460000	ECOTOX
Hyalella azteca	Scud	LOEC	MOR	SURV	4	1460000	ECOTOX
Hyalella azteca	Scud	LOEC	MOR	SURV	4	1460000	ECOTOX
Ceriodaphnia sp.	Water Flea	LOEC	MOR	SURV	7	4400000	ECOTOX
Daphnia magna	Water Flea	LOEC	MOR	MORT	2	7460000	ECOTOX
Daphnia magna	Water Flea	LOEC	MOR	MORT	2	7460000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	MOR	SURV	7	2273000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	MOR	MORT	7	3000000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	MOR	SURV	7	3000000	ECOTOX
Hyalella azteca	Scud	LOEC	MOR	MORT	4	3650000	ECOTOX
Hyalella azteca	Scud	LOEC	MOR	SURV	4	3650000	ECOTOX
Lymnaea sp.	Pond Snail	LC50	MOR	MORT	4	3553	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	MOR	MORT	7	2216000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	MOR	MORT	3	3650000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	MOR	MORT	7	3650000	ECOTOX
Lymnaea sp.	Pond Snail	LC50	MOR	MORT	3	5400	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	512000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	569000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	4	630000	ECOTOX
Tricorythus sp.	Mayfly	LC50	MOR	MORT	4	660000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	3	725000	ECOTOX

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Amphipoda	Scud Order	LC50	MOR	MORT	3	880000	ECOTOX
Amphipoda	Scud Order	LC50	MOR	MORT	4	880000	ECOTOX
Amphipoda	Scud Order	LC50	MOR	MORT	2	1110000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	1116000	ECOTOX
Ceriodaphnia dubia	Water Flea	EC50	REP	PROG	7	1148000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	1194000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	1194000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	1226130	ECOTOX
Hyalella azteca	Scud	LC50	MOR	SURV	4	1226130	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	1328000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	7	1355480	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	SURV	7	1355480	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	1387000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	1433000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	1438000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	1448000	ECOTOX
Ceriodaphnia dubia	Water Flea	EC50	REP	PROG	7	1458000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	1470000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	EC50	REP	VIAB	7	1477430	ECOTOX
Oncorhynchus sp.	Pacific Salmon	EC50	REP	VIAB	7	1477430	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	1480000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	1496000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	1551000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	1562000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	1563000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	1563000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	1580000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	1616000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	1621000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	1679000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	1684000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	1691000	ECOTOX
Lampsilis siliquoidea	Lamp-Mussel	LC50	MOR	MORT	2	1702000	ECOTOX
Lampsilis siliquoidea	Lamp-Mussel	LC50	MOR	MORT	4	1727000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	1767000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	1779000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	1793000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	1799000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	1820000	ECOTOX
Lampsilis siliquoidea	Lamp-Mussel	LC50	MOR	MORT	4	1822000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	1828000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	1830000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	1830000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	1854000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	1868000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	1879000	ECOTOX
Navicula seminulum	Diatom	EC50	POP	PGRT	4	1900000	ECOTOX

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Nitzschia linearis	Diatom	LC50*	MOR	MORT	5	1900000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	1901000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	1914000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	1925000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	1938000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	7	1955980	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	3	1966980	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	1985000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	2000000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	2002000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	2002000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2030000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	7	2049000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2050000	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	PROG	7	2061180	ECOTOX
Ceriodaphnia dubia	Water Flea	IC50	REP	RSUC	3	2061180	ECOTOX
Sphaerium simile	Grooved Fingernail Clam	LC50	MOR	MORT	4	2078000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2095000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	2101000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	2121000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2184000	ECOTOX
Sphaerium simile	Grooved Fingernail Clam	LC50	MOR	MORT	4	2186000	ECOTOX
Sphaerium simile	Grooved Fingernail Clam	LC50	MOR	MORT	4	2190000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2198000	ECOTOX
Sphaerium simile	Grooved Fingernail Clam	LC50	MOR	MORT	4	2200000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	2203000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2223000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	2240000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2243000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2269000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2272000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2289000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2295000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2300000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2357000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2383000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2402000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2404000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2417000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2419000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2436000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	7	2442000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2446000	ECOTOX

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2469000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2470000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2472000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2481000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2494000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2526000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2526000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2526000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2538000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	2564000	ECOTOX
Daphnia magna	Water Flea	LC50*	MOR	MORT	2	2564000	ECOTOX
Sphaerium simile	Grooved Fingernail Clam	LC50	MOR	MORT	4	2590000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2607000	ECOTOX
Sphaerium simile	Grooved Fingernail Clam	LC50	MOR	MORT	4	2650000	ECOTOX
Lampsilis siliquoidea	Lamp-Mussel	LC50	MOR	MORT	2	2661000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2706000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2724000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	2724000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	2725000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	2740000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	4.16666667	2752000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2757000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	2840000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2853000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	2855000	ECOTOX
Sphaerium simile	Grooved Fingernail Clam	LC50	MOR	MORT	4	2926000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	2946000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	2955000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	3000000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	3059000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	3065000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	3073000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	3080000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	3091000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	3144000	ECOTOX
Ceriodaphnia dubia	Water Flea	EC50	ITX	IMBL	2	3150210	ECOTOX
Ceriodaphnia dubia	Water Flea	EC50	ITX	IMBL	2	3150210	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	3174000	ECOTOX
Lampsilis siliquoidea	Lamp-Mussel	LC50	MOR	MORT	2	3183000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	3203000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	3203000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	3265000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	3288000	ECOTOX

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	3297000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	3338000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	3342000	ECOTOX
Pseudokirchneriella subcapitata	Green Algae	IC50	POP	ABND	3	3359120	ECOTOX
Pseudokirchneriella subcapitata	Green Algae	IC50	POP	NCHG	3	3359120	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	3361000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	3369000	ECOTOX
Lampsilis siliquoidea	Lamp-Mussel	LC50	MOR	MORT	4	3377000	ECOTOX
Pimephales promelas	Fathead Minnow	IC50	GRO	DWGT	7	3449810	ECOTOX
Pimephales promelas	Fathead Minnow	IC50	GRO	WGHT	7	3449810	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	3462000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	3506000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	3516000	ECOTOX
Lampsilis siliquoidea	Lamp-Mussel	LC50	MOR	MORT	2	3523000	ECOTOX
Lampsilis siliquoidea	Lamp-Mussel	LC50	MOR	MORT	4	3525000	ECOTOX
Lampsilis siliquoidea	Lamp-Mussel	LC50	MOR	MORT	2	3574000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	1	3590000	ECOTOX
Ceriodaphnia dubia	Water Flea	LC50	MOR	MORT	2	3716000	ECOTOX
Lampsilis siliquoidea	Lamp-Mussel	LC50	MOR	MORT	4	3729000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	3796000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	3808000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	4046000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	4.16666667	4135000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	4145000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	4336000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	4345000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	4395000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	4.2	4547000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	4	4547000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	4580000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	2.08333333	4822000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	2.08333333	5056000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	5218140	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	5218140	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	5259000	ECOTOX
Lymnaea sp.	Pond Snail	LC50	MOR	MORT	2	5400000	ECOTOX
Lymnaea sp.	Pond Snail	LC50	MOR	MORT	1	5401000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	4.16666667	5514000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	2.08333333	5966000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	1.04166	6097000	ECOTOX

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
					667		
Daphnia magna	Water Flea	LC50	MOR	MORT	2	6100000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	1	6290000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	1.04166667	6490000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	1	6800000	ECOTOX
Daphnia magna	Water Flea	LC50	ITX	IMBL	1.04166667	6949000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	2	7960000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	7960000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	1	8080000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	1	8384000	ECOTOX
Daphnia magna	Water Flea	LC50*	MOR	MORT	1	8384000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2	8600000	ECOTOX
Culex sp.	Mosquito	LC50	MOR	MORT	1	11430000	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	4	12500000	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	4	12750000	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	4	13000000	ECOTOX
Culex sp.	Mosquito	LC50	MOR	MORT	2	13350000	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	SURV	4	13500000	ECOTOX
Lepomis macrochirus	Bluegill	LC50*	MOR	MORT	4	13500000	ECOTOX
Chironomus tentans	Midge	LC50	MOR	MORT	2	14134000	ECOTOX
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	15200000	ECOTOX
Poecilia latipinna	Sailfin Molly	LC50	MOR	MORT	2	15996000	ECOTOX
Lepomis macrochirus	Bluegill	LC50	MOR	MORT	1	17500000	ECOTOX
Poecilia latipinna	Sailfin Molly	LC50	MOR	MORT	1	20040000	ECOTOX
Morone saxatilis	Striped Bass	LC50	MOR	MORT	3	110000*	ECOTOX
Morone saxatilis	Striped Bass	LC50	MOR	MORT	1	1100000*	ECOTOX
Morone saxatilis	Striped Bass	LC50	MOR	MORT	2	1100000*	ECOTOX
Morone saxatilis	Striped Bass	LC50	MOR	MORT	3	1100000*	ECOTOX
Morone saxatilis	Striped Bass	LC50	MOR	MORT	4	1100000*	ECOTOX
Morone saxatilis	Striped Bass	LC50	MOR	MORT	3	160000*	ECOTOX
Morone saxatilis	Striped Bass	LC50	MOR	MORT	2	220000*	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	6	2200000*	ECOTOX
Lepomis macrochirus	Bluegill	LC50*	MOR	MORT	4	3040000*	ECOTOX
Morone saxatilis	Striped Bass	LC50	MOR	MORT	2	320000*	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	6	3200000*	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	4	3710000*	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	2	3940000*	ECOTOX
Lepomis macrochirus	Bluegill	LC50*	MOR	MORT	4	4380000*	ECOTOX
Morone saxatilis	Striped Bass	LC50	MOR	MORT	1	450000*	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	4	5350000*	ECOTOX

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	1	5400000*	ECOTOX
Morone saxatilis	Striped Bass	LC50	MOR	MORT	4	56000*	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	2	5670000*	ECOTOX
Morone saxatilis	Striped Bass	LC50	MOR	MORT	1	650000*	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	1	7800000*	ECOTOX
Morone saxatilis	Striped Bass	LC50	MOR	MORT	1	790000*	ECOTOX
Morone saxatilis	Striped Bass	LC50	MOR	MORT	2	790000*	ECOTOX
Morone saxatilis	Striped Bass	LC50	MOR	MORT	3	790000*	ECOTOX
Morone saxatilis	Striped Bass	LC50	MOR	MORT	4	790000*	ECOTOX
Morone saxatilis	Striped Bass	LC50	MOR	MORT	4	81000*	ECOTOX
Chronic toxicity data							
Pimephales promelas	Fathead Minnow	NOEC	GRO	WGHT	7	220000	ECOTOX
Pseudacris regilla	Pacific Chorus Frog	NOEC	GRO	LGTH	10	343000	ECOTOX
Pseudacris regilla	Pacific Chorus Frog	NOEC	GRO	WGHT	10	343000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	780000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	906000	ECOTOX
Pseudokirchneriella subcapitata	Green Algae	NOEC	POP	ABND	3	1060000	ECOTOX
Pseudokirchneriella subcapitata	Green Algae	NOEC	POP	NCHG	3	1060000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	1060000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	RSUC	3	1060000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	NOEC	REP	VIAB	7	1060000	ECOTOX
Oncorhynchus sp.	Pacific Salmon	NOEC	REP	VIAB	7	1060000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	DWGT	7	1060000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	WGHT	7	1060000	ECOTOX
Caridina nilotica	Shrimp	NOEC	GRO	LGTH	80	1070000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEC	REP	PROG	7	1300900	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	BMAS	7	1300900	ECOTOX
Pseudokirchneriella subcapitata	Green Algae	NOEC	POP	PBMS	14	1500000	ECOTOX
Corbicula manilensis	Asiatic Clam	NOEC	GRO	DWGT	28	1500000	ECOTOX
Corbicula manilensis	Asiatic Clam	NOEC	GRO	LGTH	28	1500000	ECOTOX
Caridina nilotica	Shrimp	NOEC	GRO	DWGT	80	1900000	ECOTOX
Ceriodaphnia sp.	Water Flea	NOEC	REP	PROG	7	2200000	ECOTOX
Ceriodaphnia sp.	Water Flea	NOEC	REP	FCND	7	2220000	ECOTOX
Caridina nilotica	Shrimp	NOEC	GRO	DWGT	80	6000000	ECOTOX
Caridina nilotica	Shrimp	NOEC	REP	GMET	80	6000000	ECOTOX
Pimephales promelas	Fathead Minnow	LOEC	GRO	WGHT	7	220000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	REP	PROG	7	899000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	REP	PROG	7	934000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	REP	PROG	2	1000000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	REP	PROG	3	1000000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	REP	PROG	4	1000000	ECOTOX

Chronic toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Ceriodaphnia dubia	Water Flea	LOEC	REP	PROG	5	1000000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	REP	PROG	8	1000000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	REP	PROG	7	1195000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	REP	PROG	7	1236000	ECOTOX
Caridina nilotica	Shrimp	LOEC	GRO	LGTH	80	1400000	ECOTOX
Corbicula manilensis	Asiatic Clam	LOEC	GRO	COND	28	1500000	ECOTOX
Corbicula manilensis	Asiatic Clam	LOEC	GRO	DWGT	28	1500000	ECOTOX
Ceriodaphnia sp.	Water Flea	LOEC	REP	PROG	7	2200000	ECOTOX
Ceriodaphnia sp.	Water Flea	LOEC	REP	FCND	7	2220000	ECOTOX
Caridina nilotica	Shrimp	LOEC	GRO	DWGT	80	2530000	ECOTOX
Caridina nilotica	Shrimp	LOEC	MOR	MORT	80	2530000	ECOTOX
Pseudokirchneriella subcapitata	Green Algae	LOEC	POP	PBMS	14	3000000	ECOTOX
Oncorhynchus mykiss	Rainbow Trout	LOEC	REP	VIAB	7	3500000	ECOTOX
Oncorhynchus sp.	Pacific Salmon	LOEC	REP	VIAB	7	3500000	ECOTOX
Pseudokirchneriella subcapitata	Green Algae	LOEC	POP	ABND	3	3650000	ECOTOX
Pseudokirchneriella subcapitata	Green Algae	LOEC	POP	NCHG	3	3650000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	REP	PROG	7	3650000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEC	REP	RSUC	3	3650000	ECOTOX
Pimephales promelas	Fathead Minnow	LOEC	GRO	DWGT	7	3650000	ECOTOX
Pimephales promelas	Fathead Minnow	LOEC	GRO	WGHT	7	3650000	ECOTOX
Caridina nilotica	Shrimp	LC50	MOR	MORT	80	2530000	ECOTOX
Myriophyllum spicatum	Eurasian Watermilfoil	EC50	GRO	GGRO	32	928000*	ECOTOX
Myriophyllum spicatum	Eurasian Watermilfoil	EC50	GRO	GGRO	32	1335000*	ECOTOX
Myriophyllum spicatum	Eurasian Watermilfoil	EC50	POP	BMAS	32	2305000*	ECOTOX
Myriophyllum spicatum	Eurasian Watermilfoil	EC50	GRO	GGRO	32	2337000*	ECOTOX
Myriophyllum spicatum	Eurasian Watermilfoil	EC50	POP	BMAS	32	3037000*	ECOTOX
Myriophyllum spicatum	Eurasian Watermilfoil	EC50	POP	BMAS	32	3313000*	ECOTOX
Myriophyllum spicatum	Eurasian Watermilfoil	EC50	GRO	GGRO	32	3360000*	ECOTOX
Myriophyllum spicatum	Eurasian Watermilfoil	EC50	POP	BMAS	32	2113000*	ECOTOX
Caridina nilotica	Shrimp	LC50	MOR	MORT	80	2670000	ECOTOX
Caridina nilotica	Shrimp	LC50	MOR	MORT	80	2800000	ECOTOX

Media Type: freshwater

IMBL: immobile

ABND: abundance

ITX : Intoxicated

MOR/MORT: Mortality

POP: Population

REP: Reproduction

PROG : Progeny Counts

SEXR : Sex ratio

FCND: Fecundity

HTCH : Hatch

The asterisk (*) denotes several meanings depending upon the field you are viewing. An asterisk can be used in these fields:

- *Concentration:* This means the reported concentration has been recalculated to meet database conformity. For example, the concentration unit was reported as Molar units, but the standard database unit is micrograms per liter. Another example would be if the reported value was as a metal compound and it was recalculated to the ion level. Note: These recalculations are no longer performed.
- *Endpoint*: This denotes the reported endpoint acronym provided was modified to conform to the standard database acronym terminology. For example, if the author reported a TLM, the endpoint was coded as an LC50*.

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.
ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Sodium sulfite
Synonyms	Sulfurous acid, disodium salt, disodium sulfite
CAS number	7757-83-7
Molecular formula	$H_2O_3S.{}_2Na$
Product name	

Physical Properties	Value	Reference
Phase/state	Small crystals or powder	HSDB, 2011
Molecular weight	126.044 g/mol	HSDB, 2011
Melting point	340.4 (estimate)	EPISUITE
Boiling point	773.7 (estimate)	EPISUITE
Solubility	Soluble in 3.2 parts water	HSDB, 2011

Other Relevant Factors	Value	Reference
Reactivity		
Species	No oxidizing properties	
Reaction type	Sodium sulphite reacts with acids to liberate sulphur dioxide. It sometimes reacts with oxidizing agents violently.	IUCLID 2000
pH		
acid / alkaline	Salt	HSDB, 2011

Notes: 1 EPI Suite™ v4.0, United States Environmental Protection Agency.

2. Hazardous Substances Data Bank (HSDB) National library of Medicine (sodium sulfite) accessed on line : 7 June 2011.

3. IUCLID, 2000. European Commission: European Chemicals Bureau. Accessed on 7 June 2011. Accessed at : http://ecb.jrc.ec.europa.eu/iuclid-datasheet/7757837.pdf

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc (µg/L)**	**Reference**
Poecilia reticulata	Guppy	LT50	MOR	MORT	1.17	16000*	ECOTOX
Poecilia reticulata	Guppy	LT50	MOR	MORT	1.75	16000*	ECOTOX
Poecilia reticulata	Guppy	LT50	MOR	MORT	2	16000*	ECOTOX
Poecilia reticulata	Guppy	LT50	MOR	MORT	1	32000*	ECOTOX
Poecilia reticulata	Guppy	LT50	MOR	MORT	1.67	32000*	ECOTOX
Poecilia reticulata	Guppy	LT50	MOR	MORT	1.67	32000*	ECOTOX
Poecilia reticulata	Guppy	LT50	MOR	MORT	2	32000*	ECOTOX
Poecilia reticulata	Guppy	LT50	MOR	MORT	1.25	64000*	ECOTOX
Poecilia reticulata	Guppy	LT50	MOR	MORT	1.25	64000*	ECOTOX
Poecilia reticulata	Guppy	LT50	MOR	MORT	1.96	64000*	ECOTOX
Poecilia reticulata	Guppy	LT50	MOR	MORT	1	96000*	ECOTOX
Poecilia reticulata	Guppy	LT50	MOR	MORT	1.25	96000*	ECOTOX
Poecilia reticulata	Guppy	LT50	MOR	MORT	1.88	96000*	ECOTOX
Poecilia reticulata	Guppy	LT50	MOR	MORT	1.67	160000*	ECOTOX
Poecilia reticulata	Guppy	LT50	MOR	MORT	1.88	160000*	ECOTOX
Poecilia reticulata	Guppy	LT50	MOR	MORT	1.92	160000*	ECOTOX
Poecilia reticulata	Guppy	LT50	MOR	MORT	2	160000*	ECOTOX
Poecilia reticulata	Guppy	LT50	MOR	MORT	2	160000*	ECOTOX
Poecilia reticulata	Guppy	LT50	MOR	MORT	1	320000*	ECOTOX
Poecilia reticulata	Guppy	LT50	MOR	MORT	1	320000*	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	4.2	203000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2.08	273000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	1.04	299000	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	1	660000*	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	2	660000*	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	4	660000*	ECOTOX

Media Type: freshwater

IMBL: immobile

ABND: abundance

ITX : Intoxicated

MOR/MORT: Mortality

POP: Population

REP: Reproduction

PROG : Progeny Counts

SEXR : Sex ratio

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- *Endpoint*: This denotes the reported endpoint acronym provided was modified to conform to the standard database acronym terminology. For example, if the author reported a TLM, the endpoint was coded as an LC50*.

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

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ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Sodium Thiosulfate
Synonyms	Disodium thiosulfate, sodium oxide sulphide, Sodothiol, thiosulfric acid, sulfothiorine.
CAS number	7772-98-7
Molecular formula	$Na_2S_2O_3$
Product name	GEL-STA L Stabilizer

Physical Properties	Value	Reference
Phase/state	Clear to hazy liquid	MSDS, 2010 (1)
Molecular weight	158.13 g/mol	HSDB, 2011
Melting point	48.5°C	IPCS, 2011
Boiling point	106°C	MSDS, 2011 (1)
Solubility	231g at 100°C	HSDB, 2011
	20.9 g/100mL at 20°C	IPCS, 2011

Persistence/ Bioaccumulation	Value	Reference
Reactivity		
Species	NA	
Reaction type	Reacts with acids to release sulfur dioxide	MSDS, 2011 (3)
pH		
acid / alkaline	Slightly acidic to neutral	
pH	pH 6.5- 8	Merck, 1996
pH (5% solution)	pH 5.5 - 7.5	MSDS, 2011 (4)

Notes: 1. Halliburton Material Safety Data Sheet GEL-STA L Stabilizer. Issue Date:24th May 2010.

2. Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line 25th March 2011.

3. Caledon. Material Safety Data Sheet 8460-1 Sodium thiosulphate. Accssed on 1 April 2011 at http://www.inchem.org/documents/icsc/icsc/eics1138.htm

4. Mubychem Material Safety Data Sheet. Sodium thiosulfate. Accessed on 1st April 2011 at http://mubychem.com/MSDS/Sodium_Thiosulfate%20MSDS.htm

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	Used to neutralise chloride
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Acute toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Daphnia magna	Water Flea	LC50	MOR	MORT	4.2	805000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	2.083	1334000	ECOTOX
Spirostomum ambiguum	Protozoa	LC50	MOR	MORT	2	1700000	ECOTOX
Spirostomum ambiguum	Protozoa	LC50	MOR	MORT	1	1710000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	1.042	2245000	ECOTOX
Pimephales promelas	Fathead Minnow	LT50	MOR	MORT	4	10000000	ECOTOX
Gambusia affinis	Western Mosquitofish	LC50*	MOR	MORT	4	24000000	ECOTOX
Gambusia affinis	Western Mosquito fish	LC50*	MOR	MORT	2	26000000	ECOTOX
Gambusia affinis	Western Mosquito fish	LC50*	MOR	MORT	1	26400000	ECOTOX

Media Type : freshwater

MOR/MORT : Mortality

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

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WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.

ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Sweet Orange Oil
Synonyms	Orange oil (composition of orange oil differs from sweet orange oil; its aldehyde content is lower and its ester content higher).
CAS number	68647-72-3 or 8008-57-9
Molecular formula	C10H16
Product name	GasPerm 1100

Physical Properties	Value	Reference
Phase/state	Yellow to reddish yellow liquid.	HSDB, 2011
Molecular weight	136.24	EPISUITE
Melting point	-40.76	EPISUITE
Boiling point	176 ^{o}C	Chembook 2011
Density/ specific gravity	0.844 - 0.847 at 20 ^{o}C	HSDB, 2011
Vapour pressure	NA	HSDB, 2011
Solubility	Slightly soluble in water	HSDB, 2011
	4.581 mg/L at 25 ^{o}C	EPISUITE
Henrys law constant	3.8 x 10 $^{-1}$ atm-m^{3} / mol (Bond Method)	EPISUITE
Log organic carbon partition coefficient (log Koc)	3.049 (MCI Method)	EPISUITE
Log octanol-water partition coefficient (log Kow)	4.83	EPISUITE

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation	NA	HSDB, 2011
Aerobic BOD	NA	HSDB, 2011
Anaerobic BOD	NA	HSDB, 2011
Biowin7 (Anaerobic Model Prediction)	Does not biograde fast	EPISUITE
Fugacity		
Air %	0.298	EPISUITE
Water %	50.2	EPISUITE
Soil %	47.5	EPISUITE
Sediment %	1.96	EPISUITE
Bioconcentration factor (BCF)	360.5	EPISUITE
Biotransformation half-life	3.531 days	EPISUITE

Notes: 1 EPI Suite™ v4.0, United States Environmental Protection Agency.

2. Halliburton Material Safety Data Sheet GasPerm 1100. Issue Date: 4 March 2010.

3. Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line: 25 March 201.

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Estimated acute toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Concentration (ug/L)**	**Reference**
-	Daphnid	LC50	MOR	MORT	2	292	ECOSAR v1.0
-	Fish	LC50	MOR	MORT	4	341	ECOSAR v1.0
-	Fish	LC50	MOR	MORT	14	361	ECOSAR v1.0
Estimated chronic toxicity data							
-	Green Algae	EC50	POP	GPOP	4	474	ECOSAR v1.0

Media Type : freshwater

MOR/MORT : Mortality

POP: Population

GPOP: Population changes, general

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7. ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

Name	Tetramethylammonium chloride
Synonyms	N,N,N-trimethylmethanaminium chloride
CAS number	75-57-0
Molecular formula	$C_4H_{12}NCl$
Product name	Clayfix II Plus

Physical Properties	Value	Reference
Phase/state	Solid	EPISUITE V 4.0
Molecular weight	109.6	EPISUITE v 4.0
Melting point	420^{o}C	EPISUITE V 4.0
Boiling point	NA	
Vapour pressure	1.21 x10^{-8} mm Hg at 25^{o}C	EPISUITE v 4.0
Solubility	1 x 10^{6} mg/L at 25^{o}C	EPISUITE v 4.0
Henrys law constant	1.74x10^{-15} atm m^{3}/mole	EPISUITE v 4.0
Organic carbon partition coefficient (koc)	8.214	EPISUITE v 4.0
Log organic carbon partition coefficient (log Koc)	0.915	EPISUITE v 4.0
Log octanol-water partition coefficient (log Kow)	-4.18	

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation	NA	
Aerobic BOD	NA	
Anaerobic BOD	NA	
Ready Biodegradability Prediction	No	EPISUITE v 4.0
Fugacity		
Air %	0.0012	EPISUITE v 4.0
Water %	32	EPISUITE v 4.0
Soil %	68	EPISUITE v 4.0
Sediment %	0.070	EPISUITE v 4.0
Bioconcentration factor (BCF)	3.2 L/kg (wet weight)	EPISUITE v 4.0
Biotransformation half-life	0.0075 days	EPISUITE v 4.0
Soil adsorption coefficient	0.034-8.2 L/kg	EPISUITE v 4.0

Notes : 1 EPI Suite™ v4.0, United States Environmental Protection Agency.
Product sheet updated in June 2011.

Aquatic ecosystem guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic ecosystem	None	
USEPA	2006	Aquatic ecosystem	None	
Other guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	None	
NZDWS	2008	Drinking water	None	
WHO	2006	Drinking water	None	
USEPA	2006	Human Health	None	
IARC	2006	Carcinogen risk	None	
ANZECC	2000	Stock water	None	

Estimated acute toxicity data							
Species Scientific Name	**Species Common Name**	**Endpoint**	**Effect**	**Effect Measurement**	**Exposure Duration (Days)**	**Conc (ug/L)**	**Reference**
Pimephales promelas	Fathead Minnow	LC50	MOR	MORT	4	462000	ECOTOX

Estimated chronic toxicity data							
Common name	**Species name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Concentration (ug/L)**	**Reference**
Bluegill	Lepomis macrochirus	LC50	MOR	MORT	4	320	ECOTOX
Rainbow trout	Oncorhynchus mykiss	LC50	MOR	MORT	4	1150	ECOTOX
CTV	**0.32**						
ENEV	**0.032**						

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines. Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, United States Environmental Protection Agency ECOTOX database for alkylbenzyldimethyl quaternary ammonium compounds chlorides (only quaternary ammonium compound in the database with toxicity data for several phyla); and [1] data presented as geometric mean (range), N=4.

Name	Monoethanolamine borate
Synonyms	Orthoboric acid, compound with 2-aminoethanol, 2-aminoethoxyboronic acid
CAS number	26038-87-9 (surrogate CASRN 68130-12-1 boric acid, 2 aminoethyl ester used for EPISUITE data)
Molecular formula	$C_2H_8BNO_3$
Product name	BC 140C

Physical Properties	Value	Reference
Phase/state	Clear colourless	ECHA 2011
Molecular weight	140.90	EPISUITE
Melting point	84.11	EPISUITE
Boiling point	286.89	EPISUITE
Density/ specific gravity	1.245 - 1.355 g/cm^3 at 20^{o}C	ECHA 2011
Vapour pressure	Study not technically feasible	ECHA 2011
Solubility	1 x 10 ^{6} mg/L at 25^{o}C	EPISUITE
Henrys law constant	NA	
Log organic carbon partition coefficient (log Koc)	1.26	ECHA 2011
Log octanol-water partition coefficient (log Kow)	-1.76	EPISUITE

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation	NA	
Aerobic BOD	NA	
Anaerobic BOD	NA	
Ready Biodegradability Prediction	Readily biodegradable	EPISUITE
Fugacity		
Air %	0.00012	EPISUITE
Water %	18.8	EPISUITE
Soil %	81.1	EPISUITE
Sediment %	0.127	EPISUITE
Bioconcentration factor (BCF)	3.162	EPISUITE
Biotransformation half-life	0.01283	EPISUITE

Notes: 1 ECHA (2011) European Chemical Agency Information on Registered Substances. Accessed at:http://apps.echa.europa.eu/registered/data/dossiers/DISS-9d9b4310-79ac-1a5d-e044-00144f67d249/AGGR-7f7a7d52-32c9-4b9a-84b1-aee88979e712_DISS-9d9b4310-79ac-1a5d-e044-00144f67d249.html#section_1.1

2 EPI Suite™ v4.0, United States Environmental Protection Agency.

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Estimated acute toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Concentration (ug/L)**	**Reference**
Brachydanio rerio	Zebra fish	LC50	MOR	MORT	1	100000	ECHA 2011
Brachydanio rerio	Zebra fish	LC50	MOR	MORT	2	100000	ECHA 2011
Brachydanio rerio	Zebra fish	LC50	MOR	MORT	3	100000	ECHA 2011
Brachydanio rerio	Zebra fish	LC50	MOR	MORT	4	100000	ECHA 2011
Cyprinus cerpion	Carp	LC50	MOR	MORT	4	617000	ECHA 2011
Daphnid	Daphnia magna	EC50	MOR	MORT	1	1000000	ECHA 2011
Daphnid	Daphnia magna	EC50	MOR	MORT	2	496000	ECHA 2011
Daphnid	Daphnia magna	EC50	MOR	MORT	1	496000	ECHA 2011
Daphnid	Daphnia magna	EC50	MOR	MORT	2	423000	ECHA 2011
Estimated chronic toxicity data							
Psedokirhnerella subcapitata	Freshwater algae	EC50	Growth	POP	3	26000	ECHA 2011
Psedokirhnerella subcapitata	Freshwater algae	EC50	Growth	POP	3	13000	ECHA 2011
Psedokirhnerella subcapitata	Freshwater algae	NOEC	Growth	POP	3	3200	ECHA 2011
Psedokirhnerella subcapitata	Freshwater algae	EC50	Growth	POP	3	67000	ECHA 2011
Psedokirhnerella subcapitata	Freshwater algae	EC50	Growth	POP	3	32000	ECHA 2011
Psedokirhnerella subcapitata	Freshwater algae	NOEC	Growth	POP	3	18000	ECHA 2011

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.

Name	Fatty acid ester *
Synonyms	NA *
CAS number	NA *
Molecular formula	NA *
Product name	-

* Chemical name and identifiers not included due to commercial confidentiality. Refer to Table D3, Appendix D, for further details.

Physical Properties	Value	Reference
Phase/state	Amber liquid	HSDB 2011
Molecular weight	428.61	HSDB 2011
Melting point	0-10 ^{o}C	IUCLID 2000
Boiling point	>240 ^{o}C	IUCLID 2000
Density/ specific gravity	1 g/cm^{3} at 20 ^{o}C	IUCLID 2000
Vapour pressure		
Solubility	Dispersible in water	HSDB 2011
	<10 g/L at 20 ^{o}C	IUCLID 2000
	0.01914 mg/L at 25 ^{o}C	EPISUITE
Henrys law constant	1.42 x 10^{-12} atm m^{3}/mole (BOND Method)	EPISUITE
Organic carbon partition coefficient (Koc)	2423	EPISUITE
Log organic carbon partition coefficient (log Koc)	3.384	EPISUITE
Log octanol-water partition coefficient (log Kow)	5.89	EPISUITE

Persistence/ Bioaccumulation		Reference
Aquatic biodegradation		
Aerobic BOD		
Anaerobic BOD		
Ready Biodegradability Prediction	Readily biodegradable	EPISUITE
Fugacity		
Air %	0.101	EPISUITE
Water %	23.7	EPISUITE
Soil %	74.4	EPISUITE
Sediment %	1.78	EPISUITE
Bioconcentration factor (BCF)	149.9 L/kg wet-wt	EPISUITE
Biotransformation half-life	0.09698	EPISUITE

Notes: 1 EPI Suite^{TM} v4.1, United States Environmental Protection Agency.

2. Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line 26/07/11

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (mg/L)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2010	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (mg/L)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2010	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Concentration (µg/L)**	**Reference**
-	Daphnid	LC50	MOR	MORT	2	4.36E+02 [1]	ECOSAR v1.00
-	Daphnid	LC50	MOR	MORT	2	1.57E+02 [2]	ECOSAR v1.00
-	Fish	LC50	MOR	MORT	4	3.50E+02 [1]	ECOSAR v1.00
-	Fish	LC50	MOR	MORT	4	1.70E+02 [2]	ECOSAR v1.00
-	Daphnid	LC50	MOR	MORT	2	4.36E+02 [1]	ECOSAR v1.00

Chronic toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Concentration (µg/L)**	**Reference**
-	Green Algae	EC50	POP	GPOP	4	1.22E+02 [1]	ECOSAR v1.00
-	Green Algae	EC50	POP	GPOP	4	3.34E+02 [2]	ECOSAR v1.00
-	Fish	EC50	MOR	MORT	14	1.49E+02 [1]	ECOSAR v1.00

[1]Modelled as an ester
[2]Modelled as a neutral organic

MOR/MORT: Mortality
ITX/IMBL : Intoxication/Immobile
POP: Population
REP: Reproduction
GPOP: Population growth, general
ABND: Abundance
PGRT: Population growth rate
SPGR: Growth/specific growth rate

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans .

ECOTOX, United States Environmental Protection Agency ECOTOX database contained over 400 test, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; and[1] data presented as geometric mean (range) N=8.

AJE, 1999: Organic Chemical Toxicity Data Database. Australasian Journal of Ecotoxicology. 5: 21-84.

RIVM, 2005. Environmental Risk Limit for Alcohols, glycols, and some other relatively soluble and /or volatile compounds. 1 ecotoxicological evaluation. RIVM report 601501016/2005

Name	Ethoxylated fatty acid ester *
Synonyms	NA *
CAS number	NA *
Molecular formula	NA *
Product name	-

* Chemical name and identifiers not included due to commercial confidentiality. Refer to Table D3, Appendix D, for further details.

Physical Properties	Value	Reference
Phase/state	Yellow to orange coloured oily liquid	HSDB 2011
Molecular weight	54	EPISUITE
Melting point	349.84 ^{o}C (estimate)	EPISUITE
Boiling point	1074.99 ^{o}C (estimate)	EPISUITE
Density/ specific gravity	1.06-1.10	HSDB 2011
Vapour pressure	NA	
Solubility	1.9 x 10^{-2} mg/L at 25^{o}C	HSDB 2011
	0.01999 mg/L at 25^{o}C	EPISUITE
Henrys law constant	1.05 x10 $^{-39}$	EPISUITE
Organic carbon partition coefficient (Koc)	8.78 x 10^{9} [a]	EPISUITE
Log organic carbon partition coefficient (log Koc)	9.943	EPISUITE
Log octanol-water partition coefficient (log Kow)	0.7	EPISUITE

Persistence/ Bioaccumulation		Reference
Aquatic biodegradation		
Aerobic BOD	1000 mg/L degraded by 17.8% over 20 days	HSDB 2011
Anaerobic BOD	200 mg/L exhibited 16.6% and 18.6% methane production in glucose and lactate fed cultures after 7 days.	HSDB 2011
Ready Biodegradability Prediction	Not readily bioadegradable	EPISUITE
Fugacity	3.12 x 10^{-8}	EPISUITE
Air %	0.548	EPISUITE
Water %	52.1	EPISUITE
Soil %	47.4	EPISUITE
Sediment %		
Bioconcentration factor (BCF)	3.162 L/kg wet wt	EPISUITE
Biotransformation half-life	0.0002525 days	EPISUITE

Notes: 1. EPI Suite™ v4.1, United States Environmental Protection Agency.

2. Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line 26/07/11

NA - not available

[a] EPISUITE provided two values for Koc: 8.78 x 10^{9} L/kg using the MCI method and 0.6161 using the Kow method. For consistency with other chemical sheets, the value derived using the MCI method has been included here.

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (mg/L)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2010	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (mg/L)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2010	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Aquatic Toxicological Data

Acute toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Concentration (µg/L)**	**Reference**
-	Daphnid	LC50	MOR	MORT	2	1.98E+06	ECOSAR v1.00
-	Fish	LC50	MOR	MORT	4	8.15E+05	ECOSAR v1.00

Chronic toxicity data							
Species Name	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Concentration (µg/L)**	**Reference**
-	Green Algae	EC50	POP	GPOP	4	9.70E+05	ECOSAR v1.00
-	Fish	EC50	MOR	MORT	14	8.20E+08	ECOSAR v1.00

MOR/MORT: Mortality

ITX/IMBL : Intoxication/Immobile

POP: Population

REP: Reproduction

GPOP: Population growth, general

ABND: Abundance

PGRT: Population growth rate

SPGR: Growth/specific growth rate

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans .

ECOTOX, United States Environmental Protection Agency ECOTOX database contained over 400 test, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; and[1] data presented as geometric mean (range) N=8.

AJE, 1999: Organic Chemical Toxicity Data Database. Australasian Journal of Ecotoxicology. 5: 21-84.

RIVM, 2005. Environmental Risk Limit for Alcohols, glycols, and some other relatively soluble and /or volatile compounds. 1 ecotoxicological evaluation.RIVM report 601501016/2005

Santos

APPENDIX E.3 HALLIBURTON CLEANSTIMAUS SYSTEM

Name	Carbohydrate
Synonyms	Carbohydrate
CAS Number	Carbohydrate
Molecular Formula	Carbohydrate

Physical Properties	Value	Reference
PhaseState:	Powder	
Molecular Weight (g/mol):	342.3	HSDB 2012
Melting Point (°C):	203.50	HSDB 2012
Boiling Point (°C):	586.65	EPISUITE
Density / Specific Gravity (units not given:	1.53	HSDB 2012
Vapour Pressure (mm Hg at 25°C):	3.42E-16	HSDB 2012
Solubility (mg/L):	1,950,000.00	HSDB 2012
Henry's Law Constant (atm m³/mole):	3.4E-19	HSDB 2012
Organic carbon partition coefficient (Koc):	0.00	EPISUITE
Log organic carbon partition coefficient (log Koc):	-3.09	EPISUITE
Log octanol - water partition coefficient (log Kow):	-5.03E+00	HSDB 2012

Persistance / Bioaccumulation	Value	Reference
Biowin 3 (Ultimate Survey Biodegradation):	3.7575	EPISUITE
Biowin 4 (Primary Biodegradation):	4.5666	EPISUITE
EPISUITE Ready Biodegradability:	Biodegrades fast	EPISUITE
Biowin 7 (Anaerobic Model Prediction):	1.0921	EPISUITE
Fugacity_Air: (%)	0.000477	EPISUITE
Fugacity_Water: (%)	28	EPISUITE
Fugacity_Soil: (%)	72	EPISUITE
Fugacity_Sediment: (%)	0.0592	EPISUITE
Bioconcentration factor (BCF):	3.162	EPISUITE
Biotransformation half - life (Days):	0.069	EPISUITE

Project number: 117636002

ORGANIC

Aquatic Ecotoxicological Data

Acute toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
	Fish	Fish LC50	MOR	MORT	4	93396.016	ECOSAR 2012
Daphnid	Water flea	Invertebrate LC50	MOR	MORT	2	5000000	ECOSAR 2012
	Green algae	Plant EC50	POP	GROW	4	1560000	ECOSAR 2012

Created By: Naomi Cooper Date: 4/09/2012

Checked By: Date:

Name	Crystalline Silica, Quartz
Synonyms	Associated chemicals: Tridymite; 15468-32-3, Cristobalite; 14464-46-1, Silican dioxide; 7631-86-9 and Tripoli; 1317-95-9
CAS Number	14808-60-7
Molecular Formula	SiO2

Physical Properties	Value	Reference
PhaseState:	Transparent crystals	HSDB 2011
Molecular Weight (g/mol):	60.09	HSDB 2011
Melting Point (°C):	1,710.00	HSDB 2011
Boiling Point (°C):	2230	HSDB 2011
Solubility (atm m³/mole):		

Other Relevant Factors	Value	Reference
Reactivity		
Species:	Silica is attacked by alkaline aqueous solutions, by hydrofluoric acid and by catechol. The rates of etching in hydrofluoric acid vary in the following sequence: stishovite < coesite < quartz < tridymite, cristobalite < vitreous silica	HSDB 2011
Reaction type:		
pH / Acidity		
acid / alkaline		
pH (10% solution)		

Aquatic Ecotoxicological Data

Acute toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
	Fish	Fish LC50	MOR	MORT	4	911.259	ECOSAR 2012
Daphnid	Water flea	Invertebrate LC50	ITX	IMBL	2	413.456	ECOSAR 2012
	Green algae	Plant EC50	POP	GPOP	4	103.627	ECOSAR 2012

Project number: 117636002

INORGANIC

Terrestrial Ecotoxicological Data

SpeciesName	Common Name	Endpoint	Effect	Effect Measure	Test Time (Days)	Conc	Reference
	Earthworm	QSAR Earthworm LC50	MOR	MORT	14	148.41	ECOSAR 2012

Created By: Naomi Cooper Date: 7/09/2012

Checked By: Date:

Project number: 117636002

ORGANIC

Name	Enzyme
Synonyms	
CAS Number	
Molecular Formula	

Physical Properties	Value	Reference
PhaseState:	White crystals or powder (pure enzyme)	HERA 2005
Molecular Weight (g/mol):		
Melting Point (°C):		
Boiling Point (°C):		
Density / Specific Gravity (Not given):	1.00	HERA 2005
Vapour Pressure (mm Hg at 25°C):	0.0000000075	HERA 2005
Solubility (mg/L):	800.00	HERA 2005
Henry's Law Constant (atm m³/mole):	0.00000245	HERA 2005
Organic carbon partition coefficient (Koc):	0.11	HERA 2005
Log organic carbon partition coefficient (log Koc):	1.30	HERA 2005
Log octanol - water partition coefficient (log Kow):	-2.95E+00	HERA 2005

Persistance / Bioaccumulation	Value	Reference
Biowin 3 (Ultimate Survey Biodegradation):		
Biowin 4 (Primary Biodegradation):		
EPISUITE Ready Biodegradability:		
Biowin 7 (Anaerobic Model Prediction):		
Fugacity_Air: (%)		
Fugacity_Water: (%)		
Fugacity_Soil: (%)		
Fugacity_Sediment: (%)		
Bioconcentration factor (BCF):		
Biotransformation half - life (Days):		

Project number: 117636002

ORGANIC

Aquatic Ecotoxicological Data

Acute toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Daphnia magna	Water flea	Invertebrate EC50	Mortality	Mortality	2	793.28	ECOSAR 2012
Brachydario rerio	Zebra Fish	Fish LC50	Mortality	Mortality	4	330	HERA 2005

Created By: Lisa Brookes Date: 21/09/2012

Checked By: Kirsten Broadgate Date: 30/10/2012

Project number: 117636002

ORGANIC

Name	Fatty acid ester
Synonyms	Fatty acid ester
CAS Number	Fatty acid ester
Molecular Formula	Fatty acid ester

Physical Properties	Value	Reference
PhaseState:	Liquid	HSDB 2012
Molecular Weight (g/mol):	1288	HSDB 2012
Melting Point (°C):	349.84	EPISUITE
Boiling Point (°C):	1001.79	EPISUITE
Density / Specific Gravity (g/mL at 25	1.10	HSDB 2012
Vapour Pressure (mm Hg at 25°C):	8.65E-33	EPISUITE
Solubility (mg/L):	15.76	EPISUITE
Henry's Law Constant (atm m³/mole):	2.19E-40	EPISUITE
Organic carbon partition coefficient (Koc):	0.02	EPISUITE
Log organic carbon partition coefficient (log Koc):	-1.72	EPISUITE
Log octanol - water partition coefficient (log Kow):		

Persistance / Bioaccumulation	Value	Reference
Biowin 3 (Ultimate Survey Biodegradation):	1.753	EPISUITE
Biowin 4 (Primary Biodegradation):	3.125	EPISUITE
EPISUITE Ready Biodegradability:	Does not biodegrade fast	EPISUITE
Biowin 7 (Anaerobic Model Prediction):	-2.209	EPISUITE
Fugacity_Air: (%)	0.0000000000301	EPISUITE
Fugacity_Water: (%)	1	EPISUITE
Fugacity_Soil: (%)	42	EPISUITE
Fugacity_Sediment: (%)	57.3	EPISUITE
Bioconcentration factor (BCF):	3.162	EPISUITE
Biotransformation half - life (Days):	0.039	EPISUITE

Project number: 117636002

ORGANIC

Aquatic Ecotoxicological Data

Acute toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Daphnid	Water flea	Invertebrate LC50	MOR	MORT	2	96899.742	ECOSAR 2012
	Green algae	Plant EC50	POP	GROW	4	78056.250	ECOSAR 2012
Poecilia reticula	Guppy	Fish LC50	MOR	MORT	1	350	ECOTOX 2012

Terrestrial Ecotoxicological Data

SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc**	**Reference**
	Hamster	Mammalian LD50	MOR	MORT		18000 mg/kg	HSDB 2012
	Earthworm	QSAR Earthworm LC50	MOR	MORT	14	261000	ECOSAR 2012

Created By: Naomi Cooper Date: 4/09/2012

Checked By: Date:

Project number: 117636002

ORGANIC

Name	Food coating
Synonyms	Food coating
CAS Number	Food coating
Molecular Formula	Food coating

Physical Properties	Value	Reference
PhaseState:		
Molecular Weight (g/mol):	321.46	EPISUITE
Melting Point (°C):	253.24	EPISUITE
Boiling Point (°C):	587.01	EPISUITE
Density / Specific Gravity:		
Vapour Pressure (mm Hg at 25°C):	7.83E-17	EPISUITE
Solubility (mg/L):	10,100.00	EPISUITE
Henry's Law Constant (atm m³/mole):	6.8E-21	EPISUITE
Organic carbon partition coefficient (Koc):	0.70	EPISUITE
Log organic carbon partition coefficient (log Koc):	-0.16	EPISUITE
Log octanol - water partition coefficient (log Kow):	-5.00E-02	EPISUITE

Persistance / Bioaccumulation	Value	Reference
Biowin 3 (Ultimate Survey Biodegradation):	2.9687	EPISUITE
Biowin 4 (Primary Biodegradation):	3.7723	EPISUITE
EPISUITE Ready Biodegradability:	Biodegrades fast	EPISUITE
Biowin 7 (Anaerobic Model Prediction):	0.8028	EPISUITE
Fugacity_Air: (%)	0.000008	EPISUITE
Fugacity_Water: (%)	20	EPISUITE
Fugacity_Soil: (%)	80	EPISUITE
Fugacity_Sediment: (%)	0.101	EPISUITE
Bioconcentration factor (BCF):	70.79	EPISUITE
Biotransformation half - life (Days):	0.262	EPISUITE

Project number: 117636002

ORGANIC

Aquatic Ecotoxicological Data

Acute toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
	Fish	Fish LC50	MOR	MORT	4	18263.180	ECOSAR 2012
Daphnid	Water flea	Invertebrate LC50	MOR	MORT	2	8582.770	ECOSAR 2012
	Green algae	Plant EC50	POP	GROW	4	2924.621	ECOSAR 2012

Terrestrial Ecotoxicological Data

SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc**	**Reference**
	Earthworm	QSAR Earthworm LC50	MOR	MORT	14	911.525	ECOSAR 2012

Created By: Naomi Cooper Date: 4/09/2012

Checked By: Date:

Name	Inorganic salt
Synonyms	Inorganic salt
CAS Number	Inorganic salt
Molecular Formula	Inorganic salt

Physical Properties	Value	Reference
PhaseState:	Granules or Powder	HSDB 2012
Molecular Weight (g/mol):	342.14	HSDB 2012
Melting Point (°C):	770.00	HSDB 2012
Boiling Point (°C):		
Solubility (mg/L):	313,000.00	INCHEM 2012

Other Relevant Factors	Value	Reference
Reactivity		
Species:		
Reaction type:		
pH / Acidity		
acid / alkaline	2	HSDB 2012
pH (10% solution)		

Aquatic Ecotoxicological Data

Acute toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Perca fluviatilis	Perch	Fish LC50	MOR	MORT	7	0.068	ECOTOX 2012
Daphnia magna	Water flea	Invertebrate LC50	MOR	MORT	7	1.77	ECOTOX 2012
Opercularia sp.	Ciliate	Plant EC50	POP	PGRT	2	0.039	ECOTOX 2012

Chronic toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Salvelinus fontinalis	Brook Trout	Fish LOEC	GRO	WGHT	60	0.024	ECOTOX 2012
Daphnia magna	Water flea	Invertebrate LOEC	REP	PROG	28	4.260	ECOTOX 2012
Salvelinus fontinalis	Brook Trout	Fish NOEC	GRO	WGHT	30	0.013	ECOTOX 2012
Daphnia magna	Water flea	Invertebrate NOEC	REP	PROG	7	0.700	ECOTOX 2012

Project number: 117636002

INORGANIC

Terrestrial Ecotoxicological Data

SpeciesName	Common Name	Endpoint	Effect	Effect Measure	Test Time (Days)	Conc	Reference
	Guinea Pig	Mammalian LD50	MOR	MORT	1	490 mg Al/kg bw	HSDB 2012

Created By: Naomi Cooper Date: 4/09/2012

Checked By: Date:

Project number: 117636002

ORGANIC

Name	Polysaccharide
Synonyms	Polysaccharide
CAS Number	Polysaccharide
Molecular Formula	Polysaccharide

Physical Properties	Value	Reference
PhaseState:		
Molecular Weight (g/mol):		
Melting Point (°C):		
Boiling Point (°C):		
Density / Specific Gravity:		
Vapour Pressure (mm Hg at 25°C):		
Solubility (mg/L):		
Henry's Law Constant (atm m³/mole):		
Organic carbon partition coefficient (Koc):		
Log organic carbon partition coefficient (log Koc):		
Log octanol - water partition coefficient (log Kow):		

Persistance / Bioaccumulation	Value	Reference
Biowin 3 (Ultimate Survey Biodegradation):		
Biowin 4 (Primary Biodegradation):		
EPISUITE Ready Biodegradability:		
Biowin 7 (Anaerobic Model Prediction):		
Fugacity_Air: (%)		
Fugacity_Water: (%)		
Fugacity_Soil: (%)		
Fugacity_Sediment: (%)		
Bioconcentration factor (BCF):		
Biotransformation half - life (Days):		

Project number: 117636002

ORGANIC

Aquatic Ecotoxicological Data

Acute toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Ceriodaphnia dubia	Water flea	Invertebrate EC50	ITX	IMBL	2	82.76	ECOTOX 2012
Carassius carassius	Crucian carp	Fish LC50	MOR	MORT	4	10000	ECOTOX 2012
Oncorhynchus mykiss	Rainbow Trout	Fish LC50	MOR	MORT	4	10000	ECOTOX 2012

Created By: Naomi Cooper Date: 4/09/2012

Checked By: Date:

Name	Potassium chloride
Synonyms	Chloride of potash, potassium monochloride, dipotassium dichloride
CAS Number	7447-40-7
Molecular Formula	7447-40-7

Physical Properties	Value	Reference
PhaseState:	White crystals or crystalline powder	HSDB 2011
Molecular Weight (g/mol):	74.55	HSDB 2011
Melting Point (°C):	771.00	HSDB 2011
Boiling Point (°C):	1500	HSDB 2011
Solubility (mg/L):	34.20	HSDB 2011

Other Relevant Factors	Value	Reference
Reactivity		
Species:	Violent reaction with bromine triflouride	HSDB 2011
Reaction type:		
pH / Acidity		
acid / alkaline		
pH (10% solution)		

Aquatic Ecotoxicological Data

Acute toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Ictalurus punctulus	Catfish	Fish LC50	Mortality	Mortality	2	720	SIDS 2001
Daphnia magna	Water flea	Invertebrate LC50	Mortality	Mortality	2	177	SIDS 2001
Ceriodaphnia dubia	Water flea	Invertebrate EC50	Mortality	Mortality	2	630	SIDS 2001

Chronic toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Daphnia magna	Water flea	Invertebrate LOEC	Reproduction	Reproduction	21	101	SIDS 2001
Daphnia magna	Water flea	Invertebrate EC50	Reproduction	Reproduction	21	130	SIDS 2001

Project number: 117636002

INORGANIC

Terrestrial Ecotoxicological Data

Common Name	Endpoint	Effect	Effect Measure	Test Time (Days)	Conc	Reference	Units
Mouse	Mammalian LD50	MOR	MORT		383	HSDB 2012	mg/kg

Created By: Naomi Cooper Date: 7/09/2012

Checked By: Kirsten Broadgate Date: 31/10/2012

Project number: 117636002

ORGANIC

Name	Saccharide
Synonyms	Proprietary
CAS Number	Proprietary
Molecular Formula	Proprietary

Physical Properties	Value	Reference
PhaseState:		
Molecular Weight (g/mol):	180.1559	USEPA 2012
Melting Point (°C):		
Boiling Point (°C):		
Density / Specific Gravity:		
Vapour Pressure (mm Hg at 25°C):		
Solubility (mg/L):		
Henry's Law Constant (atm m^3/mole):		
Organic carbon partition coefficient (Koc):		
Log organic carbon partition coefficient (log Koc):		
Log octanol - water partition coefficient (log Kow):		

Persistance / Bioaccumulation	Value	Reference
Biowin 3 (Ultimate Survey Biodegradation):		
Biowin 4 (Primary Biodegradation):		
EPISUITE Ready Biodegradability:		
Biowin 7 (Anaerobic Model Prediction):		
Fugacity_Air: (%)		
Fugacity_Water: (%)		
Fugacity_Soil: (%)		
Fugacity_Sediment: (%)		
Bioconcentration factor (BCF):		
Biotransformation half - life (Days):		

Project number: 117636002

ORGANIC

Created By: Naomi Cooper Date: 4/09/2012

Checked By: Date:

Name	Sodium lauryl sulfate
Synonyms	Dodecyl sodium sulfate
CAS Number	151-21-3
Molecular Formula	C12-H26-O4-S.Na

Physical Properties	Value	Reference
PhaseState:	Crystals, flakes or powder	HSDB 2012
Molecular Weight (g/mol):	288.38	HSDB 2012
Melting Point (°C):	205.50	EPISUITE
Boiling Point (°C):	588.52	EPISUITE
Density / Specific Gravity:		
Vapour Pressure (mm Hg at 25°C):	0.0000000000018	EPISUITE
Solubility (mg/L):	100,000.00	HSDB 2012
Henry's Law Constant (atm m³/mole):	0.000000187	EPISUITE
Organic carbon partition coefficient (Koc):	93.70	EPISUITE
Log organic carbon partition coefficient (log Koc):	1.97	EPISUITE
Log octanol - water partition coefficient (log Kow):		

Persistance / Bioaccumulation	Value	Reference
Biowin 3 (Ultimate Survey Biodegradation):	2.9088	EPISUITE
Biowin 4 (Primary Biodegradation):	3.7325	EPISUITE
EPISUITE Ready Biodegradability:	Does not biodegrade fast	EPISUITE
Biowin 7 (Anaerobic Model Prediction):	0.7427	EPISUITE
Fugacity_Air: (%)	0.701	EPISUITE
Fugacity_Water: (%)	20	EPISUITE
Fugacity_Soil: (%)	78	EPISUITE
Fugacity_Sediment: (%)	1.99	EPISUITE
Bioconcentration factor (BCF):	70.79	EPISUITE
Biotransformation half - life (Days):	0.721	EPISUITE

Project number: 117636002

ORGANIC

Aquatic Ecotoxicological Data

Acute toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Cirrhinus mrigala	Carp, Hawk fish	Fish LC50	MOR	MORT	4	0.590	ECOTOX 2012
Ceriodaphnia dubia	Water flea	Invertebrate LC50	MOR	MORT	2	1.260	ECOTOX 2012
Spirostomum ambiguum	Protozoa	Plant EC50	MOR	MORT	1	1.630	ECOTOX 2012

Chronic toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Corbicula manilensis	Asiatic clam	Invertebrate NOEC	GRO	GGRO	42	0.418	ECOTOX 2012
Pimephales promelas	Fathead minnow	Fish NOEC	GRO	GGRO	42	1.357	ECOTOX 2012
Pimephales promelas	Fathead minnow	Fish MATC	GRO	GGRO	7	3.200	ECOTOX 2012
Pseudokirchneriella subcapita	Green algae	Plant EC50	POP	GPOP	4	8.800	ECOTOX 2012

Terrestrial Ecotoxicological Data

SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc**	**Reference**
	Rat	Mammalian LD50	MOR	MORT		977 mg/kg	EPA NZ 2012
	Earthworm	QSAR Earthworm LC50	MOR	MORT	14	418.785	ECOSAR 2012

Created By: Naomi Cooper Date: 4/09/2012

Checked By: Date:

Name	Sulfuric acid
Synonyms	Dihydrogen sulphate
CAS Number	7664-93-9
Molecular Formula	H2-S-O4

Physical Properties	Value	Reference
PhaseState:	Liquid	HSDB 2012
Molecular Weight (g/mol):	98.079	HSDB 2012
Melting Point (°C):	10.31	HSDB 2012
Boiling Point (°C):	337	HSDB 2012
Solubility (mg/L):	1,000,000.00	HSDB 2012

Other Relevant Factors	Value	Reference
Reactivity		
Species:		
Reaction type:		
pH / Acidity		
acid / alkaline		
pH (10% solution)		

Aquatic Ecotoxicological Data

Acute toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Daphnid	Water flea	Invertebrate LC50	MOR	MORT	2	184000	ECOSAR 2012
	Green algae	Plant EC50	POP	GROW	4	27532.549	ECOSAR 2012
Gambusia affinis	Western mosquitofish	Fish LC50	MOR	MORT	1	42	ECOTOX 2012

Project number: 117636002

INORGANIC

Terrestrial Ecotoxicological Data

SpeciesName	Common Name	Endpoint	Effect	Effect Measure	Test Time (Days)	Conc	Reference
	Rat	Mammalian LD50	MOR	MORT		2140 mg/kg	HSDB 2012

Created By: Naomi Cooper Date: 4/09/2012

Checked By: Date:

Name	Talc
Synonyms	Magnesium silicate hydrate, talc, talcum
CAS Number	14807-96-6
Molecular Formula	H2O3Si3/4Mg

Physical Properties	Value	Reference
PhaseState:	White to greyish white, very fine crystalline powder	HSDB 2012
Molecular Weight (g/mol):	78.1	
Melting Point (°C):	219.70	
Boiling Point (°C):	549.7	
Solubility (mg/L):	1,000,000.00	

Other Relevant Factors	Value	Reference
Reactivity		
Species:	Insoluble and degradable in soil or water	IUCLID 2000a
Reaction type:		
pH / Acidity		
acid / alkaline		
pH (10% solution)		

Aquatic Ecotoxicological Data

Acute toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
	Fish	Fish LC50	Mortality	Mortality	4	89581.016	ECOSAR 2012
	Daphnid	Invertebrate LC50	Mortality	Mortality	2	36812.359	ECOSAR 2012

Chronic toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
	Green algae	Plant EC50	Population	Growth	4	7202.7	ECOSAR 2012

Project number: 117636002

INORGANIC

Terrestrial Ecotoxicological Data

SpeciesName	Common Name	Endpoint	Effect	Effect Measure	Test Time (Days)	Conc	Reference
	Earthworm	QSAR Earthworm LC50	Mortality	Mortality	14	313.318 mg/L	ECOSAR 2012

Created By: Lisa Brookes Date: 27/08/2012

Checked By: Carolyn Brumley Date: 31/08/2012

Project number: 117636002

ORGANIC

Name	Tributyl tetradecyl phosphonium chloride
Synonyms	Phosphonium tributyl tetradecyl-chloride
CAS Number	81741-28-8
Molecular Formula	C26-H56P.Cl

Physical Properties	Value	Reference
PhaseState:		
Molecular Weight (g/mol):	435.16	USEPA SSR 2012
Melting Point (°C):		
Boiling Point (°C):		
Density / Specific Gravity:		
Vapour Pressure (mm Hg at 25°C):		
Solubility (mg/L):		
Henry's Law Constant (atm m³/mole):		
Organic carbon partition coefficient (Koc):		
Log organic carbon partition coefficient (log Koc):		
Log octanol - water partition coefficient (log Kow):		

Persistance / Bioaccumulation	Value	Reference
Biowin 3 (Ultimate Survey Biodegradation) ():		
Biowin 4 (Primary Biodegradation) ():		
EPISUITE Ready Biodegradability:		
Biowin 7 (Anaerobic Model Prediction):		
Fugacity_Air: (%)		
Fugacity_Water: (%)		
Fugacity_Soil: (%)		
Fugacity_Sediment: (%)		
Bioconcentration factor (BCF):		
Biotransformation half - life (Days):		

Project number: 117636002

ORGANIC

Created By: Naomi Cooper Date: 4/09/2012

Checked By: Date:

APPENDIX E.4 SCHLUMBERGER CLEARFRAC XT

ClearFrac was not included in this assessment

APPENDIX E.5 HALLIBURTON ALTERNATIVE FLUID SYSTEM

Project number: 117636002

ORGANIC

Name	Acetic Acid
Synonyms	Glacial Acetic Acid, ethanoic acid
CAS Number	64-19-7
Molecular Formula	C2-H4-O2

Physical Properties	Value	Reference
PhaseState:	Liquid	MSDS, 2010
Molecular Weight (g/mol):	60.05	HSDB 2011
Melting Point (°C):	16.60	HSDB 2011
Boiling Point (°C):	117.9	HSDB 2011
Density / Specific Gravity (at 20oC):	1.05	HSDB 2011
Vapour Pressure (mm Hg at 25°C):	15.7	HSDB 2011
Solubility (mg/L):	475,900.00	EPISUITE 2011 v4.0
Henry's Law Constant (atm m³/mole):	0.0000001	HSDB 2011
Organic carbon partition coefficient (Koc):	1.00	EPISUITE 2011 v4.0
Log organic carbon partition coefficient (log Koc):	0.00	EPISUITE 2011 v4.0
Log octanol - water partition coefficient (log Kow):	-7.10E-01	HSDB 2011

Persistance / Bioaccumulation	Value	Reference
Biowin 3 (Ultimate Survey Biodegradation):	3.4311	EPISUITE 2011 v4.0
Biowin 4 (Primary Biodegradation):	4.1467	EPISUITE 2011 v4.0
EPISUITE Ready Biodegradability:	Biodegrades fast	EPISUITE 2011 v4.0
Biowin 7 (Anaerobic Model Prediction):	0.9433	EPISUITE 2011 v4.0
Fugacity_Air: (%)	2.66	EPISUITE 2011 v4.0
Fugacity_Water: (%)	35	EPISUITE 2011 v4.0
Fugacity_Soil: (%)	62	EPISUITE 2011 v4.0
Fugacity_Sediment: (%)	0.0619	EPISUITE 2011 v4.0
Bioconcentration factor (BCF):	3.2	HSDB 2011
Biotransformation half - life (Days):	0.0762	EPISUITE 2011 v4.0

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Project number: 117636002

ORGANIC

Aquatic Ecotoxicological Data

Acute toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Branchiura sowerbyi	Oligochaete	Invertebrate LC50	Mortality	Mortality	1	14.9	ECOTOX 2012
Cyprinus carpio	Common carp	Fish LC50	Mortality	Mortality	2	49	ECOTOX 2012

Chronic toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Navicula seminulum	Diatom	Plant EC50	Population	Population growth	4	73.4	ECOTOX 2012
Oreochromis mossambicus	Mozambique tilapia	Fish NOEC	Growth	Growth rate	90	1.26	ECOTOX 2012

Terrestrial Ecotoxicological Data

Common Name	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc**	**Reference**	**Units**
Rabbit	Mammalian LD50	Mortality	Mortality		600 mg/kg/bw	IUCLID 2012	
Earth worm	QSAR Earthworm LC50	Mortality	Mortality	14	1649 mg/L	ECOSAR 2012	

DRAFT

Created By: Lisa Brookes Date: 31/07/2012

Checked By: Kirsten Broadgate Date: 15/07/2013

Project number: 117636002

ORGANIC

Name	Alcohols C6-C12, Ethoxylated Propxylated
Synonyms	
CAS Number	68937-66-6
Molecular Formula	C21H44O7

Physical Properties	Value	Reference
PhaseState:		
Molecular Weight (g/mol):	408.5	USEPA 2013
Melting Point (°C):	132.65	EPISUITE 2011 v4.1
Boiling Point (°C):	397.19	EPISUITE 2011 v4.1
Density / Specific Gravity (Enter Unit):		
Vapour Pressure (mm Hg at 25°C):	0.0000000186	EPISUITE 2011 v4.1
Solubility (mg/L):	1,587.00	EPISUITE 2011 v4.1
Henry's Law Constant (atm m³/mole):	4.77E-18	EPISUITE 2011 v4.1
Organic carbon partition coefficient (Koc):	2.17	EPISUITE 2011 v4.1
Log organic carbon partition coefficient (log Koc):	0.77	EPISUITE 2011 v4.1
Log octanol - water partition coefficient (log Kow):	1.29E+00	EPISUITE 2011 v4.1

Persistance / Bioaccumulation	Value	Reference
Biowin 3 (Ultimate Survey Biodegradation):	2.8396	EPISUITE 2011 v4.1
Biowin 4 (Primary Biodegradation):	3.6919	EPISUITE 2011 v4.1
EPISUITE Ready Biodegradability:	Does not biodegrade fast	EPISUITE 2011 v4.1
Biowin 7 (Anaerobic Model Prediction):	-0.8677	EPISUITE 2011 v4.1
Fugacity_Air: (%)	0.000000000525	EPISUITE 2011 v4.1
Fugacity_Water: (%)	30	EPISUITE 2011 v4.1
Fugacity_Soil: (%)	69	EPISUITE 2011 v4.1
Fugacity_Sediment: (%)	0.0688	EPISUITE 2011 v4.1
Bioconcentration factor (BCF):	3.279	EPISUITE 2011 v4.1
Biotransformation half - life (Days):		

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Project number: 117636002

ORGANIC

Aquatic Ecotoxicological Data

Acute toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Cyprinus carpio	Carp	Fish LC50	MOR	Mortality	4	1.2	HERA 2005

Chronic toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Scenedesmus subspicatus	Green algae	Plant NOEC	GRO	Growth	3	0.09	HERA 2005
Scenedesmus subspicatus	Green algae	Plant EC50	GRO	Growth	3	0.18	HERA 2005

Common Name	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc**	**Reference**	**Units**
Earthworm	1	MOR	Mortality	14	722.584	ECOSAR 2012	mg/L

Created By: Naomi Cooper Date: 23/07/2013

Checked By: Kirsten Broadgate Date: 23/07/2013

DRAFT

Project number: 117636002

ORGANIC

Name	Alcohols, C10-C16, Ethoxylated Propyxlated
Synonyms	
CAS Number	69227-22-1
Molecular Formula	C17H36O2

Physical Properties	Value	Reference
PhaseState:	Liquid	
Molecular Weight (g/mol):	272.467	0
Melting Point (°C):	-3.92	EPISUITE 2011 v4.1
Boiling Point (°C):	225.63	EPISUITE 2011 v4.1
Density / Specific Gravity (Enter Unit):		
Vapour Pressure (mm Hg at 25°C):	0.15	EPISUITE 2011 v4.1
Solubility (mg/L):	2.87	USEPA 2013
Henry's Law Constant (atm m³/mole):	0.0144	EPISUITE 2011 v4.1
Organic carbon partition coefficient (Koc):	36.20	EPISUITE 2011 v4.1
Log organic carbon partition coefficient (log Koc):	3.59	EPISUITE 2011 v4.1
Log octanol - water partition coefficient (log Kow):	4.98E+00	EPISUITE 2011 v4.1

Persistance / Bioaccumulation	Value	Reference
Biowin 3 (Ultimate Survey Biodegradation):	0.4199	EPISUITE 2011 v4.1
Biowin 4 (Primary Biodegradation):	0.2274	EPISUITE 2011 v4.1
EPISUITE Ready Biodegradability:	Biodegrades fast	EPISUITE 2011 v4.1
Biowin 7 (Anaerobic Model Prediction):	0.3619	EPISUITE 2011 v4.1
Fugacity_Air: (%)	4.67	EPISUITE 2011 v4.1
Fugacity_Water: (%)	34	EPISUITE 2011 v4.1
Fugacity_Soil: (%)	60	EPISUITE 2011 v4.1
Fugacity_Sediment: (%)	1.37	EPISUITE 2011 v4.1
Bioconcentration factor (BCF):	37.77	EPISUITE 2011 v4.1
Biotransformation half - life (Days):		

DRAFT

Project number: 117636002

ORGANIC

Aquatic Ecotoxicological Data

Acute toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Daphnia pulex	Water flea	Invertebrate LC50	MOR	Mortality	2	0.1	HERA 2005
Pimephales promelas	Fathead minnow	Fish LC50	MOR	Mortality	4	0.48	HERA 2005

Chronic toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Scenedesmus subspicatas	Green algae	Plant EC50	GRO	Growth	3	0.13	HERA 2005
Scenedesmus subspicatas	Green algae	Plant NOEC	GRO	Growth	3	0.035	HERA 2005

Common Name	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc**	**Reference**	**Units**
Earthworm	1	MOR	Mortality	14	159.107	ECOSAR 2012	mg/L

DRAFT

Created By: Naomi Cooper Date: 23/07/2013

Checked By: Kirsten Broadgate Date: 23/07/2013

Project number: 117636002

ORGANIC

Name	Caffeine
Synonyms	Coffein, Stim, Theine
CAS Number	58-08-2
Molecular Formula	C8H10N4O2

Physical Properties	Value	Reference
PhaseState:	Solid - white crystals	HSDB 2011
Molecular Weight (g/mol):	194.19	HSDB 2011
Melting Point (°C):	238.00	HSDB 2011
Boiling Point (°C):	178	HSDB 2011
Density / Specific Gravity (at 18oC):	1.23	HSDB 2011
Vapour Pressure (mm Hg at 25°C):	0.0000000073	HSDB 2011
Solubility (mg/L):	21,600.00	HSDB 2011
Henry's Law Constant (atm m³/mole):	0.000000000036	HSDB 2011
Organic carbon partition coefficient (Koc):	22.00	HSDB 2011
Log organic carbon partition coefficient (log Koc):	1.34	HSDB 2011
Log octanol - water partition coefficient (log Kow):	-7.00E-02	HSDB 2011

Persistance / Bioaccumulation	Value	Reference
Biowin 3 (Ultimate Survey Biodegradation):	2.7700	EPISUITE 2011 v4.1
Biowin 4 (Primary Biodegradation):	3.5676	EPISUITE 2011 v4.1
EPISUITE Ready Biodegradability:	Does not biodegrade fast	EPISUITE 2011 v4.1
Biowin 7 (Anaerobic Model Prediction):	0.5019	EPISUITE 2011 v4.1
Fugacity_Air: (%)	0.00347	EPISUITE 2011 v4.1
Fugacity_Water: (%)	31	EPISUITE 2011 v4.1
Fugacity_Soil: (%)	69	EPISUITE 2011 v4.1
Fugacity_Sediment: (%)	0.0688	EPISUITE 2011 v4.1
Bioconcentration factor (BCF):		
Biotransformation half - life (Days):		

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Aquatic Ecotoxicological Data

Acute toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Daphnia magna	Water flea	Invertebrate EC50	ITX	Immobilisation	1	159.6	ECOTOX 2012
Streptocephalus proboscideus	Fairy shrimp	Invertebrate LC50	MOR	Mortality	1	409.7	ECOTOX 2012

Chronic toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Cyanophycoata	Blue green algae	Plant NOEC	POP	Abundance	56	0.005	ECOTOX 2012

Terrestrial Ecotoxicological Data

Common Name	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc**	**Reference**	**Units**
Rat	Mammalian LD50	MOR	Mortality		247	HSDB 2011	mg/kg
Mouse	Mammalian LD50	MOR	Mortality		127	HSDB 2011	mg/kg

DRAFT

Created By: Naomi Cooper Date: 18/07/2013

Checked By: Kirsten Broadgate Date: 18/07/2013

Project number: 117636002

ORGANIC

Name	Chlorogenic acid
Synonyms	Hlorogenic acid, 3-Caffeeoylquinic acid
CAS Number	327-97-9
Molecular Formula	

Physical Properties	Value	Reference
PhaseState:		
Molecular Weight (g/mol):	354.309	EPISUITE 2011 v4.1
Melting Point (°C):	247.83	EPISUITE 2011 v4.1
Boiling Point (°C):	575.43	EPISUITE 2011 v4.1
Density / Specific Gravity (Enter Unit):		
Vapour Pressure (mm Hg at 25°C):	2.25E-16	EPISUITE 2011 v4.1
Solubility (mg/L):	404,700.00	EPISUITE 2011 v4.1
Henry's Law Constant (atm m³/mole):		
Organic carbon partition coefficient (Koc):	0.38	EPISUITE 2011 v4.1
Log organic carbon partition coefficient (log Koc):	-0.96	EPISUITE 2011 v4.1
Log octanol - water partition coefficient (log Kow):	-1.01E+00	EPISUITE 2011 v4.1

Persistance / Bioaccumulation	Value	Reference
Biowin 3 (Ultimate Survey Biodegradation):	3.1416	EPISUITE 2011 v4.1
Biowin 4 (Primary Biodegradation):	4.1359	EPISUITE 2011 v4.1
EPISUITE Ready Biodegradability:	Biodegrades fast	EPISUITE 2011 v4.1
Biowin 7 (Anaerobic Model Prediction):	0.7324	EPISUITE 2011 v4.1
Fugacity_Air: (%)	0.0000000672	EPISUITE 2011 v4.1
Fugacity_Water: (%)	31	EPISUITE 2011 v4.1
Fugacity_Soil: (%)	69	EPISUITE 2011 v4.1
Fugacity_Sediment: (%)	0.0688	EPISUITE 2011 v4.1
Bioconcentration factor (BCF):	3.162	EPISUITE 2011 v4.1
Biotransformation half - life (Days):		

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Project number: 117636002

ORGANIC

Common Name	Endpoint	Effect	Effect Measure	Test Time (Days)	Conc	Reference	Units
Earthworm	1	MOR	Mortality	14	43300	ECOSAR 2012	mg/L

Created By: Naomi Cooper Date: 23/07/2013

Checked By: Kirsten Broadgate Date: 23/07/2013

DRAFT

Project number: 117636002

ORGANIC

Name	Choline Chloride
Synonyms	Hepacholine, Neocolina, Bilineurin chloride, Choline Chlorhydrate
CAS Number	67-48-1
Molecular Formula	C5H14NO.Cl

Physical Properties	Value	Reference
PhaseState:	White Crystals	HSDB 2012
Molecular Weight (g/mol):	139.63	HSDB 2012
Melting Point (°C):	305.00	HSDB 2012
Boiling Point (°C):		
Density / Specific Gravity (Enter Unit):		
Vapour Pressure (mm Hg at 25°C):	0.000000000493	OECD SIDS 2004
Solubility (mg/L):	650,000.00	OECD SIDS 2004
Henry's Law Constant (atm m³/mole):	0.000000000000208	OECD SIDS 2004
Organic carbon partition coefficient (Koc):	2.34	OECD SIDS 2004
Log organic carbon partition coefficient (log Koc):	0.37	OECD SIDS 2004
Log octanol - water partition coefficient (log Kow):	-3.77E+00	OECD SIDS 2004

Persistance / Bioaccumulation	Value	Reference
Biowin 3 (Ultimate Survey Biodegradation):	3.0506	EPISUITE 2011 v4.1
Biowin 4 (Primary Biodegradation):	3.7757	EPISUITE 2011 v4.1
EPISUITE Ready Biodegradability:	Biodegrades fast	EPISUITE 2011 v4.1
Biowin 7 (Anaerobic Model Prediction):	0.3444	EPISUITE 2011 v4.1
Fugacity_Air: (%)	0.000000659	EPISUITE 2011 v4.1
Fugacity_Water: (%)	37	EPISUITE 2011 v4.1
Fugacity_Soil: (%)	63	EPISUITE 2011 v4.1
Fugacity_Sediment: (%)	0.0704	EPISUITE 2011 v4.1
Bioconcentration factor (BCF):	3.162	HSDB 2012
Biotransformation half - life (Days):		

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Project number: 117636002

ORGANIC

Aquatic Ecotoxicological Data

Acute toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Daphnia magna	Water flea	Invertebrate EC50	MOR	MORT	2	349	ECOTOX 2012
Oryzias latipes	Japanese medaka	Fish LC50	MOR	MORT	4	>100	ECOTOX 2012

Chronic toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Daphnia magna	Water flea	Invertebrate NOEC	MOR	MORT	21	30.2	ECOTOX 2012
Pseudokircheriella subcapitata	Algae	Plant NOEC	GRO	GROWTH	72	32	ECOTOX 2012

Terrestrial Ecotoxicological Data

Common Name	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc**	**Reference**	**Units**
Rat	Mammalian LD50	MOR	MORT		3400	HSDB 2012	
Mouse	Mammalian LD50	MOR	MORT		3900	HSDB 2012	

Common Name	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc**	**Reference**	**Units**
Earthworm	1	MOR	MORT	14	1340	ECOSAR 2012	

DRAFT

Created By: Naomi Cooper Date: 13/07/2013

Checked By: Kirsten Broadgate Date: 15/07/2013

Project number: 117636002

ORGANIC

Name	Coco dimethylaminopropyl betaine
Synonyms	Coconut amide propyl betaine; (N-cocoamidopropyl) -N-N dimethylglycin, hydroxide, inner salt; 3-amino-N-(caroxymethyl)-N-N dimethyl-1-propanamminium; cocamidopropyl betaine
CAS Number	61789-40-0
Molecular Formula	C19H39N2O3

Physical Properties	Value	Reference
PhaseState:		
Molecular Weight (g/mol):	356.54	casChem Net 2012
Melting Point (°C):	0.00	IUCLID 2012
Boiling Point (°C):	100	IUCLID 2012
Density / Specific Gravity (g/m3):	1.04	IUCLID 2012
Vapour Pressure (mm Hg at 25°C):	4.81E+15	EPISUITE 2011 v4.1
Solubility (mg/L):	1,755.00	EPISUITE 2011 v4.1
Henry's Law Constant (atm m³/mole):	6.19E-21	EPISUITE 2011 v4.1
Organic carbon partition coefficient (Koc):	647.50	EPISUITE 2011 v4.1
Log organic carbon partition coefficient (log Koc):	2.81	EPISUITE 2011 v4.1
Log octanol - water partition coefficient (log Kow):	6.90E-01	EPISUITE 2011 v4.1

Persistance / Bioaccumulation	Value	Reference
Biowin 3 (Ultimate Survey Biodegradation):	3.0487	EPISUITE 2011 v4.1
Biowin 4 (Primary Biodegradation):	4.2122	EPISUITE 2011 v4.0
EPISUITE Ready Biodegradability:	Biodegrades fast	EPISUITE 2011 v4.1
Biowin 7 (Anaerobic Model Prediction):	-0.1753	EPISUITE 2011 v4.1
Fugacity_Air: (%)	0.000000057	EPISUITE 2011 v4.1
Fugacity_Water: (%)	16	EPISUITE 2011 v4.1
Fugacity_Soil: (%)	83	EPISUITE 2011 v4.1
Fugacity_Sediment: (%)	0.403	EPISUITE 2011 v4.1
Bioconcentration factor (BCF):	70.79	EPISUITE 2011 v4.1
Biotransformation half - life (Days):	0.04856	EPISUITE 2011 v4.1

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Aquatic Ecotoxicological Data

Acute toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Daphnia magna	Water flea	Invertebrate LC50	MOR	Mortality	2	6.5	IUCLID 2000
Brachydanio rerio	Zebra fish	Fish LC50	MOR	Mortality	4	2	IUCLID 2000

Chronic toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Daphnia magna	Water flea	Invertebrate NOEC	REP	Reproduction	21	0.9	IUCLID 2000
Daphnia magna	Water flea	Invertebrate LOEC	REP	Reproduction	21	3.6	IUCLID 2000
Scenedesmus subspicatus	Green algae	Plant EC50	GRO	Biomass	3	30	IUCLID 2000

Terrestrial Ecotoxicological Data

Common Name	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc**	**Reference**	**Units**
Rat	Mammalian LD50	Mortality	Mortality		4900 mg/kg	IUCLID 2000	

DRAFT

Created By: Lisa Brookes Date: 31/07/2012

Checked By: Kirsten Broadgate Date: 18/07/2013

Name	Crystalline Silica, Quartz
Synonyms	Associated chemicals: Tridymite; 15468-32-3, Cristobalite; 14464-46-1, Silican dioxide; 7631-86-9 and Tripoli; 1317-95-9
CAS Number	14808-60-7
Molecular Formula	SiO2

Physical Properties	Value	Reference
PhaseState:	Transparent crystals	HSDB 2005
Molecular Weight (g/mol):	60.09	HSDB 2005
Melting Point (°C):	1,710.00	HSDB 2005
Boiling Point (°C):	2230	HSDB 2005
Solubility (mg/L):		

Other Relevant Factors	Value	Reference
Reactivity		
Species:	Silica is attacked by alkaline aqueous solutions, by hydrofluoric acid and by catechol. The rates of etching in hydrofluoric acid vary in the following sequence: stishovite < coesite < quartz < tridymite, cristobalite < vitreous silica	HSDB 2005
Reaction type:		
pH / Acidity		
acid / alkaline		
pH (10% solution)		

DRAFT

Project number: 117636002

INORGANIC

Created By: Naomi Cooper Date: 7/09/2012

Checked By: Kirsten Broadgate Date: 18/07/2013

DRAFT

Project number: 117636002

ORGANIC

Name	Ethylene glycol
Synonyms	Ethylene alcohol, ethylene dihydrate, ethane-1,2-dil
CAS Number	107-21-1
Molecular Formula	C2H6O2

Physical Properties	Value	Reference
PhaseState:	Liquid	HSDB 2012
Molecular Weight (g/mol):	62.068	HSDB 2012
Melting Point (°C):	-12.69	HSDB 2012
Boiling Point (°C):	197.3	HSDB 2002
Density / Specific Gravity (g/cm3):	1.11	HSDB 2012
Vapour Pressure (mm Hg at 25°C):	0.092	HSDB 2012
Solubility (mg/L):		
Henry's Law Constant (atm m³/mole):	0.00000006	HSDB 2012
Organic carbon partition coefficient (Koc):		
Log organic carbon partition coefficient (log Koc):		
Log octanol - water partition coefficient (log Kow):	-1.36E+00	HSDB 2012

Persistance / Bioaccumulation	Value	Reference
Biowin 3 (Ultimate Survey Biodegradation):	3.3891	EPISUITE 2011 v4.1
Biowin 4 (Primary Biodegradation):	4.0171	EPISUITE 2011 v4.1
EPISUITE Ready Biodegradability:	Biodegrades fast	EPISUITE 2011 v4.1
Biowin 7 (Anaerobic Model Prediction):	1.1563	EPISUITE 2011 v4.1
Fugacity_Air: (%)	1.44	EPISUITE 2011 v4.1
Fugacity_Water: (%)	36	EPISUITE 2011 v4.1
Fugacity_Soil: (%)	62	EPISUITE 2011 v4.1
Fugacity_Sediment: (%)	0.0638	EPISUITE 2011 v4.1
Bioconcentration factor (BCF):	10	HSDB 2012
Biotransformation half - life (Days):		

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Project number: 117636002

ORGANIC

Aquatic Ecotoxicological Data

Acute toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Pimephales promelas	Fathead minnow	Fish NOEC			7	6090	ECOTOX 2012
Daphnia magna	Water flea	Invertebrate EC50			1	>10000	ECOTOX 2012

Chronic toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Lemna gibba	Inflated Duckweed	Plant EC50			7	10920	ECOTOX 2012

Terrestrial Ecotoxicological Data

Common Name	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc**	**Reference**	**Units**
Rat	Mammalian LD50	MOR	Mortality		4700	HSDB 2012	mg/kg
Mouse	Mammalian LD50	MOR	Mortality		7500	HSDB 2012	mg/kg bw

Common Name	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc**	**Reference**	**Units**
Earthworm	1	MOR	Mortality		231.62	ECOSAR 2012	mg/L

DRAFT

Created By: Naomi Cooper Date: 16/07/2013

Checked By: Kirsten Broadgate Date: 17/07/2013

Project number: 117636002

ORGANIC

Name	Guar gum
Synonyms	
CAS Number	9000-30-0
Molecular Formula	

Physical Properties	Value	Reference
PhaseState:		
Molecular Weight (g/mol):		
Melting Point (°C):		
Boiling Point (°C):		
Density / Specific Gravity (Enter Unit):		
Vapour Pressure (mm Hg at 25°C):		
Solubility (mg/L):		
Henry's Law Constant (atm m³/mole):		
Organic carbon partition coefficient (Koc):		
Log organic carbon partition coefficient (log Koc):		
Log octanol - water partition coefficient (log Kow):		

Persistance / Bioaccumulation	Value	Reference
Biowin 3 (Ultimate Survey Biodegradation):		
Biowin 4 (Primary Biodegradation):		
EPISUITE Ready Biodegradability:		
Biowin 7 (Anaerobic Model Prediction):		
Fugacity_Air: (%)		
Fugacity_Water: (%)		
Fugacity_Soil: (%)		
Fugacity_Sediment: (%)		
Bioconcentration factor (BCF):		
Biotransformation half - life (Days):		

DRAFT

Project number: 117636002

ORGANIC

Aquatic Ecotoxicological Data

Acute toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Daphnia magna	Water flea	Invertebrate LC50	MOR	Mortality	4	6.2	ECOTOX 2012
Oncorhynchus mykiss	Rainbow trout	Fish LC50	MOR	Mortality	4	218	ECOTOX 2012

Terrestrial Ecotoxicological Data

Common Name	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc**	**Reference**	**Units**
Rat	Mammalian LD50	MOR	Mortality		6770	HSDB 2002	mg/kg
Mouse	Mammalian LD50	MOR	Mortality		8100	HSDB 2002	mg/kg

DRAFT

Created By: Naomi Cooper Date: 16/07/2013

Checked By: Kirsten Broadgate Date: 17/07/2013

Project number: 117636002

ORGANIC

Name	Hemicellulase Enzyme
Synonyms	
CAS Number	9012-54-8
Molecular Formula	

Physical Properties	Value	Reference
PhaseState:	White crystals or powder (pure enzyme)	HERA 2005
Molecular Weight (g/mol):		0
Melting Point (°C):		
Boiling Point (°C):		
Density / Specific Gravity (Not given):	1.00	HERA 2005
Vapour Pressure (mm Hg at 25°C):	0.0000000075	HERA 2005
Solubility (mg/L):	800.00	HERA 2005
Henry's Law Constant (atm m³/mole):	0.00000245	HERA 2005
Organic carbon partition coefficient (Koc):	0.11	HERA 2005
Log organic carbon partition coefficient (log Koc):	1.30	HERA 2005
Log octanol - water partition coefficient (log Kow):	-2.95E+00	HERA 2005

Persistance / Bioaccumulation	Value	Reference
Biowin 3 (Ultimate Survey Biodegradation):		
Biowin 4 (Primary Biodegradation):		
EPISUITE Ready Biodegradability:		
Biowin 7 (Anaerobic Model Prediction):		
Fugacity_Air: (%)		
Fugacity_Water: (%)		
Fugacity_Soil: (%)		
Fugacity_Sediment: (%)		
Bioconcentration factor (BCF):		
Biotransformation half - life (Days):		

DRAFT

Project number: 117636002

ORGANIC

Aquatic Ecotoxicological Data

Acute toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Brachydario rerio	Zebra Fish	Fish LC50	Mortality	Mortality	4	330	HERA 2005

Created By: Lisa Brookes Date: 21/09/2012

Checked By: Kirsten Broadgate Date: 18/07/2013

DRAFT

Name	Hydrochloric Acid
Synonyms	Anhydrous hydrochloric acid, chlorohydric acid, dilute hydrochloric acid, hydrochloric acid gas, muriatic acid
CAS Number	7647-01-0
Molecular Formula	HCl

Physical Properties	Value	Reference
PhaseState:	Liquid	HSDB 2009
Molecular Weight (g/mol):	36.46	HSDB 2009
Melting Point (°C):	-114.22	HSDB 2009
Boiling Point (°C):	-85.05	HSDB 2009
Solubility (mg/L):	825,000.00	HSDB 2009

Other Relevant Factors	Value	Reference
Reactivity		
Species:		
Reaction type:		
pH / Acidity		
acid / alkaline		
pH (10% solution)		

DRAFT

Aquatic Ecotoxicological Data

Acute toxicity data

SpeciesName	Common Name	Endpoint	Effect	Effect Measure	Test Time (Days)	Conc mg/L	Reference
Gambusia affinis	Western Mosquito fish	Fish LC50	Mortality	Mortality	1	282	ECOTOX 2012

Chronic toxicity data

SpeciesName	Common Name	Endpoint	Effect	Effect Measure	Test Time (Days)	Conc mg/L	Reference
Lemna minor	Duckweed	Plant EC50	Growth	Weight	10	182.3	ECOTOX 2012

Project number: 117636002

INORGANIC

Terrestrial Ecotoxicological Data

Common Name	Endpoint	Effect	Effect Measure	Test Time (Days)	Conc	Reference	Units
Rat	Mammalian LD50	Mortality	Mortality		50 mg/kg/bw	INCHEM 2012	

Created By: Chelsea Papadopoulos Date: 16/08/2012

Checked By: Kirsten Broadgate Date: 18/07/2013

DRAFT

Project number: 117636002

ORGANIC

Name	Maltodextrin
Synonyms	Fibersol, Lycatab, Maltrin, Maldex 15
CAS Number	9050-36-6
Molecular Formula	C6-H12-O6

Physical Properties	Value	Reference
PhaseState:		
Molecular Weight (g/mol):	180.1559	USEPA 2012
Melting Point (°C):		
Boiling Point (°C):		
Density / Specific Gravity ():		
Vapour Pressure (mm Hg at 25°C):		
Solubility (mg/L):		
Henry's Law Constant (atm m³/mole):		
Organic carbon partition coefficient (Koc):		
Log organic carbon partition coefficient (log Koc):		
Log octanol - water partition coefficient (log Kow):		

Persistance / Bioaccumulation	Value	Reference
Biowin 3 (Ultimate Survey Biodegradation):		
Biowin 4 (Primary Biodegradation):		
EPISUITE Ready Biodegradability:		
Biowin 7 (Anaerobic Model Prediction):		
Fugacity_Air: (%)		
Fugacity_Water: (%)		
Fugacity_Soil: (%)		
Fugacity_Sediment: (%)		
Bioconcentration factor (BCF):		
Biotransformation half - life (Days):		

DRAFT

Project number: 117636002

ORGANIC

Created By: Naomi Cooper Date: 4/09/2012

Checked By: Kirsten Broadgate Date: 18/07/2013

DRAFT

Project number: 117636002

ORGANIC

Name	Monoethanolamine borate
Synonyms	
CAS Number	26038-87-9
Molecular Formula	C2H7No.xBH3O3

Physical Properties	Value	Reference
PhaseState:	Liquid	ECHA 2013
Molecular Weight (g/mol):		0
Melting Point (°C):		
Boiling Point (°C):		
Density / Specific Gravity (g/cm3 at 20	1.25	ECHA 2013
Vapour Pressure (mm Hg at 25°C):		
Solubility (mg/L):		
Henry's Law Constant (atm m³/mole):		
Organic carbon partition coefficient (Koc):		
Log organic carbon partition coefficient (log Koc):		
Log octanol - water partition coefficient (log Kow):		

Persistance / Bioaccumulation	Value	Reference
Biowin 3 (Ultimate Survey Biodegradation):		
Biowin 4 (Primary Biodegradation):		
EPISUITE Ready Biodegradability:		
Biowin 7 (Anaerobic Model Prediction):		
Fugacity_Air: (%)		
Fugacity_Water: (%)		
Fugacity_Soil: (%)		
Fugacity_Sediment: (%)		
Bioconcentration factor (BCF):		
Biotransformation half - life (Days):		

DRAFT

Project number: 117636002

ORGANIC

Aquatic Ecotoxicological Data

Acute toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Cyprinus carpio	Carp	Fish LC50	MOR	Mortality	4	617	ECHA 2013
Daphnia magna	Water flea	Invertebrate EC50	MOB	Mobility	2	423	ECHA 2013

Chronic toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Pseudokirchneriella subcapitata	Algae	Plant EC50	POP	Biomass	3	13	ECHA 2013
Pseudokirchneriella subcapitata	Algae	Plant NOEC	POP	Growth rate	3	18	ECHA 2013

DRAFT

Created By: Naomi Cooper Date: 17/07/2013

Checked By: Kirsten Broadgate Date: 18/07/2013

Project number: 117636002

ORGANIC

Name	Polyethylene glycol
Synonyms	
CAS Number	25322-68-3
Molecular Formula	H-(OCH2CH2)n-OH

Physical Properties	Value	Reference
PhaseState:		
Molecular Weight (g/mol):	200	OECD SIDS 2004
Melting Point (°C):		
Boiling Point (°C):		
Density / Specific Gravity (Enter Unit):		
Vapour Pressure (mm Hg at 25°C):		
Solubility (mg/L):		
Henry's Law Constant (atm m³/mole):		
Organic carbon partition coefficient (Koc):		
Log organic carbon partition coefficient (log Koc):		
Log octanol - water partition coefficient (log Kow):		

Persistance / Bioaccumulation	Value	Reference
Biowin 3 (Ultimate Survey Biodegradation):		
Biowin 4 (Primary Biodegradation):		
EPISUITE Ready Biodegradability:		
Biowin 7 (Anaerobic Model Prediction):		
Fugacity_Air: (%)		
Fugacity_Water: (%)		
Fugacity_Soil: (%)		
Fugacity_Sediment: (%)		
Bioconcentration factor (BCF):		
Biotransformation half - life (Days):		

DRAFT

Aquatic Ecotoxicological Data

Acute toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Oryzias latipes	Japanese medaka	Fish LC50	MOR	Mortality	2	>1000	ECOTOX 2012

Terrestrial Ecotoxicological Data

Common Name	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc**	**Reference**	**Units**
Rat	Mammalian LD50	MOR	Mortality		600	ChemIDPlus 201	mg/kg
Mouse	Mammalian LD50	MOR	Mortality		3400	ChemIDPlus 201	mg/kg

DRAFT

Created By: Naomi Cooper Date: 16/07/2013

Checked By: Kirsten Broadgate Date: 17/07/2013

Name	Sodium Hydroxide
Synonyms	Sodium hydroxide
CAS Number	1310-73-2
Molecular Formula	NaOH

Physical Properties	Value	Reference
PhaseState:	White orthogonal crystals	HSDB 2012
Molecular Weight (g/mol):	40	HSDB 2012
Melting Point (°C):	323.00	HSDB 2012
Boiling Point (°C):	1388	HSDB 2012
Solubility (mg/L):	1,110,000.00	HSDB 2012

Other Relevant Factors	Value	Reference
Reactivity		
Species:	OH-/NaOH	HSDB 2011
Reaction type:	Acid/base	HSDB 2011
pH / Acidity		
acid / alkaline	Alkaline	HSDB 2011
pH (10% solution)	11	HSDB 2011

DRAFT

Aquatic Ecotoxicological Data

Acute toxicity data

SpeciesName	Common Name	Endpoint	Effect	Effect Measure	Test Time (Days)	Conc mg/L	Reference
Daphnia magna	Water flea	Invertebrate NOEC	INT	Immobilisation	0.67	240	ECOTOX 2012
Ceriodaphnia dubia	Water flea	Invertebrate EC50	Intoxication	Immobilisation	2	40.38	ECOTOX 2012
Gambusia affinis	Western mosquitofish	Fish LC50	Mortality	Mortality	1	125	ECOTOX 2012

Project number: 117636002

INORGANIC

Terrestrial Ecotoxicological Data

Common Name	Endpoint	Effect	Effect Measure	Test Time (Days)	Conc	Reference	Units
Rat	Mammalian LD50	MOR	Mortality		140	HSDB 2012	mg/kg
Rabbit	Mammalian LD50	MOR	Mortality		325	OECD SIDS 200	mg/kg bw

Created By: Lisa Brookes Date: 31/07/2012

Checked By: Kirsten Broadgate Date: 15/07/2013

DRAFT

Project number: 117636002

ORGANIC

Name	Tetrakis (hydroxymethyl) phosphonium sulphate (THPS)
Synonyms	Bis(tetrakis(hydroxymethyl)phosphonium) sulphate (salt), octakis (hydroxymethyl) phosphonium sulphate
CAS Number	55566-30-8
Molecular Formula	C4H12O4P.1/2O4-S

Physical Properties	Value	Reference
PhaseState:	Crystalline solid	HSDB 2012
Molecular Weight (g/mol):	406.32	HSDB 2012
Melting Point (°C):	-35.00	EPISUITE 2011 v4.0
Boiling Point (°C):	111	EPISUITE 2011 v4.0
Density / Specific Gravity (g/cm3 at 25	1.40	EPISUITE 2011 v4.0
Vapour Pressure (mm Hg at 25°C):	8.12	HSDB 2012
Solubility (mg/L):	1,000,000.00	HSDB 2012
Henry's Law Constant (atm m³/mole):	1.7E-23	HSDB 2012
Organic carbon partition coefficient (Koc):	140.00	HSDB 2012
Log organic carbon partition coefficient (log Koc):	2.15	HSDB 2012
Log octanol - water partition coefficient (log Kow):	-2.04E+01	HSDB 2012

Persistance / Bioaccumulation	Value	Reference
Biowin 3 (Ultimate Survey Biodegradation):	3.5811	EPISUITE 2011 v4.1
Biowin 4 (Primary Biodegradation):	4.2972	EPISUITE 2011 v4.1
EPISUITE Ready Biodegradability:	Biodegrades fast	EPISUITE 2011 v4.1
Biowin 7 (Anaerobic Model Prediction):	2.1061	EPISUITE 2011 v4.1
Fugacity_Air: (%)		
Fugacity_Water: (%)		
Fugacity_Soil: (%)		
Fugacity_Sediment: (%)		
Bioconcentration factor (BCF):	3	EPISUITE 2011 v4.1
Biotransformation half - life (Days):		

DRAFT

Project number: 117636002

ORGANIC

Aquatic Ecotoxicological Data

Acute toxicity data							
SpeciesName	**Common Name**	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc mg/L**	**Reference**
Oncoryhynchus mykiss	Rainbow trout	Fish LC50	MOR	Mortality	4	94	HSDB 2012
Daphnia magna	Water flea	Invertebrate EC50	MOR	Mortaility	2	15	HSDB 2012
Oncoryhynchus	Rainbow trout	Fish NOEC	MOR	Mortality	4	22	ECOTOX 2012

Terrestrial Ecotoxicological Data

Common Name	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc**	**Reference**	**Units**
Rat	Mammalian LD50	MOR	Mortality		248	HSDB 2012	mg/kg

Common Name	**Endpoint**	**Effect**	**Effect Measure**	**Test Time (Days)**	**Conc**	**Reference**	**Units**
Earthworm	1	MOR	Mortality	14	148000	ECOSAR 2012	mg/L

DRAFT

Created By: Naomi Cooper Date: 19/07/2013

Checked By: Kirsten Broadgate Date: 19/07/2013

APPENDIX F HUMAN HEALTH TOXICOLOGICAL PROFILES

APPENDIX F.1 SCHLUMBERGER GUAR BASED SYSTEMS

Toxicity Profile

Acetic acid
(CAS No. 64-19-7)

Acetic acid dissociates in aqueous media to H^+ and the acetate anion ($CH_3CO_2^-$). It is naturally occurring as the acid in apple cider vinegar and other fruit-derived products. It and several of its salts are commonly used as food additives (*e.g.*, as flavor enhancers) and are listed as Generally Recognized as Safe (GRAS) by the U.S. Food and Drug Administration (FDA).

pH: 2.5 at 50 g/L and 20°C
pK_a: 4.76 @ 20°C

Acute Toxicity

The oral LD_{50} in rats is 4,950 mg/kg, and the dermal LD_{50} in rabbits is 1,060 mg/kg. The 4-hour LC_{50} in rats is 11.4 mg/L.

Irritation

In the EU, acetic acid is classified as a skin and eye irritant at concentrations <25%. At ≥25%, it is classified as corrosive to the skin.

Sensitization

No data are available.

Repeated Dose Toxicity

In an 8-month study, rats dosed with 60 mg/kg acetic acid (three times per week) developed hyperplasia in the esophagus and forestomach.

Genotoxicity

Acetic acid was not mutagenic to *Salmonella typhimurium* strains TA 98, TA 100, TA 1535, TA 1537, and TA 1538 in an *in vitro* bacterial mutation assay with or without metabolic activation. Acetic acid (in media adjusted to a pH of 8.5) was also not genotoxic in an *in vitro* chromosomal aberration test using Chinese Hamster Ovary cells with or without metabolic activation.

Carcinogenicity

No adequate carcinogenicity studies have been conducted on acetic acid.

Reproductive Toxicity

No studies could be located.

Developmental Toxicity

There were no effects on implantations or on maternal or fetal survival in mice, rats, or rabbits at doses up to 1,600 mg/kg.

Key Study/Critical Effect for Screening Criteria

There are no repeat dose toxicity studies that were considered adequate for human health risk assessment. The only study reported on the toxicity of acetic acid by oral gavage showed effects of irritation (probably due to the pH of acetic acid) at the site of contact in the gastrointestinal tract. No systemic effects were reported.

The Joint FAO/WHO Expert Committee on Food Additives (JECFA) has maintained a group ADI of "not limited" for acetic acid and its potassium and sodium salts.

The Australian drinking water guidance value for pH may apply to acetic acid.

References

ECHA REACH: http://apps.echa.europa.eu/registered/registered-sub.aspx

JECFA: http://apps.who.int/ipsc/database/evaluations/chemical.aspx?chemID=4785

U.S. EPA HPVIS database: http://www.epa.gov/chemrtk/hpvis/index.html

Toxicity Profile

Ammonium C6-C10 Alcohol Ethoxysulfate
(CAS No. 68187-17-7)

Alcohol ethoxysulfates (AES) are a widely used class of anionic surfactants. No data could be located on alcohol ethoxysulfates in the C6 to C10 range. Thus, the C12-C14 alcohol ethoxysulfates were used to read-across to the C6-C10 alcohol ethoxysulfates.

In the HERA report, the alcohol ethoxysulfate family covers commercial grades of linear-type primary alcohol ethoxysulfates of either sodium, ammonium or triethanolamine (TEA) salts. Sodium salts of AES are by far the commonly used grades.

Acute Toxicity

Alcohol ethoxysulfates are considered to have a low order of acute oral toxicity in the rat. In two guideline compliant acute oral toxicity studies, the oral LD_{50}s were >2,000 mg/kg.

Irritation

The irritation potential of AES is concentration dependent. Materials with concentrations >70% are moderately to severely irritating to rabbit skin . At concentrations between 10 and 30%, the AES solutions exhibit mild to moderate irritancy under the conditions of an occluded patch test. AES concentrations below 1% are virtually non-irritating under the conditions of the acute skin irritation testing protocol.

The triisopranolammonium salt of C12-14E2S (90% active material) and NaC12-14E2S (28% active material) were shown to be moderately to severely irritating to rabbit eyes.
It has been shown that solutions containing less than 1- 10% AES are slightly to moderately irritating to eyes and below 1%, AES solutions are virtually non-irritating.

Sensitization

AES are not considered to be skin sensitizers.

Repeated Dose Toxicity

Rats were given by oral gavage 0, 25, 75 or 225 mg/kg NaC12-14AE2S for 90 days. Four animals died during the treatment period and were considered incidental, and three animals died due to experimental procedures. There were no treatment-related effects on total body weight gain, food and water consumption, and systemic effects. In the 225

mg/kg animals, hyperplasia, submucosal edema and chronic ulceration were seen in the forestomach. In groups 25 and 75 mg/kg groups, 3/10 animals showed small eosinophilic foci in the stratified epithelium of the forestomach. The LOAEL appears to be 25 mg/kg/day and the NOAEL was not determined.

Rats were fed in their diet 0, 40, 200, 500, 1,000 or 5,000 ppm NaC12-15E3S for 90 days. All animals survived until the end of the study. There were no treatment-related effects on clinical signs and body weights in females. Male body weights were significantly higher than controls in the 500 ppm group from week 10 onwards and at 200 ppm at weeks 11 and 13. At higher concentrations, there was no difference in body weights from the control values. At 5,000 ppm, male and female liver weights were significantly increased, and absolute testes weights were also increased; however, there was no significant difference with control animals when adjusted for terminal body weight. These organ weight changes were not accompanied by any histopathological, clinical chemical or hematological changes and were therefore considered to be adaptive in nature and not a toxic effect of the test substance. The NOAEL for this study is 5,000 ppm (250 mg/kg/day).

Rats were given in their diet 0, 0.1 or 0.5% C12 AE3S for 2 years. There were no treatment-related effects (including tumor incidence). The results of this study suggests that the NOAEL was 0.5% (250 mg/kg/day).

Rats were given in their drinking water 0 or 0.1% C12AE3S for two years. There were no treatment-related effects on survival, growth, food consumption, body weights, clinical laboratory findings, hematology and urinalyses. The only unusual finding was slight, but consistently higher water consumption by all rats receiving the test compound in their drinking water and a significant difference in the empty cecum to body weight ratio of females. Absolute organ weights were all comparable to controls and no consistent gross or histopathology was found. The incidence and types of tumors observed in the treated group was similar to that of control animals. The NOAEL for this study is 0.1% (75 mg/kg/day).

Genotoxicity

AES are not genotoxic when tested either *in vitro* or *in vivo*.

Carcinogenicity

The available oral and dermal long term toxicity/carcinogenicity studies, even if not performed according to accepted guidelines for carcinogenicity bioassays, appear to be conducted and documented in an acceptable manner. There is sufficient evidence that AES was carcinogenic in these studies.

Reproductive Toxicity

AES did not adversely affect reproduction in the rat and the NOAEL for reproductive effects was > 300 mg/kg. Slight systemic effects were observed in the parental and F_1 generation with a NOAEL of 86 and 149 mg/kg, respectively.

Developmental Toxicity

Based on the available information, there is sufficient evidence to conclude that AES are not teratogenic or a developmental toxicants. A NOAEL of >1,000 mg/kg/day can be estimated for teratogenicity and embryotoxicity, and the NOAEL for developmental toxicity appears to be >750 mg/kg/day.

Key Study/Critical Effect for Screening Criteria

A LOAEL of 225 mg/kg/day was reported in the 90-day oral gavage study on NaC12-14AE2S based on forestomach lesions in the rat. These lesions appear to be a localized effect due to the irritation properties of the test substance. No systemic toxicity was observed in this study. In contrast, when the test AES were given in the diet or in drinking water, not such irritation effects of the gastrointestinal tract was noted. This study will not be considered for the derivation of a drinking water guidance value since repeated dosing by oral gavage (a single daily oral bolus) is not a realistic human exposure scenario. Furthermore, 90-day and 2-year dietary and drinking water studies exist. The lowest NOAEL from the 90-day and 2-year dietary and drinking water studies is 75 mg/kg/day.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD = 75/100 = 0.75 mg/kg/day

Drinking water guidance value = 2.6 ppm

References

Human and Environmental Risk Assessment (HERA) on Ingredients of Household Cleaning Products: Alcohol Ethoxysulphates, Human Risk Assessment (2003), Draft http://www.heraproject.com

Toxicity Profile

Amorphous/Non-crystalline Silica
(CAS No. 7631-86-9[1])

Silica Gel
(CAS No. 112926-00-8)

Amorphous silica and silica gel have been reviewed in the OECD-SIDS program (OECD, 2004a,b).

The CAS No. 7631-86-9 is the general CAS No. for silicon dioxide which includes all forms of silicas (*e.g.* also crystalline and natural forms). Only the silica sub-classes, the synthetic amorphous silicas, are the subject of this assessment.

Synthetic amorphous silicas (SAS) are in powder form which have a low water solubility: ≤70 mg/L

Toxicokinetics

After oral ingestion, there is no accumulation of SAS in body tissues. Upon cessation of exposure, rapid elimination occurs. Intestinal resorption appears to be insignificant in animals and humans. In a human study, the small apparent increases in the urine output of human volunteers were remarkably low as compared with the high dose of 2,500 mg SiO_2 applied.

After daily oral administration of 1,500 mg/kg SAS (FK 700) as aqueous suspension to rats for one month, there was no accumulation of SiO_2 in the body: the average SiO_2 content was: 1.5 µg in the liver, 6.4 µg in the kidney, and 5.3 µg in the spleen. The corresponding control values were 1.8, 7.2 and 7.8 µg SiO_2, respectively.

In a similar experiment in rats receiving 20 daily oral doses of 100 mg SAS (HDK V15) per animal (about 500 mg/kg) each, tissue values were slightly increased in liver and kidney: in liver 4.2 µg (control value 1.8 µg), in the spleen 5.5 µg (7.2 µg) and in the kidneys 14.2 µg (7.8 µg).

In 12 human volunteers, no significant increased renal excretion of SiO_2 was found following single oral ingestion of 2,500 mg (AEROSIL 175 and FK 700).

Acute Toxicity

The acute oral administration of various forms of SAS (aqueous suspension or gel) failed to produce signs of toxicity or deaths in treated animals with LD_{50} values greater than the

top doses applied, either by gavage: >3100 to >20000 mg/kg in mice and rats; or in the diet for 24 hours.

Irritation

Synthetic amorphous silicas are not irritating to the skin of rabbits exposed to 0.19 g (one case) or 0.5 g of dry or moistened test item under occlusive conditions for 4 or 24 hours. All products tested as a powder (0.1 g) have shown no or only weak and transient irritating effects on the conjunctivae of the eyes of rabbits with the iris and cornea not affected at all.

Sensitization

No experimental data are available on the synthetic amorphous silicas. Medical surveillance records on workers gave no evidence of skin sensitization over decades of practical experience.

Repeated Dose Toxicity/Carcinogenicity

Fischer rats and B6C3F_1 mice were administered SAS in the diet at levels of 0, 1.25, 2.5, and 5% for 102 weeks. The animals were in good condition throughout and showed high survival. The tumor responses in all organs of SAS-fed rats and mice were not statistically significantly different from the controls. The NOAEL for rats and mice were 2,500 and 6,500 mg/kg/day, respectively.

Genotoxicity

There is no evidence for synthetic amorphous silica to induce mutations either *in vitro* or *in vivo* using standard genotoxicity tests.

Reproductive Toxicity

An early limited one-generation study on rats gave no evidence of adverse effects on reproduction performan*ce* at 500 mg/kg/day, the highest dose tested (NOAEL). But the reliability is poor due to the small group size of animals.

Developmental Toxicity

SAS was examined for embryotoxic and developmental effects during the gestation phase in various animals species, rat, mouse, rabbit and hamster, at oral doses up to 1,600 mg/kg/day. . There were no significant signs of maternal or embryotoxic/developmental toxic effects in any species tested. The number of abnormalities seen in either soft or skeletal tissues of the test groups did not differ from the frequencies occurring spontaneously in the control animals.

Key Study/Critical Effect for Screening Criteria

The lowest NOAEL from the two-year dietary study was 2,500 mg/kg/day for rats.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD = 2,500/100 = 2.5 mg/kg/day

Drinking water guidance value = 0.09 ppm

References

OECD (2004a). IUCLID Data Set for Synthetic Amorphous Silica and Silicates: Silicon Dioxide (CAS No. 7631-86-9, 112945-52-5, 112926-00-8; Silicic Acid, Aluminum Sodium Salt (CAS No. 1344-00-9); Silicic Acid, Calcium Salt (CAS No. 1344-95-2), UNEP Publications.

OECD (2004b). Screening Information Dataset (SIDS) Initial Assessment Report for Synthetic Amorphous Silica and Silicates: Silicon Dioxide (CAS No. 7631-86-9, 112945-52-5, 112926-00-8; Silicic Acid, Aluminum Sodium Salt (CAS No. 1344-00-9); Silicic Acid, Calcium Salt (CAS No. 1344-95-2), UNEP Publications.

Toxicity Profile

Reaction mass of 5-chloro-2-methyl-4-isothiazolin-3-one and 2-methyl-2H-isothiazolin-3-one [3:1]
(CAS No. 55965-84-9)

Acute Toxicity

The oral LD_{50} of Kathon WT (1.5% a.i.) is >5,000 mg/kg (>75 mg a.i./kg) in male rats and >3,310 mg/kg (~49.6 mg a.i./kg) in female rats. The oral LD_{50} of Acticide 14 (14% a.i.) is 472-490 mg/kg (~66 to 69 mg a.i./kg) in rats (combined sexes); and 465 mg/kg (69 mg a.i./kg) in male rats and 393 mg/kg (59 mg a.i./kg) in female rats.

The dermal LD_{50} of Kathon CG is >5,000 mg/kg (>75 mg a.i./kg) in female rabbits. The dermal LD_{50} of Acticide 14 (14% a.i.) is 1,008 mg/kg (141 mg a.i./kg) in rats (combined sexes).

The inhalation LC_{50} of Kathon 886F (13.9% a.i.) in male and female rats is 2.36 mg/L (0.33 mg a.i./L).

Irritation

Undiluted Kathon MW (1.5% a.i.) and Acticide 14 (14% a.i.) were corrosive to rabbit skin. Undiluted Kathon CG was severely irritating to the eyes of rabbits. Kathon RH 886T at 100 ppm (0.01% a.i.) was non-irritating to the eyes of rabbits.

Sensitization

CMI/MI has been tested in the guinea pig Buehler and Magnusson-Kligman tests and has been shown to be a strong skin sensitizer. It is also a strong contact allergen in humans.

Repeat Dose Toxicity

Rats were exposed to CMI/MI in a powdered commercial diet. CMI/MI concentrations were increased over the 13-week period (initial concentration up to week 2, intermediate concentration week 3-4, final concentration week 5 to 13). Concentrations in the control and CMI/MI groups were: 0/0/0, 40/57/80, 132/187/260, 400/570/800 ppm. There were no mortalities and no effects on body weight or food consumption. In each group, some animals showed slight alopecia or reddened raw or scabbed areas on the skin. There were no other differences in general behavior or appearance. There were no treatment-related changes in hematological, biochemical, urinary parameters nor any pathology. No systemic toxicity was observed up to and including the highest dose of either CMI/MI

(800 ppm, equivalent 29.1 mg a.i./kg/day). The NOAEL in this study is 800 ppm (29.1 mg a.i. /kg/day).

Rats were exposed to CMI/MI via their drinking water at concentrations of 25, 75 or 225 ppm a.i. for three months (equivalent to an average intake of 2.38, 6.28 and 16.3 mg/kg/day in males and 4.06, 10.8, and 24.7 mg/kg/day in females). Two additional groups of rats were given tap water or tap water containing the inorganic ions present in the CMI/MI solution, at a concentration equal to that in the high dose group (225 ppm). This solution is referred to as the ion control solution. There were no mortalities in either sex at any dose level. There were no treatment-related effects on body weight up to the mid dose. A significant decrease in body weight was seen in males at the high dose during the first two weeks of the study. Food consumption was significantly decreased in males at all dose levels and in females mid and high dose groups during the first few weeks of dosing. Water consumption was significantly decreased at all concentrations. No overt clinical signs or ophthalmic were seen in any group throughout the 13 week toxicity or the reproductive phase. No adverse effects were seen in the examinations. No hematological treatment-related changes were seen in either sex at any dose level. There was a significant decrease in globulin and an increase in the albumin/globulin (A/G) ratio in males in both the high concentration and in the ion control groups, after 13 weeks of treatment. A significant decrease in total protein was also seen high concentration group, but was not seen in the ion control group. Females in the high concentration group showed a modest (40%) increase in SGOT (AST, aspartate aminotransferase) levels after 13 weeks of dosing. No changes were observed at any dose in mixed-function oxidase activities of the liver. At the end of 13 weeks of treatment, there was a significant increase in relative liver weight in males and in relative kidney weight in females at the high concentration but without any correlative changes in organ pathology. Histology revealed a local irritation of the glandular mucosa of the stomach in 7 of 15 males and 5 of 15 females at the high concentration. These subtle low level changes did not occur at the low or mid concentration nor were they present in either control group. No other compound related changes were seen. Reproductive organs at all doses were comparable to the control. The NOEL in this study was considered to be 75 ppm a.i. (equivalent to 6.28 and 10.8 mg/kg body weight/day in males and females, respectively), based primarily on irritation of the glandular stomach at the high dose. The No Observed Adverse Effect Level (NOAEL) is 225 ppm a.i. (equivalent to 16.3 and 24.7 mg/kg body weight/day in males and females, respectively), the highest dose tested, since no adverse effects were observed on the histopathology of any tissues or organs distant from the site of dosing.

Genotoxicity

The results of the *in vitro* mutagenicity tests were equivocal. In bacterial reverse mutation tests, CMI/MI was positive in *Salmonella* strain TA100 but was predominantly negative in other strains commonly tested strains. CMI/MI was mutagenic in the mouse lymphoma assay with and without metabolic activation. Effects at the Tk locus was seen both with and without S-9, but were enhanced with S9 mix. CMI/MI was not genotoxic

in the *in vitro* unscheduled DNA synthesis (UDS) assay with primary rat hepatocytes or in an *in vitro* chromosomal aberration test with Chinese hamster lung cells.

The *in vivo* studies indicated that CMI/MI does not have relevant mutagenic potential *in vivo*. The positive mutagenic effect of CMI/MI found in *in vitro* gene mutation assays was not confirmed in the sex-linked recessive lethal test in *Drosophila melanogaster* nor in two unscheduled DNA synthesis (UDS) studies in the rat. CMI/MI also did not show any increase in cells with micronuclei in mice nor did it induce chromosomal aberrations in rat bone marrow cells.

Carcinogenicity

In a two-year rat chronic study, Kathon 886 is given as 14.2% active ingredient with a pH between 2-3. In the document with compiled batch information for Kathon the active ingredient is 13.2, [10.13 % CMI/ 3.85% MI] with 15.4% magnesium nitrate and 9.0% magnesium chloride. The dose levels were 0, 30, 100 and 300 ppm (equivalent to: 0, 2.0, 6.6, 17.2 mg a.i./kg/day in males and 0, 3.1, 9.8, 25.7 mg a.i./kg/day in females. There were no deaths. There were no treatment-related effects on body weight or body weight gain at doses or food consumption up to and including the mid dose group. A treatment-related and concentration-dependent decrease in water consumption was seen in both sexes in all treated groups throughout the study. These decreases ranged from 0-22% at low dose 3-30% at mid dose and 15-40% at high dose. These decreases appear to be due to the unpalatability of the CMI/MI and not its inorganic stabilizer salts since the water consumption in the salt control was comparable to the tap water control throughout the study. Based on the average daily water consumption, the high dose was judged to be a maximum tolerated dose. The decreases in body weight and body weight gain were seen in high dose animals throughout the study and may be secondary to decreased water consumption. No treatment-related clinical effects were recorded. No treatment-related ophthalmic, hematological. biochemical or urinary changes were noted. Organ weights were comparable to the control. No effects on type or incidence of neoplasms were seen at up to and including the high dose (males: 17.2 a.i.; females 25.7 mg a.i./kg/day). Slight to moderate forestomach hyperplasia was seen at both mid and high dose groups. Gastric irritation was the primary effect observed. No adverse effects on the histopathology of any other tissues/organs were observed away from the site of dosing. No systemic effects were observed. The NOEL in this study was considered to be 30 ppm a.i. (2.0 to 3.1 mg a.i./kg/day), based primarily on gastric irritation of the stomach at 100 and 300 ppm a.i.. The NOAEL was considered to be 300 ppm a.i. (17.2 to 25.7 mg/a.i./kg/day), since no evidence of systemic toxicity was observed at any dose and there was no adverse effects on the histopathology of any tissues/organs distant from the site of dosing at any dose.

Reproductive/Developmental Toxicity

A one-generation reproductive toxicity study was combined with the 13-week drinking

water study reported above in the repeated dose toxicity section. Reproductive capability was similar in all groups. Litter size and survival at birth was also similar in all groups. One dam at the high concentration lost the entire litter by day 4 due to a lactation problem. This is not uncommon and was not considered treatment related. Pups of the other high concentration group dams, except one, survived and thrived to day 21. Thus, no adverse effects were observed on reproductive capability of male and female rats and no effects were observed on fetal health or pup survival (to day 21) up to and including the high dose (equivalent to 16.3 and 24.7 mg/kg/day in males and females, respectively].

In a two-generation reproductive toxicity study, rats were dosed with CMI/MI (Kathon 886F: 11.1% CMI, 3.7% MI a.i.) at concentrations of 0 (control), 0 (magnesium salt control), 30, 100 or 300 ppm a.i. For the P1 generation, this was equivalent to 0, 2.8-4.4; 8.5-11.8, and 22.7-28.0 mg a.i./kg/day; and in the P2 generation 0, 4.3-5.5, 13.4-16.0, and 35.7-39.1 mg a.i./kg/day. There were no treatment related effects on survival, food consumption or overt signs of toxicity. A decrease in bodyweight gain was noted initially in the P1 generation. This was thought to be linked to reduced water consumption since significant dose-related reduction in water consumption was seen at all concentrations in both the P1 and P2 generations, during the premating, gestation and lactation stages. Treatment-related histopathological changes were seen in the stomach in the P1 and P2 generation. These included erosions of the glandular mucosa, edema and inflammation in the submucosa of the glandular and nonglandular stomach, with hyperplasia and hyperkeratosis of the nonglandular stomach at the 100 and 300 ppm a.i. Other histopathological changes were seen but were not dose dependent.The estrus cycle in P1 or P2 females at any treatment level was comparable with the controls, as was the sperm motility, morphology, testicular sperm count or caudal epididymal reserves of P1 or P2 males. All other endpoints (gestation index, gestation length, number of pups per litter or treatment-related gross findings in F1 or F2 pups) were similar to those in the controls in either generation. The study authors considered that rats exposed to CMI/MI in the drinking water through two generations had a NOAEL of 30 ppm a.i. (2.8-4.4 mg/kg/day in the P1 animals; 4.3-5.5 mg/kg/day in the P2 animals) for parental animal toxicity, based on the gastric irritation of stomach at higher doses. The NOEL for reproductive toxicity is 300 ppm a.i. (22.7-28.0 mg/kg/day in the P1 animals; 35.7-39.1 mg/kg/day in the P2 animals), the highest dose tested. There were no effects on fertility or fetal development at any dose level.

In a rat oral gavage developmental toxicity study on Kathon 886 (13.9% a.i.), the developmental NOEL for CMI/MI is >15 mg a.i./kg during organogenesis (highest dose tested). In a rat oral gavage developmental toxicity study on Acticide 14 (10.2% CMi/ 4% MI), the NOAEL for maternal toxicity is <3.95 mg a.i./kg; the NOAEL for teratogenicity is >19.6 mg a.i./kg; and the NOAEL for embryotoxicity is >19.6 mg a.i./kg. In a rabbit oral gavage developmental toxicity study on Acticide 14 (10.2% CMI/ 4% MI), the developmental NOAEL is >5.49 mg a.i./kg; the NOAELs for maternal toxicity and fetal toxicity are 1.41 mg a.i./kg. In a rabbit oral gavage developmental toxicity study on Kathon MW (13.9% a.i.), the NOEL for maternal toxicity is 2 mg a.i./kg; the developmental NOEL is 8 mg a.i./kg, the highest dose based on severe

maternal toxicity at 20 mg a.i./kg.

Key Study/Critical Effect for Screening Criteria

A two-year dietary study was conducted in rats with CMI/MI (13.2% active ingredient). No systemic effects were observed. There was, however, gastric irritation of the stomach at 100 and 300 ppm. The NOEL for this study is 30 ppm (equivalent to 2.0 and 3.1 mg a.i./kg/day for males and females, respectively). The NOEL of 2.0 mg/kg/day will be used for deriving a drinking water guidance value.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral Reference Dose = 2/100 = 0.02 mg/kg/day

Drinking water guidance value = 0.07 ppm

Reference

EU SCCS (2009). Opinion on the mixture of 5-chloro-2-methyl-4-isothiazolin-3-one and 2-methyl-2H-isothiazol-3-one [3:1], Colipa N^{o} P56, Scientific Committee on Consumer Safety, SCCS/1238/09.

Toxicity Profile

C6-C10 Alcohol Ethoxylates

Alcohol ethoxylates are a class of non-ionic surfactants. The AEs have the basic structure $C_{x-y}AE_n$. The subscript (x-y) following the 'C' indicates the range of carbon chain units. AEs with carbon unit range between C8 to C18 are most commonly used in household detergent products. The hydrocarbon chain can be either linear or branched. AEs also contain an ethylene oxide (E) chain attached to the alcohol. The degree of ethylene oxide polymerization is indicated by the subscript (n) which indicates the average number of ethylene oxide units. In household products the average ethylene oxide chain length commonly ranges between 3 and 12 units.

The toxicity profile of C6-C10 alcohol ethoxylates has been evaluated as part of the class of alcohol ethoxylates ranging from C8 to C15 in the HERA report.

Acute Toxicity

The acute oral LD_{50} of C9-11AE2.5 in rats was calculated to be >4,000 mg/kg and <10,000 mg/kg. The acute oral LD_{50} of C7-9AE6 in rats was determined to be <2,000 mg/kg. The acute oral LD_{50} of C9-11AE8 in fasted rats was found to be 1,200 mg/kg. The oral LD_{50} in rats for C12-13AE6.5 is 2,100 mg/kg. The oral LD_{50} in rats for C12-15AE7 is 1,700 mg/kg. For C14-15AE11, the acute oral LD_{50} values were reported to be 720 mg/kg (neat) and 1,800 mg/kg (given as 50% (m/v) solution in corn oil). The oral LD_{50} in rats for C12-15AE11 is >2,00 mg/kg for males and between 1,000 and 2,000 mg/kg for females. The oral LD_{50} in rats for C14-15AE13 is 1,100 and 1,000 mg/kg in two separate studies.

The dermal LD_{50} of C7-9AE6 was >2 g/kg. The dermal LD_{50} values for AEs with an alkyl chain length of 9 – 11 carbon atoms in three different rat studies were determined to be >2,000 mg/kg and >4,000 mg/kg. An acute dermal LD_{50} value of >2,000 mg/kg was determined for C12-14AE3 and C12-14AE6 in two separate studies. The acute dermal LD_{50} of C12-15AE7 was determined to be >2,000 mg/kg.

The acute rat 4h-LC_{50} of C9-11AE5 generated as a mist was determined to be >0.22 mg/L. Talmage (1994) reported that alcohol ethoxylates were not acutely toxic to rats at concentrations less than or equal to their saturated vapor concentrations in air. Acute toxic thresholds were reached only when animals were exposed to the undiluted test chemical in the form of a respirable mist or aerosol. Under these conditions, 1- or 4-hour inhalation LC_{50} values ranged from 1.5 to 20.7 mg/L. Some studies reported no mortalities (1-hours LC_{50} -study) occurred at concentrations as high as 52 mg/L.

Irritation

Alcohol ethoxylates with varying alkyl chain lengths and ethoxylation degree were found to be slightly to severely irritating to skin in rabbits and rats. The degree of irritation was dependant on the type of patches used (open application versus full occlusion), the exposure time as well as the concentration of the test material. In humans, AEs are less irritating to skin than in animals. Neat applications of a range AEs in a 4h human patch test did not warrant these chemicals to be classified as skin irritants under EU legislation, while the same AEs would have been classified for skin irritation on the basis of animal data.

Alcohol ethoxylates range from mildly to severely irritating to rabbit eyes. Rinsing the eyes directly after exposure with water for 20 to 30 seconds greatly reduced the severity of the effects such that these products produced only mildly irritating effects. The degree of irritation is concentration-dependent as dilutions in water cause proportionally lower irritation. Generally, concentration of 0.1% were non-irritating, and concentrations of 1 to 10% ranged from slight to moderately irritating. No relationship could be established between the chemical structures of the tested AEs and their eye irritation responses.

Sensitization

Alcohol ethoxylates should not be considered as skin sensitizers. A substantial amount of skin sensitization studies in guinea pigs following either the Magnusson-Kligman maximization or the Buehler testing protocol are available to evaluate the skin sensitization potential of AEs. Although a mild skin sensitization reaction was observed in a study following the Magnusson-Kligman protocol, the weight of evidence clearly supports the assessment that AEs should not be considered as skin sensitizers. This is further supported by clinical and market data that demonstrate the absence skin sensitization responses to AEs when tested under the conditions of the HRIPT or when used in AE containing consumer products.

Repeated Dose Toxicity

C10AE5 was fed to rats at doses of 0, 125, 250 or 500 mg/kg for 90 days. There were not treatment-related clinical signs, body weight gain, food consumption or feed efficiency. There was a slight increase in absolute liver weights as well as a trend toward a dose-dependent increase in the liver weight/body weight ratio, with a statistically significant increase in the high dose group. However, the histological evaluation did not reveal any indication of hepatotoxicity and therefore the increase in liver weights was not interpreted to be a toxicological effect. It can be considered to be an adaptive response as a result of extensive metabolism of the test compound by the liver. There were no other gross or histopathological changes that were considered treatment-related. The NOAEL for this study can be considered to be 500 mg/kg/day.

Rats were given in their diet 0, 125, 250, 500, 1,000 and 3,000 ppm C9-11AE6 for 90

days. There were no signs of toxicity at any dose level. The NOAEL is 3,000 ppm (approximately 150 mg/kg/day).

Rats were given in their diet 0. 04, 0.2 and 1.0% C9-11AE8 for 90 days. Lower body weight gain and decreased food consumption were noted in the 1% males and females and in the 0.2% females from week 1 through the end of the study. Further statistical analyses revealed a significant decrease in the mean body weight gain noted in the 1% females and the decreases in mean food consumption noted in the 1% males and females. The differences noted in the 0.2% females were not statistically significant. The investigators considered these observations to be the result of poor palatability of the test substance. There were no other treatment-related effects. The NOAEL for this study is 1.0% (about 400 mg/kg/day).

Rats were fed C12-15AE7 in the diet at concentrations of 0%, 0.0313%, 0.0625%, 0.125%, 0.25%, 0.5% and 1.0% for 90 days. Body weight gain was significantly reduced in male and female rats in the 0.25% and higher dose groups, and was associated with marked decreases in food and water consumption. Relative liver weights were significantly increased in the 0.5% and 1% male rats fed and in female rats in the 0.25% groups and higher. There were not treatment-related changes in hematology, urinary and clinical chemistry parameters. The histological examination of the liver at necropsy revealed hepatocytic enlargement at 0.125% and higher, suggesting an increased liver metabolism on the basis of increased alkaline phosphatase activity at the higher dose levels. The NOAEL was established at 0.0625% (102 mg/kg/day).

Rats were fed C12-14AE7 in the diet at concentrations of 0%, 0.0313%, 0.0625%, 0.125%, 0.25%, 0.5% and 1.0% for 90 days. Body weight gain was significantly reduced in male and female rats in the 0.25% and higher dose groups, and was associated with marked decreases in food and water consumption. Relative liver weights were significantly increased in the 0.5% and 1% male rats fed and in female rats in the 0.25% groups and higher. There were not treatment-related changes in hematology, urinary and clinical chemistry parameters. The histological examination of the liver at necropsy revealed hepatocyte cell enlargement at 0.125% and higher, suggesting an increased liver metabolism on the basis of increased alkaline phosphatase activity at the higher dose levels. The NOAEL was established at 0.0625% (110 mg/kg/day).

Wistar rats were fed C14-15AE7 in the diet at concentrations of 0, 300, 1,000, 3,000, and 10,000 ppm for 90 days. All animals survived until their scheduled necropsy date. Significant treatment-related effects on body weight (*i.e.*, reduced mean body weights in males at 10,000 ppm and in females at 3,000 ppm), food intake (*i.e.*, reduced intake in both sexes at 10,000 ppm and at 3,000 ppm for females), organ weights (*i.e.*, increased relative liver weight in both sexes at 3,000 and 10,000 ppm and in females also at 1,000 ppm; increased spleen weight in males at 10,000 ppm; clinical chemistry (*i.e.*, confined to 10,000 ppm dose groups; significantly higher urea, chloride and potassium levels in males; significantly higher urea, chloride and cholesterol levels in females) and hematology (*i.e.*, in both sexes at 10,000 ppm and in males also at 3,000 ppm increased total leukocytes and lymphocytes; females at 10,000 ppm showed depression in numbers

of neutrophils, mean cell volume and mean cell hemoglobin) were identified in one or both sexes fed with dietary concentrations of 3,000 and 10,000 ppm. There were no compound-related histopathological effects at any dose level. Minor, but statistically significant changes in liver weight, kidney weights and plasma urea concentration were recorded in female rats in the 1,000 ppm group were not of toxicological significance. The NOAEL for this study is 1,000 ppm (50 mg/kg/day).

Rats were fed C14-15AE7 in the diet at concentrations of 0, 0.1%, 0.5% and 1% for 90 days. There were no treatment-related changes in body weight, food intake, and organ weights including those of the reproductive system, clinical chemistry and hematology at any treatment level. The NOAEL is 1% in the diet, which corresponded to 700 and 785 mg/kg/day for males and females, respectively.

Rats were fed C12-13AE6.5 in their diet at concentrations of 0, 0.1, 0.5 or 1% for two years. There was reduced food consumption in males (1%) and females (0.5 and 1%) which resulted in lower body weight gain compared to controls. At study termination, organ to body weight ratios were increased in the 0.5 and 1% females (liver, kidney and brain), 1% females (heart), and 1% males (liver). A dose-related focal myocarditis was observed in males. The NOAEL was established at 0.1% dietary level based on the relative organ weight increases. This corresponds to 50 mg/kg/day.

Rats were fed C14-15AE7 in their diet at concentrations of 0, 0.1, 0.5 or 1% for two years. There was reduced food consumption in males (1%) and females (0.5 and 1%) which resulted in lower body weight gain compared to controls. At study termination, organ to body weight ratios were increased in the 0.5 and 1% females (liver, kidney and brain), 1% females (heart), and 1% males (liver). A dose-related focal myocarditis was observed in males. The NOAEL was established at 0.1% dietary level based on the relative organ weight increases. This corresponds to 50 mg/kg/day.

Charles River rats were fed C14-15AE7 in the diet at concentrations of 0, 0.1, 0.5 and 1% for two years. There was a dose-related decrease in body weights in the 0.5 and 1% females and in the 1% males, the likely cause being poor palatability of the diet. At study termination, elevated organ-to-body weight ratios were noted for the liver, kidney, heart and thyroid/parathyroid glands in the 1% dietary group. The only significant histopathological finding prevalent in all dose groups was a dose-related increase in incidence of focal myocarditis at 12 months but not at study termination at 2 years. No other treatment-related histopathology was noted. The NOAEL was established at the 0.5% dietary level, which corresponds to about 162 and 190 mg/kg/day for males and females, respectively.

Genotoxicity

In all available *in vitro* and *in vivo* genotoxicity assays, there was no indication of genetic toxicity of broad range of structurally different alcohol ethoxylates.

Carcinogenicity

It can be concluded that alcohol ethoxylates as a class are not carcinogenic by the oral route based of available oral long term toxicity/carcinogenicity studies on AEs.

Charles River rats were given in their diet 0, 0.1, 0.5 or 1% C14-15AE7 for two years. There was no treatment-related changes in general behavior and appearance. The survival rate of the test animals was comparable if not better than the controls. Body weights of 0.5% females and 1% males and females had significantly lower weight gains than the control. There were no treatment-related effects on organ weights and tumor incidence.

Sprague-Dawley rats were fed C14-15AE7 at 0.1, 0.5 and 1% in the diet for two years. A treatment-related body weight depression was observed in females at the two highest treatment levels and in males at the 1% dose level, probably due to the poor palatability of the diet. There was no evidence for any carcinogenic activity.

Sprague-Dawley rats were fed C12-13AE6.5 in the diet at doses up to 1% (500 mg/kg/day). Reduced food consumption was noted at the higher dose levels (*i.e.*, 0.5 and 1% for females and 1% for males), resulting in a lower body weight gain compared to the control group. No treatment-related histopathology was found and no increase in tumor incidence was observed.

Reproductive Toxicity

In a two-generation reproductive toxicity study, Charles River rats were fed C12AE6 in the diet at dose levels of 0, 0.05, 0.1 and 0.5% (about 0, 25, 50 and 250 mg/kg/day). No treatment related effects in the parents or pups on general behavior, appearance or survival were observed. Fertility of treated groups was comparable with the controls. The only observation was related to a reduced weight gain of parental rats and pups relative to the control at the 0.5% dose level. The NOAEL for reproduction was therefore set at the highest dose level which was 0.5% dietary level (250 mg/kg/day).

In a two-generation developmental and teratogenicity study, CD rats were fed C14-15AE7 in the diet at dose levels of 0, 0.05, 0.1 and 0.5% (about 0, 25, 50 and 250 mg/kg). The control group and the six treated groups comprised of 25 male and 25 female animals. Three of the groups received the compound continuously during the study. In the other three groups the females received the compound only during gestational days 6-15 and the males were untreated. No treatment-related changes in behavior or appearance were observed in the parental rats or pups throughout the study. Female rats from the 0.5% continuous treatment group gained slightly less body weight compared to control females. No other consistent differences in body weight were observed. Food consumption was similar for control and treated rats. No compound related differences were seen between control and treated rats with respect to fertility, gestation or viability indices. The average 21-day body weights for pups at the 0.5% continuous treatment group were significantly lower as compared to the average pup body weights in the

controls. No other compound-related changes in body weight were observed. None of the deaths of parental rats during the study was considered to be compound-related. Examination of organ weight values revealed that compound-related effects were limited to increased group mean relative liver weights of male and female F_1 from the 0.5% continuous feeding group at the 91-day sacrifice, and increases in group mean relative liver weights of males from the 0.5% continuous feeding group of the F_2 generation at the 60-day and caesarean section sacrifices. No compound-related histopathological lesions were observed in any of the tissues examined from rats for the F_0 and F_1 generations. The NOAEL for reproductive toxicity is at least 0.5% in the diet (250 mg/kg/day).

Developmental Toxicity

In a two-generation reproductive toxicity study, Charles River rats were fed C12AE6 in the diet at dose levels of 0, 0.05, 0.1 and 0.5% (about 0, 25, 50 and 250 mg/kg/day). General behavior, appearance and survival were not affected by treatment. At the 0.5% dose level, adults and pups gained less weight than the control rats. In the 0.5% dose group, there was a statistical increase in embryo lethality and soft tissue anomalies and at the 0.1% there was a statistical decrease in mean fetal liver weight. Neither of these effects was considered to be treatment-related by the authors as they showed no dose response characteristics. The NOAEL for maternal toxicity is 50 mg/kg/day. The NOAEL for developmental and teratogenicity is 0.1% (50 mg/kg/day).

Pregnant rabbits were given by oral gavage 0, 50, 100 or 200 mg/kg C12AE6 from GD 2 to16. Nine control rabbits and 31 treated rabbits died during the study. Surviving rabbits at the 200 mg/kg dose level generally showed slight losses of body weight. At 100 and 200 mg/kg, ataxia and a slight decrease in body weight was observed in the pregnant animals. In seven treated and two control rabbits early deliveries were recorded. There were no treatment-related effects on corpora lutea, implantations, number of live fetuses and spontaneous abortions. The NOAEL for maternal toxicity is 50 mg/kg/day; the NOAEL for developmental toxicity is 200 mg/kg/day.

In two-generation developmental and teratogenicity study, CD rats were fed C14-15AE7 in the diet at dose levels of 0, 0.05, 0.1 and 0.5% (about 0, 25, 50 and 250 mg/kg). On the 13th day of the gestation period a representative number of female rats from each treatment group of the FC generation (*i.e.*, pups from the 3rd mating of the F_0 and F_1 parental generation) were sacrificed. Laparotomies were performed and the uterus was examined for uterine abnormalities, normal implantation and resorption sites. Remaining females were sacrificed on gestational day 21. Various maternal and fetal parameters showed occasional values that were significantly different from the corresponding controls. However these were not considered related to the material tested as none occurred at the high feeding level and no dose response for these parameters was apparent. With respect to body weight gains, parental female rats and pups of the high dose group did not gain as much body weight as the control rats. Examination of organ weight values reveal compound related effects were limited to increased group mean liver weighs of male and female P_1 generation from the 0.5% continuous feeding group at the

91 day sacrifice and increase in group mean relative liver weights of males of the 0.5% continuous feeding group of the P_2 generation at the 60 day section sacrifices. The NOAEL for maternal and developmental toxicity was established at the 0.1% in the diet (50 mg/kg/day).

Key Study/Critical Effect for Screening Criteria

AEs of different structures with regard to the length of the alkyl chain and the degree of ethoxylation have been evaluated in a number of 90-day and two-year oral toxicity studies. The lowest NOAEL of AEs for systemic toxicity was established at 50 mg/kg/day in two chronic (two-year) dietary studies on C12-13AE6.5 and C14-15AE7. Effects observed at the LOAEL were related to significantly elevated organ-to-body weight ratios for liver, kidney and heart, although there were no adverse histopathological changes.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD = 50/100 = 0.5 mg/kg/day

Drinking water guidance value = 1.75 ppm

References

Human and Environmental Risk Assessment (HERA) on Ingredients of Household Cleaning Products: Alcohol Ethoxylates (2009)
http://www.heraproject.com

Talmage, S.S. (1994). Environmental and Human Safety of Major Surfactants – Alcohol Ethoxylates and Alkylphenol Ethoxylates. The Soap and Detergent Association. Lewis Publishers, Boca Raton, Florida, USA.1994. page 35; cited in the HERA report.

Toxicity Profile

Crystalline Silica, Cristobalite
(CAS No 14464-46-1)

Crystalline Silica, Quartz
(CAS No. 14808-60-7)

Silica is an off-white granule that occurs naturally in various crystalline and amorphous or other non-crystalline forms. Crystalline silica is characterized by silicon dioxide (SiO_2) molecules oriented in fixed, periodic patterns to form stable crystals. The primary crystalline form of silica is quartz. Other crystalline forms of silica include cristobalite, tripoli and tridymite. Particle size is a key determinate of silica toxicity, since toxicity is restricted to particles that are small enough to be deposited into the target regions of the respiratory tract.

Oral Exposure

No oral studies were located; however, crystalline silica is not expected to exhibit toxicity by the oral route. Although absorption studies were not found for crystalline silica, kinetic studies on amorphous silica show no absorption from the gastrointestinal tract.

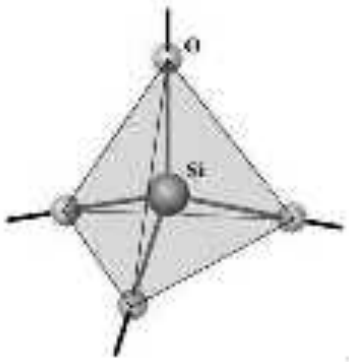
Dermal Exposure

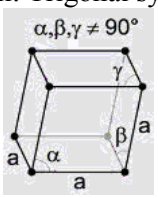
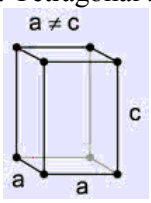
No dermal studies were located; however, crystalline silica is not expected to exhibit toxicity by the dermal route.

Inhalation Exposure

See attached OECD-SIDS Initial Targeted Assessment Profile on Quartz and Cristobalite, SIAM 32, 19-21 April 2011.

INITIAL TARGETED ASSESSMENT PROFILE (Human Health)

CAS No.	Quartz: CAS RN 14808-60-7 Cristobalite: CAS RN 14464-46-1
Chemical Name	Quartz and Cristobalite
Structural Formula	Molecular Formula: SiO_2 

Unit Cell: Trigonal symmetry	Unit Cell: Tetragonal symmetry
	
Quartz: CAS RN 14808-60-7	Cristobalite: CAS RN 14464-46-1

SUMMARY CONCLUSIONS OF THE TARGETED ASSESSMENT

NOTE: The present assessment is targeted to address the following human health endpoints: repeated dose toxicity and carcinogenicity via the inhalation route of exposure, and genotoxicity. It cannot be considered as a full SIDS Initial Assessment. Summary information on exposure is also reported here. Other endpoints for human health and the environment included in the Canadian screening assessment but have not been presented to OECD member countries, and thus are not included in this profile.

The final screening assessment will be published under the responsibility of the Government of Canada.

Rationale for Targeting the Assessment

The Government of Canada "categorized" or prioritized all 23,000 chemical substances on its Domestic Substances List (DSL) from 1999 to September 2006, as required by its *Canadian Environmental Protection Act, 1999* (CEPA 1999). Additional details may be found at http://www.chemicalsubstanceschimiques.gc.ca/about-apropos/categor/index-eng.php. Using information from Canadian industry, academic research and other countries, Government of Canada scientists applied a set of rigorous tools to the 23,000 chemical substances on the DSL. They were categorized to identify those that were: **inherently toxic** to humans or to the environment and that might be **persistent** and/or **bioaccumulative**; and substances to which people might have **greatest potential for exposure**. During this priority-setting exercise, distinct approaches were taken for identifying substances of likely concern for human health and the environment, and subsequent assessment activities may have focused on either human health or ecological endpoints. Through categorization, the Government of Canada has identified approximately 4,000 of the 23,000

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chemical substances on the DSL as priorities for further assessment, research and/or measures to control their use or release. Quartz and cristobalite were identified at that time, applying the categorization criteria, as high priorities for human health risk because they were considered to pose greatest potential for exposure and their respirable forms are classified by the International Agency for Research on Cancer as carcinogenic to humans (quartz and cristobalite) and by the National Toxicology Program as known human carcinogens (crystalline silica). These substances did not meet the ecological categorization criteria for bioaccumulation potential or inherent toxicity to aquatic organisms.

Under the Canadian legislation a determination of whether one or more of the criteria of the CANADIAN ENVIRONMENTAL PROTECTION ACT (CEPA) 1999, section 64 are met is based upon an assessment of potential risks to the environment and/or to human health associated with exposures in the general environment. For humans, this includes, but is not limited to, exposures from ambient and indoor air, drinking water, foodstuffs, and the use of consumer products. A conclusion under CEPA 1999 on the substances in the Chemicals Management Plan (CMP) Challenge is not relevant to, nor does it preclude, an assessment against the hazard criteria specified in the Controlled Products Regulations, which is part of the regulatory framework for the Workplace Hazardous Materials Information System [WHMIS] for products intended for workplace use.

Physical-chemical properties

The silicon dioxide group represents a polymorphic category containing a large number of forms identical in composition but with different atomic arrangements which afford different chemical properties. There are two sub-categories within this group: crystalline silica, to which the present substances quartz and cristobalite belong, and non-crystalline or amorphous silica. The key distinction between these sub-categories is that in crystalline substances, the building blocks are arranged in regular, repeating 3-dimensional pattern having long range order, whereas amorphous materials do not display long range order. In all forms of silica, (crystalline and non-crystalline), the silicon atom is tetrahedral and bound to four neighbouring oxygen atoms.

Quartz and cristobalite are solid at room temperature, existing normally as colourless or white crystals. The melting points for quartz and cristobalite are 1400-2000 ^{o}C and 1713-1728 ^{o}C, respectively and for both compounds, the boiling point is 2230^{o}C. Even though no experimental data were available, their vapour pressure and Henry's Law constant are likely negligible. Log K_{ow} (octanol-water partition coefficient) and log K_{oc} (organic carbon-water partition coefficient) are not applicable to these substances. The densities range from 2500-2700 kg/m^3 for quartz and 2300-2380 kg/m^3 for cristobalite.

The very similar physico-chemical properties of quartz and cristobalite reflect their closely related crystal forms. The solubility of crystalline silicates decreases as a function of silica tetrahedral packing density and long-range crystal order. For example, cristobalite has a more open framework structure than quartz and its density is lower, therefore, its solubility is higher. The water solubility of these minerals is also function of temperature, pH, particle size, and the presence of a disrupted surface layer. This may explain the variability of solubility values reported by many authors. The most probable solubility value for quartz is approximately 3.8 mg Si/L, or 6.4 mg/L expressed as the SiO_2 species, while the solubility of cristobalite is approximately 8.7 mg Si/L, or 18 mg SiO_2/L. The kinetics of dissolution of these substances is slow due to the high activation energy required to hydrolyse the Si-O-Si bond.

Human Health Targeted Endpoints

The majority of the studies described here have been reviewed by the International Agency for Research on Cancer (IARC 1997). However, additional data relevant to the screening assessment were identified up to August 2010.

Repeated dose toxicity/non-neoplastic effects (development of silicosis).

Studies on animals

Significant short-term and subchronic studies have demonstrated adverse effects in the lungs, while one of the 6 studies showed effects on the spleen in mice. Rats were exposed to 0, 10 or 100 mg/m^3 of cristobalite via inhalation for 6 hours/day during 3 days. Animals were observed 3 months after exposure. Elevated levels of granulocytes and elevated markers of cytotoxicity from the lung lavage fluid were noted in all exposed groups. Another study of similar duration (9 days) conducted in mice also identified a LOAEC of 10 mg/m^3. Effects observed included minimal interstitial thickening, accumulations of mononuclear cells and slight lymphoid tissue hypertrophy in the lungs.

In a 4-week inhalation study, female rats were exposed to 0, 0.1, 1 or 10 mg/m^3 of quartz 6 hours/day, 5 days/week. Bronchoalveolar lavage fluid was evaluated at 1, 8, and 24 weeks after exposure. Elevated levels of

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granulocytes and significant elevation of markers of cytotoxicity (Lactate dehydrogenase [LDH] and β-glucuronidase [β-glu]) were observed at 1 mg/m^3 and higher. The increased levels of LDH and β-glu were only significant at 24 weeks after exposure. A LOAEC of 1 mg/m^3 was identified at 24 weeks.

Male rats (4 animals per dose) were exposed to 0 or 3 mg/m^3 of cristobalite via inhalation for 6 hours/day, 5 days/week during 13 weeks. Pulmonary inflammation and fibrosis were observed in the exposed group at the end of treatment. When mice were similarly exposed to 5 mg/m^3 of quartz for 6 hours/day, 5 days/week for 15 or 27 weeks, the authors observed increased spleen weight and formation of plaque in the spleen.

In two separate studies, in which rats or hamsters were exposed to quartz via inhalation for at least 6 months, LOAECs of 2 and 3 mg/m^3 were identified, respectively. All the effects observed were related to inflammation and fibrosis of the lung tissue.

Several chronic studies investigated exposure of the respirable forms (i.e. accumulated via inhalation in the lung tissues) of quartz and cristobalite to rats, mice and hamsters. The following is a description of the study in which the lowest non-neoplastic LOAEC was determined. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz, containing 74% of respirable quartz, through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. The mean mass of particle at the end of the exposure period was 0.91 mg/lung. The LOAEC identified was 0.74 mg/m^3 (adjusted for 74% respirable quartz) based on lipoproteinosis, multifocal, inflammatory cell infiltrate and alveolar hyperplasia.

Human epidemiology data

In humans, the lowest observed adverse effect level was identified in a U.S. cohort study. The study was conducted on 3330 gold miners (all are males), who had an average of 9 years underground exposure during the period 1940 to 1965. The cohort was followed up through 1990. Silicosis[1] was identified through death certificates or chest X-rays. A job-exposure matrix together with work history was used to estimate individual exposure. The total silica content in the respirable dust in the mine was estimated at 13% and the median crystalline silica exposure was 0.05 mg/m^3. In this sub population of miners, 170 cases of silicosis were identified. The best predictor for risk of silicosis was cumulative exposure, which varied from less than 1% for a 0.5 mg/m^3-year exposure to 68-84% when exposed to more than 4 mg/m^3-year (based on the average daily dust exposure during the workday each year and summed over time for each miner). The main limitations identified by the authors include the limited number of radiographic surveys, the potential bias from death certificates

[1] Silicosis: Lung disease caused by inhalation of crystalline silica dust, and resulting in inflammation and scarring in forms of nodular lesions in the upper lobes of the lungs. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics). It does not follow that a history of exposure to silica necessarily results in silicosis (Nonsilicotics). The typical "Silicotic" lung nodule is shown in Figure 1.

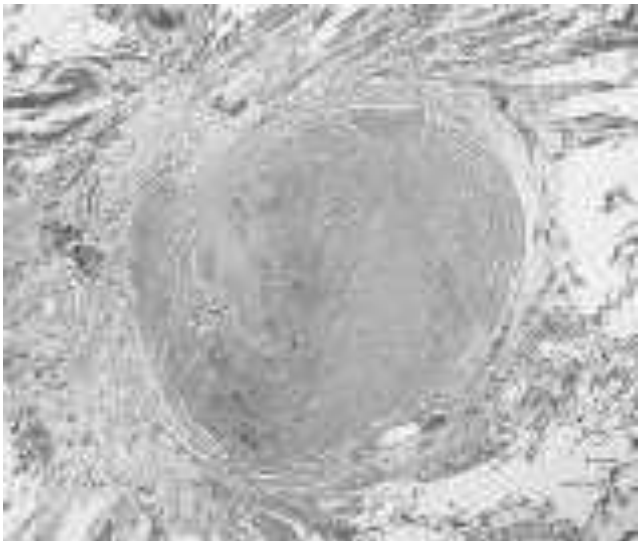


Figure 1. Silicotic nodule characterised by a central zone of hyalinised collagen with a whorled appearance and peripheral dust-containing macrophages (Rees and Murray, 2007).

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(relying on death certificates instead of relying on repeated x-rays, which were lacking for each miner, may have underestimated the number of cases) and the fact that the conversion of dust counts to

gravimetric measurements may not be accurate based on the estimation of 13% silica content in the respirable dust (although based on a relatively large number of samples (n = 82) collected in two different surveys, there was broad range of content in these samples (1% to 48%, SD = 9), and the percentage of respirable quartz may have differed in earlier years, but data were lacking for these years).

Two other human studies have identified similar LOAECs based on the critical endpoint of radiographic confirmed silicosis. A LOAEC of 0.053 mg/m^3 (mean exposure) was identified in a cross sectional study of South African gold miners and a LOAEC of 0.064 mg/m^3 (mean exposure) was derived in a mining community population-based random sample survey in Colorado.

Carcinogenicity studies

Studies on animals

Experimental studies conducted in rats have shown clear and consistent increases in lung tumours after chronic inhalation exposure. In the nine rat studies identified, five were inhalation studies and four were intratracheal instillation studies. All studies except one inhalation study showed increased incidence of lung tumours. For the inhalation studies with treatment related tumours, concentrations ranged from 1 to 50 mg/m^3 (1, 6, and 30 mg/m^3 of DQ-12 quartz; 12 and 50 mg/m^3 of Min-U-Sil 5 quartz) and duration of exposure ranged from 29 days to 2 years. In the inhalation study with no treatment-related tumours, exposure was 60 mg/m^3 of Sikron F300 quartz for 13 weeks. The following is a description of the neoplastic results in the study also identified as the critical study for non-neoplastic results. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. In the exposed group, 18 animals developed tumours (12 in females, 5 in males), as opposed to 3 and 2 for the control and positive control groups respectively. The majority (10/18) of the tumours observed were adenocarcinomas. The mean mass of particles in the lungs at the end of the exposure period was 0.91 mg/lung.

For the intratracheal instillation studies, doses ranged from 4 to 57 mg/kg-bw (based on 7, 12 or 20 mg/animal of Min-U-Sil (5) quartz or 20 mg/animal of novaculite quartz). Exposure regimes were diverse and included single instillation with observation for up to two years, to weekly instillation for 10 weeks. It is noteworthy that the single intratracheal administration of a 95% pure quartz particles (<5 μm) resulted in an increased incidence of silicotic granulomas after 3 weeks and lung tumours after 11 months. The most common tumours reported across the long term rat studies were adenocarcinomas, however other tumours such as squamous-cell carcinoma, alveolar carcinoma and bronchiole-alveolar adenoma were also reported, and all animals that developed tumours also showed some degree of fibrosis.

Of particular interest is the intratracheal instillation study, investigating the sequence of pathological events leading to lung tumors. An unspecified number of rats/sex/dose received a single intratracheal instillation of various crystalline silica dusts or ferric oxide, allowing direct administration into the bronchial tree. The doses were 12 or 20 mg of Min-U-Sil 5 quartz (MQZ), 12 mg of hydrofluoric-acid-etched Min-U-Sil 5 quartz (HFMQZ), 12 mg of cristobalite, 12 mg of tridymite and 12 mg of ferric oxide suspended in saline. All groups were observed until six months post exposure, except for both MQZ groups, the HFMQZ and the ferric oxide group which were observed up until 17 months post-exposure. Interim sacrifices were conducted at 6, 11 and 17 months. The rat lungs showed a clear progression of effects. The sequence of pathological events were, an initial inflammatory response leading to a marked hyperplasia and hypertrophy of alveolar cells after one month, and at six months hyperplasia was evident but no lung tumours were observed. In this study, lung tumours were observed starting at the 11 month sacrifice with a 17% and 42% incidence in males and females (based on 3/18 males and 8/19 females), respectively, and at 17 months incidences were 32% and 59% (based on 6/19 males and 10/17 females, respectively). No lung tumours were found in ferric oxide treated rats. Similar studies have also been conducted in hamsters and mice. Although treated mice and hamsters showed treatment related signs (inflammation or fibrosis), no tumours were observed in hamsters. No increase in the incidence of lung tumours was seen in mice treated with quartz; however silicotic granulomas and lymphoid cuffing around airways but no fibrosis were seen in the lungs of quartz-treated mice.

Human epidemiology data

There is an extensive dataset of human studies investigating the link between crystalline silica exposure and cancer. IARC (1997) identified over 50 epidemiological studies based on occupational exposure to dust containing respirable crystalline silica. Main industry sectors from which the human data is derived include gold mines, foundries, granite/stone industry, pottery workers and refractory brick workers. From the least confounded studies, it was noted that lung cancer tended to increase with the following parameters: cumulative

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exposure; duration of exposure; peak intensity of exposure; presence of radiographically defined silicosis; and length of follow-up time from date of silicosis diagnostic. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics).

Since the 1997 IARC report, a large number of epidemiological studies have been published, with the more recent studies being updates from supplementary follow-up of results from previously assessed case-control studies cohorts, new results based on refined exposure assessments or adjustment for confounders or meta-analyses of the pooled data from these epidemiology studies

In a meta-analysis of the data from 10 cohort studies of gold, tin and tungsten miners, granite workers, industrial sand, diatomaceous earth and pottery workers with quantitative exposure estimates for crystalline silica were pooled in order to analyse the risk related to lung cancer. The pooled cohort standardized mortality ratio (SMR, against national rates) [See Appendix 1 for definition] was 1.2 (Confidence Interval [CI] 1.1-1.3). The results from the case-control analyses show a statistically significant trend with duration of exposure (odds ratios (ORs) [See Appendix 1] by quintile of cumulative exposure increased from 1.0 to 1.6 [CIs of 0.85 to 2.1] and by quintile of average concentration increased from 1.0 to 1.7 [CIs of 1.1 to 2.3]), supporting the importance of the increasing lung burden of silica in the occurrence of cancer. Overall, the authors concluded that the results support the carcinogenicity conclusion presented by IARC (1997).

To investigate the link between crystalline silica, silicosis and lung cancer, epidemiological data published between 1966 and 2001 were gathered. Over 50 studies were selected and pooled according to type of study and the parameter being linked to lung cancer (i.e. silica exposure, presence of silicosis in subjects). The quality of study, adjustment for confounding factors, co-exposure to other carcinogens and availability of a more recent analysis of a same cohort were taken into consideration in the final selection of the studies. Analysis of the relationship between exposure to silica and lung cancer included 17 cohort and 13 case-control studies. For the analysis of lung cancer versus silicosis, 11 cohort and 5 case-control studies were selected. The third analysis included 6 cohort and 2 case-control studies to evaluate the risk of lung cancer in non-silicotics. A random effect model was used to conduct each meta-analysis. Pooled cancer risk ratios (RRs) were 1.32 (CI 1.23-1.41) for crystalline silica exposure, 2.37 (CI 1.98-2.84) for individuals exposed to silica with confirmed silicosis (Silicotics) and 0.96 (CI 0.81-1.15) for individuals with no evidence of silicosis (non-silicotics) with confirmed exposure to silica, supporting the general observation that silicosis has a stronger temporal relationship with crystalline silica exposure and furthermore support the view that a human silicotic response could be a preliminary stage in the development of cancer.

A more recent meta-analysis included 28 cohort, 15 case-control and two proportionate mortality ratio (PMR) [See Appendix 1] studies from a variety of occupational settings conducted between 1996 and 2005. Risk ratios (RRs) were calculated based on type of study and silicosis status using fixed and random effect models (results presented here are from the random model). RRs for all cohort studies was 1.34 (CI 1.25-1.45), and were 1.69 (CI 1.32-2.16) for silicotics, 1.25 (CI 1.18-1.33) for those with undefined silicosis status and 1.19 (CI 0.87-1.57) for non-silicotics. In the case-control studies, the general RR was 1.41 (CI1.18-1.67), and the same sub-groups as mentioned above resulted in RRs of 3.27 (CI 1.32-8.2), 1.41 (CI1.18-1.70) and 0.97 (CI 0.68-1.38), respectively. The proportionate mortality ratio for the last two studies was 1.24 (CI 1.05-1.47). The authors noted that the association between lung cancer and exposure to crystalline silica was more consistent for silicotics, i.e., those diagnosed with silicosis and RR values split into type of occupational settings in which participants worked.

Based upon the above three meta-analysis studies and the epidemiology studies discussed in IARC (1997), the following can be concluded. Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis. Cancer risk is often more significant in workers exposed to crystalline silica over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours. Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles.

There have been reports of tumours outside of the lungs in persons with high silica exposure; however, these reports are sparse and the data inconsistent and have not been unequivocally linked to exposure to either one of the crystalline forms (quartz or cristobalite). Some of the reported locations are: oesophagus, stomach, liver, skin and bone. Sufficient epidemiological or toxicological data do not currently exist for quantitative assessment of the exposure-response relationship on these other tissues or organs.

Genotoxicity

Potential genotoxicity has been assessed in multiple *in vitro* and *in vivo* assays. Table 1 below gives a brief summary of the positive results observed in each type of assay.

Table 1. Summary of positive results over total number of results for each assay and each category (all studies

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conducted with crystalline silica: quartz, except where indicated).

Assay	Animal data		Human data		Positives/Total	
	In vitro	In vivo	In vitro	In vivo[d]	In vitro	In vivo
Rec Assay	0/1				0/1	
DNA strand break	1/1	2/2	5/5[b]	1/1	6/6	3/3
Sister chromatid exchange	0/1		0/1[c]	1/1	0/2	1/1
Micronucleus	2/3	0/1	2/2[b]	1/1	4/5	1/2
Chromosome aberration	0/1			1/1	0/1	1/1
Aneuploidy/polyploidy	0/3				0/3	
Cell transformation	4/4				4/4	
Hprt mutation	1/2	2/2[a]	1/1[b]		2/3	2/2
Oxidative DNA damage		4/5	2/2		2/2	4/5
DNA binding		1/1				1/1
p53 activation		0/1				0/1

a. one assay conducted with crystalline silica: cristobalite
b. one assay conducted with "ultrafine crystalline silicon dioxide".
c. crystalline silica: tridymite
d. crystalline silica dust (subtypes not provided).

All the *in vivo* human genotoxicity studies are based on three independent studies that used blood samples from workers from diverse occupational settings with confirmed exposures to crystalline silica dust; however, quantification of exposure was not provided. After stratification by smoking status, sister chromatid exchange remained statistically significant in both smokers and non-smokers although the frequency was higher in smokers. For the chromosome aberration assay conducted as part of the same study (blood samples from workers in the stone crusher industry), the increased frequency was no longer significant after stratification. In the DNA damage study of foundry and pottery workers and the micronucleus assay of workers involved in sandblasting and related jobs, results were positive when compared to controls. However, in both studies, smoking status influenced the results, contributing to the increased DNA damage observed since results were greater in smokers versus non-smokers, and the frequency of micronuclei in nasal epithelial cells was higher in smokers (p=0.002) but when using peripheral blood lymphocytes did not differ statistically between smokers and non-smokers who were similarly exposed to silica dust,

The role of *in situ* generation of reactive oxygen species (ROS) and reactive nitrogen species (RNS) has been well established in the following types of DNA damage: small scale insertions, DNA base pair deletion, base modification, chromosomal change/loss, microsatellite instability, DNA strand break, 8-hydroxydeoxyguanosine (8-OHdG) mutation and point mutations. ROS and RNS generation is postulated to be (a part of) the DNA damage mechanism for crystalline silica. Studies are described below to support this hypothesis.

DNA was exposed *in vitro* to various crystalline silica dusts, to H_2O_2, or to both. Results show that DNA damage was limited when dust or H_2O_2 were administered alone but increased with the co-exposure. When the reactive oxygen scavenger, dimethylsulfoxide, was added to the test system, DNA strand break was inhibited, data supporting the viewpoint that it is the presence of radicals generated in response to quartz and cristobalite that causes the DNA damage and not quartz or cristobalite themselves.

Hprt mutation assays in rat alveolar epithelial cells, both *in vitro* and *in vivo,* were positive in response to quartz. The positive results *in vivo* were seen only in the presence of significant inflammatory responses in the treated animals. Also, in a parallel *in vitro* experiment, rat alveolar epithelial cells were incubated with the bronchoalveolar lavage fluid from the rats exposed to quartz. Both macrophage and neutrophil enriched lavage cells induced mutation in the exposed alveolar epithelial cells. Addition of catalase (an enzyme which inactivates H_2O_2) before incubation inhibited the increase in *hprt* mutation.

Rats were exposed to either crystalline or amorphous silica in a manner to induce the same level of

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inflammation in the lungs. The inflammatory response was assessed by measuring the proportion of neutrophils in the bronchiolar lavage fluid. The actual concentrations were 3 and 50 mg/m^3 for crystalline and amorphous silica respectively. The animals were exposed for 13 weeks. *Hprt* mutation frequency was measured in the alveolar epithelial cells at the end of the exposure period. Mutation frequency was greatly increased only in the crystalline silica treated rats; no treatment related increase was found in the rats treated with the amorphous form.

In an 8-OHdG assay conducted to monitor DNA damage by reactive oxygen species, female rats were exposed to 0, 0.3, 1.5 and 7.5 mg/animal of quartz via intratracheal instillation. Effects were observed 90 days post-exposure. A clear dose-response relationship was identified between quartz exposure and various inflammation markers (differential cell count, protein, lung surfactant lipids and tumour necrosis factor alpha). Inflammation was present starting at the lowest dose. However, 8-OHdG showed a statistically significant increase starting at 1.5 mg/animal only. Similarly, in another study, 8-OHdG and DNA strand breaks were observed at concentrations of or above 10 ug/m^3 in rat lung epithelial cells.

In the aim of investigating the role of ROS in lung carcinogenesis, rat lung epithelial cells were incubated with polymorphonuclear (PMN) leukocytes (involved in the inflammatory process and responsible for the release of certain ROS) or hydrogen peroxide. Statistically significant increases in 8-OHdG were observed in the presence of PMN or hydrogen peroxide in a dose-response manner.

In a series of experiments which used *in vitro* stimulation of macrophages with crystalline silica and *in vivo* intranasal instillation of crystalline silica in mice, it was demonstrated that that the chronic fibrosis seen in a murine model of silicosis *in vivo* is dependent on the presence of adaptor molecule ASC and Nalp3 inflammazome. These data support a potential mode of action whereby silica triggers cellular responses that in turn activate alveolar macrophages, resulting in an inflammatory response and silicosis. In mice deficient in Nalp3 inflammazome, the development of inflammation and collagen deposition was significantly reduced compared with normal mice 3 months after the initial intranasal instillation of silica.

Analysis of Lung Tumour Data

The weight of evidence for both rats and humans indicates that fibrotic and silicotic lesions in the lung result from inhalation exposure to crystalline silica and that lung cancer is secondary to those lesions in the lung. Although the mechanism of induction for the lung tumours has not been fully elucidated, there is sufficient supportive mode of action evidence from the data presented to demonstrate that a threshold approach to risk assessment is appropriate based on an understanding of the key events in the pathogenesis of crystalline silica induced lung tumours. The body of evidence include the following:

- In experimental studies, all rats that developed tumours also showed fibrosis.
- Adenocarcinomas, the most common type of tumour identified in rats, are commonly associated with fibrosis and deeply scarred lung tissue.
- Experimental rat studies showed a clear progression of the effects from initially mild inflammation, followed by fibrosis over-time, leading eventually to lung tumours.
- Tumours are not present in all treated species dosed in the same way.
- The tumours, both in rats and humans, are concentrated in the lungs only, although other organs are indirectly exposed.
- In human studies, cancer risk is often more significant in workers exposed over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours.
- Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles
- Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis.
- For genotoxicity, in vitro results were mostly mixed and in vivo results were mostly positive. However, the vast majority of the positive genotoxicity assay results can be explained by the generation of reactive oxygen species, as demonstrated experimentally, where ROS scavenging prevents the genotoxicity.
- *In vivo*, macrophage deficient mice (macrophages produce ROS in response to crystalline silica) do not develop silicosis nor do they develop tumours and the Nalp3 inflammazome, a key player in the macrophage initiated inflammatory response, is required for the development of pulmonary fibrosis after

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inhalation of silica.

- Though inhalation exposure to crystalline silica in multiple occupational settings is clear, the increase in risk, based on the several recent meta-analyses of the multiple human epidemiological studies, remains low.

It is worth noting that where aggressive engineering controls have been made to reduce silica dust levels in the workplace (Sweden), silicosis has been eliminated. By corollary, existing exposures outside of the workplace in such areas do not pose a risk for silicosis to the general population.

The respirable forms of quartz and cristobalite possess properties indicating a hazard for human health (repeated dose toxicity, carcinogenicity and genotoxicity). The mode of action in the lungs involves irritation, inflammation and reactive species formation, leading to silicosis, and eventually to tumour formation.

Exposure

Uses

Consistent with oxygen and silicon being the two most abundant elements in the Earth's crust, silicon-oxide minerals, including quartz are ubiquitous in the natural environment. In particular, as a component of sand, quartz may find use in a diverse array of applications. Several high volume uses include, but are not limited to, the use of sand as a filling material for the construction of roads and in general building activities, the use of sand and gravel aggregates as abrasives on roads in winter and the use of fly-ash, which may contain 4-14% quartz and 0.5-1% cristobalite, as a cement additive. These abrasives when used on winter roads are usually mixed with road salts and may be sand only, stone dust, sand and gravel aggregates, or pre-treated sand. They are used mainly by rural municipalities or in areas where cold temperatures diminish the efficiency of salts for de-icing. Quantities of abrasives used in Canada were 5.73×10^9 kg, 4.59×10^9 kg, and 4.93×10^9 kg for 2007, 2008 and 2009, respectively.

Industrial sand, high purity silica sand products with closely controlled sizing are expected to contain quartz and cristobalite, include lump silica (2-3mm up to 15 cm or more), silica sand (75µm to 2-3mm) and silica flour (less than 75µm). Lump silica may be used in the production of silicon alloys, silica bricks, and the linings of certain types of pulverizers (eg. ball mills and tube mills).

Silica sand may be used in the manufacture of glass and glass fibres, silicate chemicals and silicon carbide, the hydraulic fracturing of wells, foundry moulding, and for sandblasting. Silica flour may find use in the ceramics and cement industries, as a filler and extender in rubber and coatings, and as an abrasive in soaps.

Natural clays, such as bentonite and fuller's earth, are used in cat litters for their high water absorbance capacities. Quartz is a natural component of these clays, and consequently, it may be present in cat litter products. High purity α-quartz is a piezoelectric material, which means that application of a voltage induces a distortion in the crystal shape and vice versa. This ability to interconvert electrical and mechanical energy has led to the use of quartz crystals in electronic devices requiring precise timing control, for example telephones, radios, watches and computers.

According to a survey conducted in Canada, quartz and cristobalite are also used in abrasives, adsorbents, filter products (diatomaceous earth), grout and cement. These substances reportedly also find use as fillers, which add bulk and improve wear resistance, in paints and coatings, adhesives, sealants, polymer films, caulking, epoxy resins and silicones. Also, quartz is listed as an ingredient in 60 cosmetic products in Canada. The types of products include anti-wrinkle preparation, eye and face makeup, lipstick, hair dyes, shampoos and grooming products, as well as skin cleansers, moisturizers and tanning preparations.

Natural Sources

In Canada, quartz naturally occurs in many types of rock formations. Those with high silicon dioxide content (95% SiO_2 or more) include vein and massive intrusion bodies, quartz pebbles, silica sand, sandstone and quartzite. Sandstone is a sedimentary rock mostly composed of quartz grains cemented by a bonding material such as clay, calcite or iron oxide. Quartzite is a hard, compact, metamorphosed sandstone made of grains of quartz firmly bonded with a siliceous cement. Mineral aggregates (e.g., sand and gravel) have variable silicon dioxide content. Quartz is also found as crystals, aggregates or discrete particles in certain igneous rocks (e.g., granites and pegmatites), soils, sediments, air and surface water. This omnipresence is consistent with the fact that silicon is the second most abundant chemical element on Earth.

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Cristobalite is naturally produced in the ashes of volcanic eruptions, and by combustion metamorphism which is a local phenomenon of spontaneous combustion of naturally occurring substances such as bituminous rocks, coal or oil. It may be found in cavities in volcanic rocks and in thermally metamorphosed sandstones and may also be a transient stage in the diagenesis of diatomaceous shale with the result that soils made of these geologic formations may be rich in cristobalite. Unlike quartz, the natural occurrence of cristobalite is limited to specific geographic regions and mineral types.

Anthropogenic Sources

Natural quartz is isolated from ore via beneficiation, which involves milling or grinding the material into particles that are separated into desired mineral and waste. The materials obtained are either used directly or further purified. In Canada, in 2006, 2.146×10^{9} kg of pure quartz were mined, and 2.385×10^{11} kg of sand and gravel aggregates were produced. The proportion of quartz in silica sand deposits and gravel aggregates will vary from one site to another.

Cristobalite can form from silica melts during the preparation of silica glass; quartz is not obtained from melts but is manufactured at elevated temperature and pressure via a hydrothermal process. Cristobalite also forms during the calcination[2] of diatomaceous earth.

Human Exposure Estimate

Ambient air

The exposure assessment is focussed on respirable quartz and cristobalite, which in ambient air comprises a component of total particulate matter (PM). In Canada, data on the concentrations of silicon in PM was available and used as a surrogate for quartz and cristobalite. This approach is conservative because the measured silicon includes all silicon-containing substances and therefore represents the upper limit for quartz and cristobalite in ambient air.

The National Air Pollution Surveillance (NAPS) Program measured concentrations in $\mu g/m^3$ of silicon in PM with aerodynamic radii less than 2.5 µm ($PM_{2.5}$ (dichot)), and from 2.5 to 10 µm (PM_{10} (dichot)) (the total particulate matter with aerodynamic radii less than 10 µm (PM_{10}) is obtained by adding these values) in Canada. In 2009, as part of the NAPS Program, silicon concentrations were determined on over 1600 samples of $PM_{2.5}$(dichot) and over 1500 samples of PM_{10}(dichot) at 24 urban locations across Canada. An estimate of exposure to quartz and cristobalite can be obtained by assuming that all the silicon in the PM is represented stoichiometrically as SiO_2, and multiplying the reported concentration of silicon by 2.14 to obtain a value for silica.

The intake of respirable quartz and cristobalite by the general population of Canada is estimated using a range covering the lowest 50^{th} percentile SiO_2 concentration in PM_{10}, measured in Pt. Petre, ON, (0.12 $\mu g/m^3$) to the highest 50^{th} percentile concentration in PM_{10} measured in Calgary, AB (2.1 $\mu g/m^3$). The 50^{th} percentile SiO_2 concentrations ranged from 0.1 to 2.1 $\mu g/m^3$ across the survey sites; the top of this range is quite close to the average of the maximum values for the 24 sites (3.7 $\mu g/m^3$). The outdoor data were used to represent the indoor levels, because information on indoor silicon concentrations was not available, and the range of PM_{10} measured indoors is generally lower than the outdoor range. Thus, this approach conservatively overestimates indoor exposure in homes.

The highest exposure group based on these calculations is children ages 0.5 to 4 years with an estimated daily intake ranging from 0.07 to 5.26 µg/kg-bw per day; the estimated daily intake decreases with age due to changes in the ratio of inhalation rates to body weights; the daily intake of adults, 20-59 years old, is estimated to range from 0.03 to 2.00 µg/kg-bw per day.

Consumer Products

Exposure to respirable quartz from the use of cosmetic products, which contained quartz as an ingredient, was considered low because they are not formulated for spray application, the loose powders were reported to contain less than 0.1% quartz, and in these products the substance is not expected to be associated with other components of the formulation and not available in a free form.

For consumer Do It Yourself (DIY) activities around the home, the highest mean breathing zone concentration of particles from sanding dry wall (median cut-point of 10µm) of 6.31 mg/m^3, was used to derive an upper-

[2] Calcinations: Heat treating a substance, but without fusion, to bring about change in its physical or chemical constitution.

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bound exposure estimate ranging from 2 to10 µg/kg-bw per event.

Quartz is used to formulate a large number of paints and coatings. To estimate potential inhalation exposure to quartz from these products, the spray painting of wall paints with an airless spray gun was considered appropriate as a conservative scenario. Exposure to respirable paint particles was estimated using data from controlled a laboratory study in which walls of poorly ventilated test rooms were painted by professional painters using an airless sprayer to apply interior latex paint. The maximum concentration of 13% quartz in paint in Canada was used to estimate exposure. The upper-bound estimate of exposure to quartz, based on the maximum concentration of 13% quartz in paint in the Canadian market and the maximum concentration of respirable paint particles measured in these controlled studies when recommended personal protective equipment is used, is 0.954 µg/kg-bw per event.

Inhalation of ambient air containing quartz and cristobalite is the dominant pathway of chronic exposure (excluding that from DIY activities) for the general population. Because SiO_2 makes up only approximately 5% of PM_{10}, silicon concentrations (expressed as SiO_2) measured in the Canadian NAPS survey of 24 urban locations were considered most relevant to the estimation of exposure by the general population. Quartz and cristobalite comprise only a portion of the total SiO_2 in PM_{10}, therefore, the use of the total silicon concentration to represent the upper bound crystalline silica concentrations results in an overestimation of exposure.

Appendix 1: Definitions of Epidemiological Terms in the ITAP

SMR (Standardized Mortality Ratio): The ratio (x 100) of observed to expected deaths in a study population. Expected deaths are calculated by applying a set of standard age-specific mortality rates to the age distribution of the study population. Standardized ratios are only useful for comparisons. They have no intrinsic meaning.

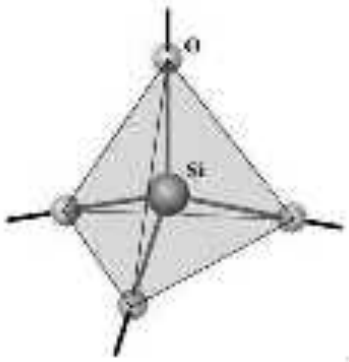
OR (Odds Ratio): In epidemiological case-control studies, a relative measure of disease occurrence. The odds in favour of a particular disease occurring in an exposed group are divided by the odds in favour of its occurring in an unexposed group. If the condition being studied is rare, the odds ratio is a close approximation to the relative risk.

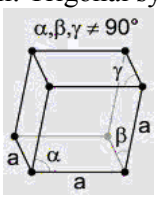
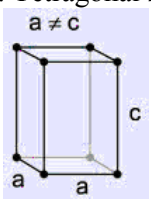
RR (Risk Ratio): The probability of the occurrence of a disease in a group that has been exposed to some environmental, medicinal, microbial, or toxic influence, relative to its probability in a randomly selected population.

PMR (Proportionate Mortality Ratio): Proportionate mortality is the proportion of deaths in a specified population over a period of time attributable to different causes. Each cause is expressed as a percentage of all deaths, and the sum of the causes must add to 100%. These proportions are not mortality rates, since the denominator is all deaths, not the population in which the deaths occurred. Thus, proportionate mortality ratio is a measure of the frequency of occurrence of the proportionate mortality in a defined population during a specified interval of time.

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INITIAL TARGETED ASSESSMENT PROFILE (Human Health)

CAS No.	Quartz: CAS RN 14808-60-7 Cristobalite: CAS RN 14464-46-1
Chemical Name	Quartz and Cristobalite
Structural Formula	Molecular Formula: SiO_2 

Unit Cell: Trigonal symmetry	Unit Cell: Tetragonal symmetry
	
Quartz: CAS RN 14808-60-7	Cristobalite: CAS RN 14464-46-1

SUMMARY CONCLUSIONS OF THE TARGETED ASSESSMENT

NOTE: The present assessment is targeted to address the following human health endpoints: repeated dose toxicity and carcinogenicity via the inhalation route of exposure, and genotoxicity. It cannot be considered as a full SIDS Initial Assessment. Summary information on exposure is also reported here. Other endpoints for human health and the environment included in the Canadian screening assessment but have not been presented to OECD member countries, and thus are not included in this profile.

The final screening assessment will be published under the responsibility of the Government of Canada.

Rationale for Targeting the Assessment

The Government of Canada "categorized" or prioritized all 23,000 chemical substances on its Domestic Substances List (DSL) from 1999 to September 2006, as required by its *Canadian Environmental Protection Act, 1999* (CEPA 1999). Additional details may be found at http://www.chemicalsubstanceschimiques.gc.ca/about-apropos/categor/index-eng.php. Using information from Canadian industry, academic research and other countries, Government of Canada scientists applied a set of rigorous tools to the 23,000 chemical substances on the DSL. They were categorized to identify those that were: **inherently toxic** to humans or to the environment and that might be **persistent** and/or **bioaccumulative**; and substances to which people might have **greatest potential for exposure**. During this priority-setting exercise, distinct approaches were taken for identifying substances of likely concern for human health and the environment, and subsequent assessment activities may have focused on either human health or ecological endpoints. Through categorization, the Government of Canada has identified approximately 4,000 of the 23,000

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chemical substances on the DSL as priorities for further assessment, research and/or measures to control their use or release. Quartz and cristobalite were identified at that time, applying the categorization criteria, as high priorities for human health risk because they were considered to pose greatest potential for exposure and their respirable forms are classified by the International Agency for Research on Cancer as carcinogenic to humans (quartz and cristobalite) and by the National Toxicology Program as known human carcinogens (crystalline silica). These substances did not meet the ecological categorization criteria for bioaccumulation potential or inherent toxicity to aquatic organisms.

Under the Canadian legislation a determination of whether one or more of the criteria of the CANADIAN ENVIRONMENTAL PROTECTION ACT (CEPA) 1999, section 64 are met is based upon an assessment of potential risks to the environment and/or to human health associated with exposures in the general environment. For humans, this includes, but is not limited to, exposures from ambient and indoor air, drinking water, foodstuffs, and the use of consumer products. A conclusion under CEPA 1999 on the substances in the Chemicals Management Plan (CMP) Challenge is not relevant to, nor does it preclude, an assessment against the hazard criteria specified in the Controlled Products Regulations, which is part of the regulatory framework for the Workplace Hazardous Materials Information System [WHMIS] for products intended for workplace use.

Physical-chemical properties

The silicon dioxide group represents a polymorphic category containing a large number of forms identical in composition but with different atomic arrangements which afford different chemical properties. There are two sub-categories within this group: crystalline silica, to which the present substances quartz and cristobalite belong, and non-crystalline or amorphous silica. The key distinction between these sub-categories is that in crystalline substances, the building blocks are arranged in regular, repeating 3-dimensional pattern having long range order, whereas amorphous materials do not display long range order. In all forms of silica, (crystalline and non-crystalline), the silicon atom is tetrahedral and bound to four neighbouring oxygen atoms.

Quartz and cristobalite are solid at room temperature, existing normally as colourless or white crystals. The melting points for quartz and cristobalite are 1400-2000 ^{o}C and 1713-1728 ^{o}C, respectively and for both compounds, the boiling point is 2230^{o}C. Even though no experimental data were available, their vapour pressure and Henry's Law constant are likely negligible. Log K_{ow} (octanol-water partition coefficient) and log K_{oc} (organic carbon-water partition coefficient) are not applicable to these substances. The densities range from 2500-2700 kg/m^3 for quartz and 2300-2380 kg/m^3 for cristobalite.

The very similar physico-chemical properties of quartz and cristobalite reflect their closely related crystal forms. The solubility of crystalline silicates decreases as a function of silica tetrahedral packing density and long-range crystal order. For example, cristobalite has a more open framework structure than quartz and its density is lower, therefore, its solubility is higher. The water solubility of these minerals is also function of temperature, pH, particle size, and the presence of a disrupted surface layer. This may explain the variability of solubility values reported by many authors. The most probable solubility value for quartz is approximately 3.8 mg Si/L, or 6.4 mg/L expressed as the SiO_2 species, while the solubility of cristobalite is approximately 8.7 mg Si/L, or 18 mg SiO_2/L. The kinetics of dissolution of these substances is slow due to the high activation energy required to hydrolyse the Si-O-Si bond.

Human Health Targeted Endpoints

The majority of the studies described here have been reviewed by the International Agency for Research on Cancer (IARC 1997). However, additional data relevant to the screening assessment were identified up to August 2010.

Repeated dose toxicity/non-neoplastic effects (development of silicosis).

Studies on animals

Significant short-term and subchronic studies have demonstrated adverse effects in the lungs, while one of the 6 studies showed effects on the spleen in mice. Rats were exposed to 0, 10 or 100 mg/m^3 of cristobalite via inhalation for 6 hours/day during 3 days. Animals were observed 3 months after exposure. Elevated levels of granulocytes and elevated markers of cytotoxicity from the lung lavage fluid were noted in all exposed groups. Another study of similar duration (9 days) conducted in mice also identified a LOAEC of 10 mg/m^3. Effects observed included minimal interstitial thickening, accumulations of mononuclear cells and slight lymphoid tissue hypertrophy in the lungs.

In a 4-week inhalation study, female rats were exposed to 0, 0.1, 1 or 10 mg/m^3 of quartz 6 hours/day, 5 days/week. Bronchoalveolar lavage fluid was evaluated at 1, 8, and 24 weeks after exposure. Elevated levels of

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granulocytes and significant elevation of markers of cytotoxicity (Lactate dehydrogenase [LDH] and β-glucuronidase [β-glu]) were observed at 1 mg/m^3 and higher. The increased levels of LDH and β-glu were only significant at 24 weeks after exposure. A LOAEC of 1 mg/m^3 was identified at 24 weeks.

Male rats (4 animals per dose) were exposed to 0 or 3 mg/m^3 of cristobalite via inhalation for 6 hours/day, 5 days/week during 13 weeks. Pulmonary inflammation and fibrosis were observed in the exposed group at the end of treatment. When mice were similarly exposed to 5 mg/m^3 of quartz for 6 hours/day, 5 days/week for 15 or 27 weeks, the authors observed increased spleen weight and formation of plaque in the spleen.

In two separate studies, in which rats or hamsters were exposed to quartz via inhalation for at least 6 months, LOAECs of 2 and 3 mg/m^3 were identified, respectively. All the effects observed were related to inflammation and fibrosis of the lung tissue.

Several chronic studies investigated exposure of the respirable forms (i.e. accumulated via inhalation in the lung tissues) of quartz and cristobalite to rats, mice and hamsters. The following is a description of the study in which the lowest non-neoplastic LOAEC was determined. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz, containing 74% of respirable quartz, through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. The mean mass of particle at the end of the exposure period was 0.91 mg/lung. The LOAEC identified was 0.74 mg/m^3 (adjusted for 74% respirable quartz) based on lipoproteinosis, multifocal, inflammatory cell infiltrate and alveolar hyperplasia.

Human epidemiology data

In humans, the lowest observed adverse effect level was identified in a U.S. cohort study. The study was conducted on 3330 gold miners (all are males), who had an average of 9 years underground exposure during the period 1940 to 1965. The cohort was followed up through 1990. Silicosis[1] was identified through death certificates or chest X-rays. A job-exposure matrix together with work history was used to estimate individual exposure. The total silica content in the respirable dust in the mine was estimated at 13% and the median crystalline silica exposure was 0.05 mg/m^3. In this sub population of miners, 170 cases of silicosis were identified. The best predictor for risk of silicosis was cumulative exposure, which varied from less than 1% for a 0.5 mg/m^3-year exposure to 68-84% when exposed to more than 4 mg/m^3-year (based on the average daily dust exposure during the workday each year and summed over time for each miner). The main limitations identified by the authors include the limited number of radiographic surveys, the potential bias from death certificates

[1] Silicosis: Lung disease caused by inhalation of crystalline silica dust, and resulting in inflammation and scarring in forms of nodular lesions in the upper lobes of the lungs. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics). It does not follow that a history of exposure to silica necessarily results in silicosis (Nonsilicotics). The typical "Silicotic" lung nodule is shown in Figure 1.

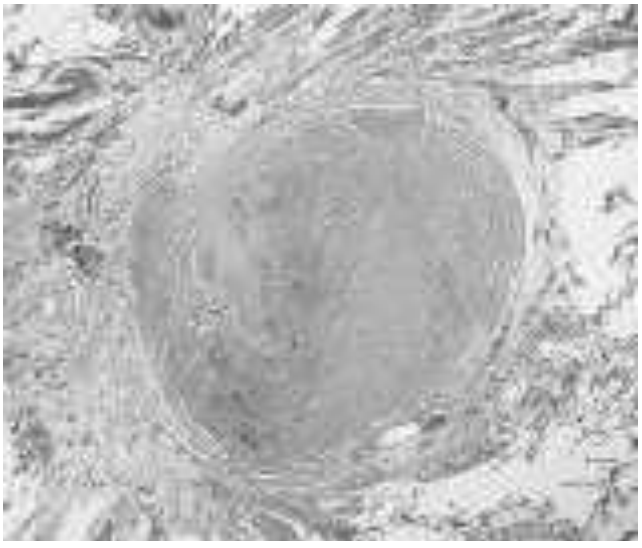


Figure 1. Silicotic nodule characterised by a central zone of hyalinised collagen with a whorled appearance and peripheral dust-containing macrophages (Rees and Murray, 2007).

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(relying on death certificates instead of relying on repeated x-rays, which were lacking for each miner, may have underestimated the number of cases) and the fact that the conversion of dust counts to

gravimetric measurements may not be accurate based on the estimation of 13% silica content in the respirable dust (although based on a relatively large number of samples (n = 82) collected in two different surveys, there was broad range of content in these samples (1% to 48%, SD = 9), and the percentage of respirable quartz may have differed in earlier years, but data were lacking for these years).

Two other human studies have identified similar LOAECs based on the critical endpoint of radiographic confirmed silicosis. A LOAEC of 0.053 mg/m^3 (mean exposure) was identified in a cross sectional study of South African gold miners and a LOAEC of 0.064 mg/m^3 (mean exposure) was derived in a mining community population-based random sample survey in Colorado.

Carcinogenicity studies

Studies on animals

Experimental studies conducted in rats have shown clear and consistent increases in lung tumours after chronic inhalation exposure. In the nine rat studies identified, five were inhalation studies and four were intratracheal instillation studies. All studies except one inhalation study showed increased incidence of lung tumours. For the inhalation studies with treatment related tumours, concentrations ranged from 1 to 50 mg/m^3 (1, 6, and 30 mg/m^3 of DQ-12 quartz; 12 and 50 mg/m^3 of Min-U-Sil 5 quartz) and duration of exposure ranged from 29 days to 2 years. In the inhalation study with no treatment-related tumours, exposure was 60 mg/m^3 of Sikron F300 quartz for 13 weeks. The following is a description of the neoplastic results in the study also identified as the critical study for non-neoplastic results. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. In the exposed group, 18 animals developed tumours (12 in females, 5 in males), as opposed to 3 and 2 for the control and positive control groups respectively. The majority (10/18) of the tumours observed were adenocarcinomas. The mean mass of particles in the lungs at the end of the exposure period was 0.91 mg/lung.

For the intratracheal instillation studies, doses ranged from 4 to 57 mg/kg-bw (based on 7, 12 or 20 mg/animal of Min-U-Sil (5) quartz or 20 mg/animal of novaculite quartz). Exposure regimes were diverse and included single instillation with observation for up to two years, to weekly instillation for 10 weeks. It is noteworthy that the single intratracheal administration of a 95% pure quartz particles (<5 μm) resulted in an increased incidence of silicotic granulomas after 3 weeks and lung tumours after 11 months. The most common tumours reported across the long term rat studies were adenocarcinomas, however other tumours such as squamous-cell carcinoma, alveolar carcinoma and bronchiole-alveolar adenoma were also reported, and all animals that developed tumours also showed some degree of fibrosis.

Of particular interest is the intratracheal instillation study, investigating the sequence of pathological events leading to lung tumors. An unspecified number of rats/sex/dose received a single intratracheal instillation of various crystalline silica dusts or ferric oxide, allowing direct administration into the bronchial tree. The doses were 12 or 20 mg of Min-U-Sil 5 quartz (MQZ), 12 mg of hydrofluoric-acid-etched Min-U-Sil 5 quartz (HFMQZ), 12 mg of cristobalite, 12 mg of tridymite and 12 mg of ferric oxide suspended in saline. All groups were observed until six months post exposure, except for both MQZ groups, the HFMQZ and the ferric oxide group which were observed up until 17 months post-exposure. Interim sacrifices were conducted at 6, 11 and 17 months. The rat lungs showed a clear progression of effects. The sequence of pathological events were, an initial inflammatory response leading to a marked hyperplasia and hypertrophy of alveolar cells after one month, and at six months hyperplasia was evident but no lung tumours were observed. In this study, lung tumours were observed starting at the 11 month sacrifice with a 17% and 42% incidence in males and females (based on 3/18 males and 8/19 females), respectively, and at 17 months incidences were 32% and 59% (based on 6/19 males and 10/17 females, respectively). No lung tumours were found in ferric oxide treated rats. Similar studies have also been conducted in hamsters and mice. Although treated mice and hamsters showed treatment related signs (inflammation or fibrosis), no tumours were observed in hamsters. No increase in the incidence of lung tumours was seen in mice treated with quartz; however silicotic granulomas and lymphoid cuffing around airways but no fibrosis were seen in the lungs of quartz-treated mice.

Human epidemiology data

There is an extensive dataset of human studies investigating the link between crystalline silica exposure and cancer. IARC (1997) identified over 50 epidemiological studies based on occupational exposure to dust containing respirable crystalline silica. Main industry sectors from which the human data is derived include gold mines, foundries, granite/stone industry, pottery workers and refractory brick workers. From the least confounded studies, it was noted that lung cancer tended to increase with the following parameters: cumulative

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exposure; duration of exposure; peak intensity of exposure; presence of radiographically defined silicosis; and length of follow-up time from date of silicosis diagnostic. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics).

Since the 1997 IARC report, a large number of epidemiological studies have been published, with the more recent studies being updates from supplementary follow-up of results from previously assessed case-control studies cohorts, new results based on refined exposure assessments or adjustment for confounders or meta-analyses of the pooled data from these epidemiology studies

In a meta-analysis of the data from 10 cohort studies of gold, tin and tungsten miners, granite workers, industrial sand, diatomaceous earth and pottery workers with quantitative exposure estimates for crystalline silica were pooled in order to analyse the risk related to lung cancer. The pooled cohort standardized mortality ratio (SMR, against national rates) [See Appendix 1 for definition] was 1.2 (Confidence Interval [CI] 1.1-1.3). The results from the case-control analyses show a statistically significant trend with duration of exposure (odds ratios (ORs) [See Appendix 1] by quintile of cumulative exposure increased from 1.0 to 1.6 [CIs of 0.85 to 2.1] and by quintile of average concentration increased from 1.0 to 1.7 [CIs of 1.1 to 2.3]), supporting the importance of the increasing lung burden of silica in the occurrence of cancer. Overall, the authors concluded that the results support the carcinogenicity conclusion presented by IARC (1997).

To investigate the link between crystalline silica, silicosis and lung cancer, epidemiological data published between 1966 and 2001 were gathered. Over 50 studies were selected and pooled according to type of study and the parameter being linked to lung cancer (i.e. silica exposure, presence of silicosis in subjects). The quality of study, adjustment for confounding factors, co-exposure to other carcinogens and availability of a more recent analysis of a same cohort were taken into consideration in the final selection of the studies. Analysis of the relationship between exposure to silica and lung cancer included 17 cohort and 13 case-control studies. For the analysis of lung cancer versus silicosis, 11 cohort and 5 case-control studies were selected. The third analysis included 6 cohort and 2 case-control studies to evaluate the risk of lung cancer in non-silicotics. A random effect model was used to conduct each meta-analysis. Pooled cancer risk ratios (RRs) were 1.32 (CI 1.23-1.41) for crystalline silica exposure, 2.37 (CI 1.98-2.84) for individuals exposed to silica with confirmed silicosis (Silicotics) and 0.96 (CI 0.81-1.15) for individuals with no evidence of silicosis (non-silicotics) with confirmed exposure to silica, supporting the general observation that silicosis has a stronger temporal relationship with crystalline silica exposure and furthermore support the view that a human silicotic response could be a preliminary stage in the development of cancer.

A more recent meta-analysis included 28 cohort, 15 case-control and two proportionate mortality ratio (PMR) [See Appendix 1] studies from a variety of occupational settings conducted between 1996 and 2005. Risk ratios (RRs) were calculated based on type of study and silicosis status using fixed and random effect models (results presented here are from the random model). RRs for all cohort studies was 1.34 (CI 1.25-1.45), and were 1.69 (CI 1.32-2.16) for silicotics, 1.25 (CI 1.18-1.33) for those with undefined silicosis status and 1.19 (CI 0.87-1.57) for non-silicotics. In the case-control studies, the general RR was 1.41 (CI1.18-1.67), and the same sub-groups as mentioned above resulted in RRs of 3.27 (CI 1.32-8.2), 1.41 (CI1.18-1.70) and 0.97 (CI 0.68-1.38), respectively. The proportionate mortality ratio for the last two studies was 1.24 (CI 1.05-1.47). The authors noted that the association between lung cancer and exposure to crystalline silica was more consistent for silicotics, i.e., those diagnosed with silicosis and RR values split into type of occupational settings in which participants worked.

Based upon the above three meta-analysis studies and the epidemiology studies discussed in IARC (1997), the following can be concluded. Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis. Cancer risk is often more significant in workers exposed to crystalline silica over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours. Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles.

There have been reports of tumours outside of the lungs in persons with high silica exposure; however, these reports are sparse and the data inconsistent and have not been unequivocally linked to exposure to either one of the crystalline forms (quartz or cristobalite). Some of the reported locations are: oesophagus, stomach, liver, skin and bone. Sufficient epidemiological or toxicological data do not currently exist for quantitative assessment of the exposure-response relationship on these other tissues or organs.

Genotoxicity

Potential genotoxicity has been assessed in multiple *in vitro* and *in vivo* assays. Table 1 below gives a brief summary of the positive results observed in each type of assay.

Table 1. Summary of positive results over total number of results for each assay and each category (all studies

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conducted with crystalline silica: quartz, except where indicated).

Assay	Animal data		Human data		Positives/Total	
	In vitro	In vivo	In vitro	In vivo[d]	In vitro	In vivo
Rec Assay	0/1				0/1	
DNA strand break	1/1	2/2	5/5[b]	1/1	6/6	3/3
Sister chromatid exchange	0/1		0/1[c]	1/1	0/2	1/1
Micronucleus	2/3	0/1	2/2[b]	1/1	4/5	1/2
Chromosome aberration	0/1			1/1	0/1	1/1
Aneuploidy/polyploidy	0/3				0/3	
Cell transformation	4/4				4/4	
Hprt mutation	1/2	2/2[a]	1/1[b]		2/3	2/2
Oxidative DNA damage		4/5	2/2		2/2	4/5
DNA binding		1/1				1/1
p53 activation		0/1				0/1

a. one assay conducted with crystalline silica: cristobalite
b. one assay conducted with "ultrafine crystalline silicon dioxide".
c. crystalline silica: tridymite
d. crystalline silica dust (subtypes not provided).

All the *in vivo* human genotoxicity studies are based on three independent studies that used blood samples from workers from diverse occupational settings with confirmed exposures to crystalline silica dust; however, quantification of exposure was not provided. After stratification by smoking status, sister chromatid exchange remained statistically significant in both smokers and non-smokers although the frequency was higher in smokers. For the chromosome aberration assay conducted as part of the same study (blood samples from workers in the stone crusher industry), the increased frequency was no longer significant after stratification. In the DNA damage study of foundry and pottery workers and the micronucleus assay of workers involved in sandblasting and related jobs, results were positive when compared to controls. However, in both studies, smoking status influenced the results, contributing to the increased DNA damage observed since results were greater in smokers versus non-smokers, and the frequency of micronuclei in nasal epithelial cells was higher in smokers (p=0.002) but when using peripheral blood lymphocytes did not differ statistically between smokers and non-smokers who were similarly exposed to silica dust,

The role of *in situ* generation of reactive oxygen species (ROS) and reactive nitrogen species (RNS) has been well established in the following types of DNA damage: small scale insertions, DNA base pair deletion, base modification, chromosomal change/loss, microsatellite instability, DNA strand break, 8-hydroxydeoxyguanosine (8-OHdG) mutation and point mutations. ROS and RNS generation is postulated to be (a part of) the DNA damage mechanism for crystalline silica. Studies are described below to support this hypothesis.

DNA was exposed *in vitro* to various crystalline silica dusts, to H_2O_2, or to both. Results show that DNA damage was limited when dust or H_2O_2 were administered alone but increased with the co-exposure. When the reactive oxygen scavenger, dimethylsulfoxide, was added to the test system, DNA strand break was inhibited, data supporting the viewpoint that it is the presence of radicals generated in response to quartz and cristobalite that causes the DNA damage and not quartz or cristobalite themselves.

Hprt mutation assays in rat alveolar epithelial cells, both *in vitro* and *in vivo,* were positive in response to quartz. The positive results *in vivo* were seen only in the presence of significant inflammatory responses in the treated animals. Also, in a parallel *in vitro* experiment, rat alveolar epithelial cells were incubated with the bronchoalveolar lavage fluid from the rats exposed to quartz. Both macrophage and neutrophil enriched lavage cells induced mutation in the exposed alveolar epithelial cells. Addition of catalase (an enzyme which inactivates H_2O_2) before incubation inhibited the increase in *hprt* mutation.

Rats were exposed to either crystalline or amorphous silica in a manner to induce the same level of

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inflammation in the lungs. The inflammatory response was assessed by measuring the proportion of neutrophils in the bronchiolar lavage fluid. The actual concentrations were 3 and 50 mg/m^3 for crystalline and amorphous silica respectively. The animals were exposed for 13 weeks. *Hprt* mutation frequency was measured in the alveolar epithelial cells at the end of the exposure period. Mutation frequency was greatly increased only in the crystalline silica treated rats; no treatment related increase was found in the rats treated with the amorphous form.

In an 8-OHdG assay conducted to monitor DNA damage by reactive oxygen species, female rats were exposed to 0, 0.3, 1.5 and 7.5 mg/animal of quartz via intratracheal instillation. Effects were observed 90 days post-exposure. A clear dose-response relationship was identified between quartz exposure and various inflammation markers (differential cell count, protein, lung surfactant lipids and tumour necrosis factor alpha). Inflammation was present starting at the lowest dose. However, 8-OHdG showed a statistically significant increase starting at 1.5 mg/animal only. Similarly, in another study, 8-OHdG and DNA strand breaks were observed at concentrations of or above 10 ug/m^3 in rat lung epithelial cells.

In the aim of investigating the role of ROS in lung carcinogenesis, rat lung epithelial cells were incubated with polymorphonuclear (PMN) leukocytes (involved in the inflammatory process and responsible for the release of certain ROS) or hydrogen peroxide. Statistically significant increases in 8-OHdG were observed in the presence of PMN or hydrogen peroxide in a dose-response manner.

In a series of experiments which used *in vitro* stimulation of macrophages with crystalline silica and *in vivo* intranasal instillation of crystalline silica in mice, it was demonstrated that that the chronic fibrosis seen in a murine model of silicosis *in vivo* is dependent on the presence of adaptor molecule ASC and Nalp3 inflammazome. These data support a potential mode of action whereby silica triggers cellular responses that in turn activate alveolar macrophages, resulting in an inflammatory response and silicosis. In mice deficient in Nalp3 inflammazome, the development of inflammation and collagen deposition was significantly reduced compared with normal mice 3 months after the initial intranasal instillation of silica.

Analysis of Lung Tumour Data

The weight of evidence for both rats and humans indicates that fibrotic and silicotic lesions in the lung result from inhalation exposure to crystalline silica and that lung cancer is secondary to those lesions in the lung. Although the mechanism of induction for the lung tumours has not been fully elucidated, there is sufficient supportive mode of action evidence from the data presented to demonstrate that a threshold approach to risk assessment is appropriate based on an understanding of the key events in the pathogenesis of crystalline silica induced lung tumours. The body of evidence include the following:

- In experimental studies, all rats that developed tumours also showed fibrosis.
- Adenocarcinomas, the most common type of tumour identified in rats, are commonly associated with fibrosis and deeply scarred lung tissue.
- Experimental rat studies showed a clear progression of the effects from initially mild inflammation, followed by fibrosis over-time, leading eventually to lung tumours.
- Tumours are not present in all treated species dosed in the same way.
- The tumours, both in rats and humans, are concentrated in the lungs only, although other organs are indirectly exposed.
- In human studies, cancer risk is often more significant in workers exposed over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours.
- Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles
- Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis.
- For genotoxicity, in vitro results were mostly mixed and in vivo results were mostly positive. However, the vast majority of the positive genotoxicity assay results can be explained by the generation of reactive oxygen species, as demonstrated experimentally, where ROS scavenging prevents the genotoxicity.
- *In vivo*, macrophage deficient mice (macrophages produce ROS in response to crystalline silica) do not develop silicosis nor do they develop tumours and the Nalp3 inflammazome, a key player in the macrophage initiated inflammatory response, is required for the development of pulmonary fibrosis after

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inhalation of silica.

- Though inhalation exposure to crystalline silica in multiple occupational settings is clear, the increase in risk, based on the several recent meta-analyses of the multiple human epidemiological studies, remains low.

It is worth noting that where aggressive engineering controls have been made to reduce silica dust levels in the workplace (Sweden), silicosis has been eliminated. By corollary, existing exposures outside of the workplace in such areas do not pose a risk for silicosis to the general population.

The respirable forms of quartz and cristobalite possess properties indicating a hazard for human health (repeated dose toxicity, carcinogenicity and genotoxicity). The mode of action in the lungs involves irritation, inflammation and reactive species formation, leading to silicosis, and eventually to tumour formation.

Exposure

Uses

Consistent with oxygen and silicon being the two most abundant elements in the Earth's crust, silicon-oxide minerals, including quartz are ubiquitous in the natural environment. In particular, as a component of sand, quartz may find use in a diverse array of applications. Several high volume uses include, but are not limited to, the use of sand as a filling material for the construction of roads and in general building activities, the use of sand and gravel aggregates as abrasives on roads in winter and the use of fly-ash, which may contain 4-14% quartz and 0.5-1% cristobalite, as a cement additive. These abrasives when used on winter roads are usually mixed with road salts and may be sand only, stone dust, sand and gravel aggregates, or pre-treated sand. They are used mainly by rural municipalities or in areas where cold temperatures diminish the efficiency of salts for de-icing. Quantities of abrasives used in Canada were 5.73×10^9 kg, 4.59×10^9 kg, and 4.93×10^9 kg for 2007, 2008 and 2009, respectively.

Industrial sand, high purity silica sand products with closely controlled sizing are expected to contain quartz and cristobalite, include lump silica (2-3mm up to 15 cm or more), silica sand (75µm to 2-3mm) and silica flour (less than 75µm). Lump silica may be used in the production of silicon alloys, silica bricks, and the linings of certain types of pulverizers (eg. ball mills and tube mills).

Silica sand may be used in the manufacture of glass and glass fibres, silicate chemicals and silicon carbide, the hydraulic fracturing of wells, foundry moulding, and for sandblasting. Silica flour may find use in the ceramics and cement industries, as a filler and extender in rubber and coatings, and as an abrasive in soaps.

Natural clays, such as bentonite and fuller's earth, are used in cat litters for their high water absorbance capacities. Quartz is a natural component of these clays, and consequently, it may be present in cat litter products. High purity α-quartz is a piezoelectric material, which means that application of a voltage induces a distortion in the crystal shape and vice versa. This ability to interconvert electrical and mechanical energy has led to the use of quartz crystals in electronic devices requiring precise timing control, for example telephones, radios, watches and computers.

According to a survey conducted in Canada, quartz and cristobalite are also used in abrasives, adsorbents, filter products (diatomaceous earth), grout and cement. These substances reportedly also find use as fillers, which add bulk and improve wear resistance, in paints and coatings, adhesives, sealants, polymer films, caulking, epoxy resins and silicones. Also, quartz is listed as an ingredient in 60 cosmetic products in Canada. The types of products include anti-wrinkle preparation, eye and face makeup, lipstick, hair dyes, shampoos and grooming products, as well as skin cleansers, moisturizers and tanning preparations.

Natural Sources

In Canada, quartz naturally occurs in many types of rock formations. Those with high silicon dioxide content (95% SiO_2 or more) include vein and massive intrusion bodies, quartz pebbles, silica sand, sandstone and quartzite. Sandstone is a sedimentary rock mostly composed of quartz grains cemented by a bonding material such as clay, calcite or iron oxide. Quartzite is a hard, compact, metamorphosed sandstone made of grains of quartz firmly bonded with a siliceous cement. Mineral aggregates (e.g., sand and gravel) have variable silicon dioxide content. Quartz is also found as crystals, aggregates or discrete particles in certain igneous rocks (e.g., granites and pegmatites), soils, sediments, air and surface water. This omnipresence is consistent with the fact that silicon is the second most abundant chemical element on Earth.

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Cristobalite is naturally produced in the ashes of volcanic eruptions, and by combustion metamorphism which is a local phenomenon of spontaneous combustion of naturally occurring substances such as bituminous rocks, coal or oil. It may be found in cavities in volcanic rocks and in thermally metamorphosed sandstones and may also be a transient stage in the diagenesis of diatomaceous shale with the result that soils made of these geologic formations may be rich in cristobalite. Unlike quartz, the natural occurrence of cristobalite is limited to specific geographic regions and mineral types.

Anthropogenic Sources

Natural quartz is isolated from ore via beneficiation, which involves milling or grinding the material into particles that are separated into desired mineral and waste. The materials obtained are either used directly or further purified. In Canada, in 2006, 2.146×10^{9} kg of pure quartz were mined, and 2.385×10^{11} kg of sand and gravel aggregates were produced. The proportion of quartz in silica sand deposits and gravel aggregates will vary from one site to another.

Cristobalite can form from silica melts during the preparation of silica glass; quartz is not obtained from melts but is manufactured at elevated temperature and pressure via a hydrothermal process. Cristobalite also forms during the calcination[2] of diatomaceous earth.

Human Exposure Estimate

Ambient air

The exposure assessment is focussed on respirable quartz and cristobalite, which in ambient air comprises a component of total particulate matter (PM). In Canada, data on the concentrations of silicon in PM was available and used as a surrogate for quartz and cristobalite. This approach is conservative because the measured silicon includes all silicon-containing substances and therefore represents the upper limit for quartz and cristobalite in ambient air.

The National Air Pollution Surveillance (NAPS) Program measured concentrations in $\mu g/m^3$ of silicon in PM with aerodynamic radii less than 2.5 µm ($PM_{2.5}$ (dichot)), and from 2.5 to 10 µm (PM_{10} (dichot)) (the total particulate matter with aerodynamic radii less than 10 µm (PM_{10}) is obtained by adding these values) in Canada. In 2009, as part of the NAPS Program, silicon concentrations were determined on over 1600 samples of $PM_{2.5}$(dichot) and over 1500 samples of PM_{10}(dichot) at 24 urban locations across Canada. An estimate of exposure to quartz and cristobalite can be obtained by assuming that all the silicon in the PM is represented stoichiometrically as SiO_2, and multiplying the reported concentration of silicon by 2.14 to obtain a value for silica.

The intake of respirable quartz and cristobalite by the general population of Canada is estimated using a range covering the lowest 50^{th} percentile SiO_2 concentration in PM_{10}, measured in Pt. Petre, ON, (0.12 $\mu g/m^3$) to the highest 50^{th} percentile concentration in PM_{10} measured in Calgary, AB (2.1 $\mu g/m^3$). The 50^{th} percentile SiO_2 concentrations ranged from 0.1 to 2.1 $\mu g/m^3$ across the survey sites; the top of this range is quite close to the average of the maximum values for the 24 sites (3.7 $\mu g/m^3$). The outdoor data were used to represent the indoor levels, because information on indoor silicon concentrations was not available, and the range of PM_{10} measured indoors is generally lower than the outdoor range. Thus, this approach conservatively overestimates indoor exposure in homes.

The highest exposure group based on these calculations is children ages 0.5 to 4 years with an estimated daily intake ranging from 0.07 to 5.26 µg/kg-bw per day; the estimated daily intake decreases with age due to changes in the ratio of inhalation rates to body weights; the daily intake of adults, 20-59 years old, is estimated to range from 0.03 to 2.00 µg/kg-bw per day.

Consumer Products

Exposure to respirable quartz from the use of cosmetic products, which contained quartz as an ingredient, was considered low because they are not formulated for spray application, the loose powders were reported to contain less than 0.1% quartz, and in these products the substance is not expected to be associated with other components of the formulation and not available in a free form.

For consumer Do It Yourself (DIY) activities around the home, the highest mean breathing zone concentration of particles from sanding dry wall (median cut-point of 10µm) of 6.31 mg/m^3, was used to derive an upper-

[2] Calcinations: Heat treating a substance, but without fusion, to bring about change in its physical or chemical constitution.

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bound exposure estimate ranging from 2 to10 µg/kg-bw per event.

Quartz is used to formulate a large number of paints and coatings. To estimate potential inhalation exposure to quartz from these products, the spray painting of wall paints with an airless spray gun was considered appropriate as a conservative scenario. Exposure to respirable paint particles was estimated using data from controlled a laboratory study in which walls of poorly ventilated test rooms were painted by professional painters using an airless sprayer to apply interior latex paint. The maximum concentration of 13% quartz in paint in Canada was used to estimate exposure. The upper-bound estimate of exposure to quartz, based on the maximum concentration of 13% quartz in paint in the Canadian market and the maximum concentration of respirable paint particles measured in these controlled studies when recommended personal protective equipment is used, is 0.954 µg/kg-bw per event.

Inhalation of ambient air containing quartz and cristobalite is the dominant pathway of chronic exposure (excluding that from DIY activities) for the general population. Because SiO_2 makes up only approximately 5% of PM_{10}, silicon concentrations (expressed as SiO_2) measured in the Canadian NAPS survey of 24 urban locations were considered most relevant to the estimation of exposure by the general population. Quartz and cristobalite comprise only a portion of the total SiO_2 in PM_{10}, therefore, the use of the total silicon concentration to represent the upper bound crystalline silica concentrations results in an overestimation of exposure.

Appendix 1: Definitions of Epidemiological Terms in the ITAP

SMR (Standardized Mortality Ratio): The ratio (x 100) of observed to expected deaths in a study population. Expected deaths are calculated by applying a set of standard age-specific mortality rates to the age distribution of the study population. Standardized ratios are only useful for comparisons. They have no intrinsic meaning.

OR (Odds Ratio): In epidemiological case-control studies, a relative measure of disease occurrence. The odds in favour of a particular disease occurring in an exposed group are divided by the odds in favour of its occurring in an unexposed group. If the condition being studied is rare, the odds ratio is a close approximation to the relative risk.

RR (Risk Ratio): The probability of the occurrence of a disease in a group that has been exposed to some environmental, medicinal, microbial, or toxic influence, relative to its probability in a randomly selected population.

PMR (Proportionate Mortality Ratio): Proportionate mortality is the proportion of deaths in a specified population over a period of time attributable to different causes. Each cause is expressed as a percentage of all deaths, and the sum of the causes must add to 100%. These proportions are not mortality rates, since the denominator is all deaths, not the population in which the deaths occurred. Thus, proportionate mortality ratio is a measure of the frequency of occurrence of the proportionate mortality in a defined population during a specified interval of time.

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Toxicity Profile

Diammonium peroxidisulfate
Ammonium persulfate
(CAS No. 7727-54-0)

Diammonium peroxisulfate or ammonium persulfate has been reviewed in the OECD-SIDS program (OECD, 2005a,b).

Ammonium persulfate is distributed into the water compartment in the ionic form of the ammonium cation and persulfate ion. The persulfate anion will readily hydrolyze (decompose) into sulfate ions.

Acute Toxicity

The acute oral LD_{50} in rats is 495 mg/kg, and the acute dermal LD_{50}s in rats and rabbits are >5,000 mg/kg. In acute inhalation studies in rats, the 4-hour LC_{50} was generally greater than the maximum attainable concentration (>2,950 mg/m^3 for ammonium persulfate).

Irritation

Ammonium persulfate is slightly irritating to the eye and skin of rabbits. Studies in humans indicate that aqueous solutions of 5% persulfate or higher can cause skin irritation.

Sensitization

Results of animal skin sensitization tests (Buehler Test and Maximization Test) were negative when persulfate was applied topically, but was positive when persulfate was injected intradermally in induction and challenge phases in a non-standard Maximization Test. Numerous dermal challenge tests indicate that all persulfates are dermal and respiratory sensitizers in humans occupationally exposed to persulfates in hairdressing salons and, in one case, in a production facility. In controlled clinical trials with non-occupationally exposed-subjects (ammonium and sodium salts), no sensitization reactions were observed.

Repeated Dose Toxicity

Rats were fed in their diet 0, 300, 1,000 or 3,000 ppm sodium persulfate (0, 23, 100 and 225 mg/kg/day) for 90 days. On day 48 of the study, the concentration of the group

receiving 1,000 ppm was increased to 5,000 ppm for the remainder of the study. Body weights was decreased in the two highest dose groups during the last six weeks of treatment. There were no treatment-related effects on urinalysis, clinical chemistry or hematology parameters. Pathological findings were limited to the 3,000 ppm group only and consisted of necrosis and atrophy of the gastrointestinal tract epithelial lining. The absence of the gastrointestional lesions in the group receiving 1,000 ppm for 8 weeks, followed by 5000 ppm for 5 weeks, indicates that the lesions are related both to concentration in diet (dose) and length of exposure. There were no treatment-related pathological findings in reproductive organs or any other organ system or tissue.

Genotoxicity

Sodium persulfate was not genotoxic in a bacterial reverse mutation (Ames) assay or in an unscheduled DNA synthesis (UDS) assay with rat hepatocytes. It was also not active in a rat bone marrow micronucleus assay and when tested in vivo in a rat hepatocyte UDS assay.

Carcinogenicity

A 51-week dermal study in female SENCAR mice exposed to 0.2 ml of a 200 mg/ml solution of ammonium persulfate showed that ammonium persulfate is neither a tumor promoter nor a complete carcinogen when applied to the skin.

Reproductive/Developmental Toxicity

In a developmental/reproduction study with ammonium persulfate in rats (OECD 421), no effects on reproductive performance, fertility, fetal anomalies, fetal viability, spermatogenesis, spermatogenic cycle were reported up to 250 mg/kg/day. Dose levels were chosen based on the acute lethality studies for the ammonium salt and on a 90-day repeat-dose study in rats with the sodium salt (high dose: 225 mg/kg/day). In the developmental/reproduction study, animals were dosed prior to and during mating through gestation until lactation day 4. There was a transient depression in pup body weight at the 250 mg/kg dose level on lactation day 0 which resolved by day 4. This effect was not considered adverse. Based on the available data, the persulfates do not show evidence of reproductive or developmental toxicity. The NOAEL is 250 mg/kg/day.

Key Study/Critical Effect for Screening Criteria

The Australian drinking water guideline value for sulfate may apply to sulfate (500 ppm, health; 250 ppm, aesthetic). There are no existing drinking water guideline values for ammonium ions.

Reference

OECD (2005a). IUCLID Data Set for Ammonium persulfate (CAS No. 7727-54-0); Potassium persulfate (CAS No. 7727- 27-1); Sodium persulfate (CAS No. 7775-27-1), UNEP Publications.

OECD (2005b). Screening Information Dataset (SIDS) Initial Assessment Report for Ammonium persulfate (CAS No. 7727-54-0); Potassium persulfate (CAS No. 7727- 27-1); Sodium persulfate (CAS No. 7775-27-1), UNEP Publications.

Toxicity Profile

Diatomaceous Earth, Calcined
(CAS No. 91053-39-3)

Silica is an off-white granule that occurs naturally in various crystalline and amorphous or other non-crystalline forms. Crystalline silica is characterized by silicon dioxide (SiO_2) molecules oriented in fixed, periodic patterns to form stable crystals. The primary crystalline form of silica is quartz. Other crystalline forms of silica include cristobalite, tripoli and tridymite. Particle size is a key determinate of silica toxicity, since toxicity is restricted to particles that are small enough to be deposited into the target regions of the respiratory tract.

Uncalcined diatomaceous earth (CAS No. 61790-53-2) typically contains around 1% crystalline silica. When diatomaceous earth is subjected to pressure or is processed ("calcined") at temperatures above 1000°C some of the amorphous silica is converted to crystalline silica in the form of cristobalite. Calcined diatomaceous earth can contain anywhere from 1% to 75% cristobalite.

Oral Exposure

No oral studies were located; however, crystalline silica is not expected to exhibit toxicity by the oral route. Although absorption studies were not found for crystalline silica, kinetic studies on amorphous silica show no absorption from the gastrointestinal tract.

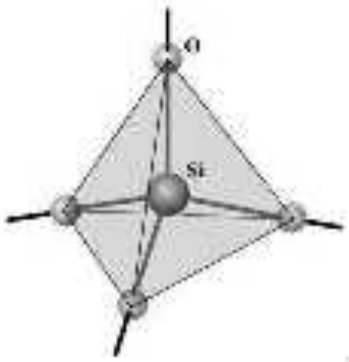
Dermal Exposure

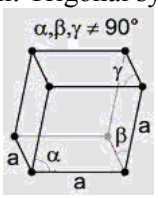
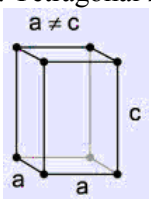
No dermal studies were located; however, crystalline silica is not expected to exhibit toxicity by the dermal route.

Inhalation Exposure

See attached OECD-SIDS Initial Targeted Assessment Profile on Quartz and Cristobalite, SIAM 32, 19-21 April 2011.

INITIAL TARGETED ASSESSMENT PROFILE (Human Health)

CAS No.	Quartz: CAS RN 14808-60-7 Cristobalite: CAS RN 14464-46-1
Chemical Name	Quartz and Cristobalite
Structural Formula	Molecular Formula: SiO_2 

Unit Cell: Trigonal symmetry	Unit Cell: Tetragonal symmetry
	
Quartz: CAS RN 14808-60-7	Cristobalite: CAS RN 14464-46-1

SUMMARY CONCLUSIONS OF THE TARGETED ASSESSMENT

NOTE: The present assessment is targeted to address the following human health endpoints: repeated dose toxicity and carcinogenicity via the inhalation route of exposure, and genotoxicity. It cannot be considered as a full SIDS Initial Assessment. Summary information on exposure is also reported here. Other endpoints for human health and the environment included in the Canadian screening assessment but have not been presented to OECD member countries, and thus are not included in this profile.

The final screening assessment will be published under the responsibility of the Government of Canada.

Rationale for Targeting the Assessment

The Government of Canada "categorized" or prioritized all 23,000 chemical substances on its Domestic Substances List (DSL) from 1999 to September 2006, as required by its *Canadian Environmental Protection Act, 1999* (CEPA 1999). Additional details may be found at http://www.chemicalsubstanceschimiques.gc.ca/about-apropos/categor/index-eng.php. Using information from Canadian industry, academic research and other countries, Government of Canada scientists applied a set of rigorous tools to the 23,000 chemical substances on the DSL. They were categorized to identify those that were: **inherently toxic** to humans or to the environment and that might be **persistent** and/or **bioaccumulative**; and substances to which people might have **greatest potential for exposure**. During this priority-setting exercise, distinct approaches were taken for identifying substances of likely concern for human health and the environment, and subsequent assessment activities may have focused on either human health or ecological endpoints. Through categorization, the Government of Canada has identified approximately 4,000 of the 23,000

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chemical substances on the DSL as priorities for further assessment, research and/or measures to control their use or release. Quartz and cristobalite were identified at that time, applying the categorization criteria, as high priorities for human health risk because they were considered to pose greatest potential for exposure and their respirable forms are classified by the International Agency for Research on Cancer as carcinogenic to humans (quartz and cristobalite) and by the National Toxicology Program as known human carcinogens (crystalline silica). These substances did not meet the ecological categorization criteria for bioaccumulation potential or inherent toxicity to aquatic organisms.

Under the Canadian legislation a determination of whether one or more of the criteria of the CANADIAN ENVIRONMENTAL PROTECTION ACT (CEPA) 1999, section 64 are met is based upon an assessment of potential risks to the environment and/or to human health associated with exposures in the general environment. For humans, this includes, but is not limited to, exposures from ambient and indoor air, drinking water, foodstuffs, and the use of consumer products. A conclusion under CEPA 1999 on the substances in the Chemicals Management Plan (CMP) Challenge is not relevant to, nor does it preclude, an assessment against the hazard criteria specified in the Controlled Products Regulations, which is part of the regulatory framework for the Workplace Hazardous Materials Information System [WHMIS] for products intended for workplace use.

Physical-chemical properties

The silicon dioxide group represents a polymorphic category containing a large number of forms identical in composition but with different atomic arrangements which afford different chemical properties. There are two sub-categories within this group: crystalline silica, to which the present substances quartz and cristobalite belong, and non-crystalline or amorphous silica. The key distinction between these sub-categories is that in crystalline substances, the building blocks are arranged in regular, repeating 3-dimensional pattern having long range order, whereas amorphous materials do not display long range order. In all forms of silica, (crystalline and non-crystalline), the silicon atom is tetrahedral and bound to four neighbouring oxygen atoms.

Quartz and cristobalite are solid at room temperature, existing normally as colourless or white crystals. The melting points for quartz and cristobalite are 1400-2000 ^{o}C and 1713-1728 ^{o}C, respectively and for both compounds, the boiling point is 2230^{o}C. Even though no experimental data were available, their vapour pressure and Henry's Law constant are likely negligible. Log K_{ow} (octanol-water partition coefficient) and log K_{oc} (organic carbon-water partition coefficient) are not applicable to these substances. The densities range from 2500-2700 kg/m^3 for quartz and 2300-2380 kg/m^3 for cristobalite.

The very similar physico-chemical properties of quartz and cristobalite reflect their closely related crystal forms. The solubility of crystalline silicates decreases as a function of silica tetrahedral packing density and long-range crystal order. For example, cristobalite has a more open framework structure than quartz and its density is lower, therefore, its solubility is higher. The water solubility of these minerals is also function of temperature, pH, particle size, and the presence of a disrupted surface layer. This may explain the variability of solubility values reported by many authors. The most probable solubility value for quartz is approximately 3.8 mg Si/L, or 6.4 mg/L expressed as the SiO_2 species, while the solubility of cristobalite is approximately 8.7 mg Si/L, or 18 mg SiO_2/L. The kinetics of dissolution of these substances is slow due to the high activation energy required to hydrolyse the Si-O-Si bond.

Human Health Targeted Endpoints

The majority of the studies described here have been reviewed by the International Agency for Research on Cancer (IARC 1997). However, additional data relevant to the screening assessment were identified up to August 2010.

Repeated dose toxicity/non-neoplastic effects (development of silicosis).

Studies on animals

Significant short-term and subchronic studies have demonstrated adverse effects in the lungs, while one of the 6 studies showed effects on the spleen in mice. Rats were exposed to 0, 10 or 100 mg/m^3 of cristobalite via inhalation for 6 hours/day during 3 days. Animals were observed 3 months after exposure. Elevated levels of granulocytes and elevated markers of cytotoxicity from the lung lavage fluid were noted in all exposed groups. Another study of similar duration (9 days) conducted in mice also identified a LOAEC of 10 mg/m^3. Effects observed included minimal interstitial thickening, accumulations of mononuclear cells and slight lymphoid tissue hypertrophy in the lungs.

In a 4-week inhalation study, female rats were exposed to 0, 0.1, 1 or 10 mg/m^3 of quartz 6 hours/day, 5 days/week. Bronchoalveolar lavage fluid was evaluated at 1, 8, and 24 weeks after exposure. Elevated levels of

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granulocytes and significant elevation of markers of cytotoxicity (Lactate dehydrogenase [LDH] and β-glucuronidase [β-glu]) were observed at 1 mg/m^3 and higher. The increased levels of LDH and β-glu were only significant at 24 weeks after exposure. A LOAEC of 1 mg/m^3 was identified at 24 weeks.

Male rats (4 animals per dose) were exposed to 0 or 3 mg/m^3 of cristobalite via inhalation for 6 hours/day, 5 days/week during 13 weeks. Pulmonary inflammation and fibrosis were observed in the exposed group at the end of treatment. When mice were similarly exposed to 5 mg/m^3 of quartz for 6 hours/day, 5 days/week for 15 or 27 weeks, the authors observed increased spleen weight and formation of plaque in the spleen.

In two separate studies, in which rats or hamsters were exposed to quartz via inhalation for at least 6 months, LOAECs of 2 and 3 mg/m^3 were identified, respectively. All the effects observed were related to inflammation and fibrosis of the lung tissue.

Several chronic studies investigated exposure of the respirable forms (i.e. accumulated via inhalation in the lung tissues) of quartz and cristobalite to rats, mice and hamsters. The following is a description of the study in which the lowest non-neoplastic LOAEC was determined. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz, containing 74% of respirable quartz, through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. The mean mass of particle at the end of the exposure period was 0.91 mg/lung. The LOAEC identified was 0.74 mg/m^3 (adjusted for 74% respirable quartz) based on lipoproteinosis, multifocal, inflammatory cell infiltrate and alveolar hyperplasia.

Human epidemiology data

In humans, the lowest observed adverse effect level was identified in a U.S. cohort study. The study was conducted on 3330 gold miners (all are males), who had an average of 9 years underground exposure during the period 1940 to 1965. The cohort was followed up through 1990. Silicosis[1] was identified through death certificates or chest X-rays. A job-exposure matrix together with work history was used to estimate individual exposure. The total silica content in the respirable dust in the mine was estimated at 13% and the median crystalline silica exposure was 0.05 mg/m^3. In this sub population of miners, 170 cases of silicosis were identified. The best predictor for risk of silicosis was cumulative exposure, which varied from less than 1% for a 0.5 mg/m^3-year exposure to 68-84% when exposed to more than 4 mg/m^3-year (based on the average daily dust exposure during the workday each year and summed over time for each miner). The main limitations identified by the authors include the limited number of radiographic surveys, the potential bias from death certificates

[1] Silicosis: Lung disease caused by inhalation of crystalline silica dust, and resulting in inflammation and scarring in forms of nodular lesions in the upper lobes of the lungs. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics). It does not follow that a history of exposure to silica necessarily results in silicosis (Nonsilicotics). The typical "Silicotic" lung nodule is shown in Figure 1.

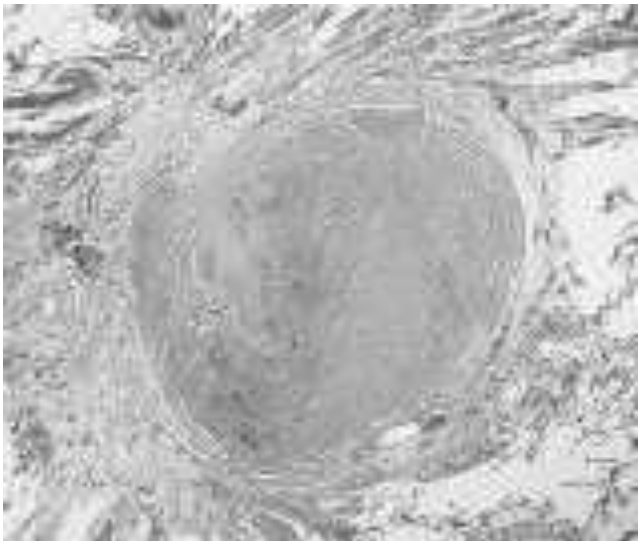


Figure 1. Silicotic nodule characterised by a central zone of hyalinised collagen with a whorled appearance and peripheral dust-containing macrophages (Rees and Murray, 2007).

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(relying on death certificates instead of relying on repeated x-rays, which were lacking for each miner, may have underestimated the number of cases) and the fact that the conversion of dust counts to

gravimetric measurements may not be accurate based on the estimation of 13% silica content in the respirable dust (although based on a relatively large number of samples (n = 82) collected in two different surveys, there was broad range of content in these samples (1% to 48%, SD = 9), and the percentage of respirable quartz may have differed in earlier years, but data were lacking for these years).

Two other human studies have identified similar LOAECs based on the critical endpoint of radiographic confirmed silicosis. A LOAEC of 0.053 mg/m^3 (mean exposure) was identified in a cross sectional study of South African gold miners and a LOAEC of 0.064 mg/m^3 (mean exposure) was derived in a mining community population-based random sample survey in Colorado.

Carcinogenicity studies

Studies on animals

Experimental studies conducted in rats have shown clear and consistent increases in lung tumours after chronic inhalation exposure. In the nine rat studies identified, five were inhalation studies and four were intratracheal instillation studies. All studies except one inhalation study showed increased incidence of lung tumours. For the inhalation studies with treatment related tumours, concentrations ranged from 1 to 50 mg/m^3 (1, 6, and 30 mg/m^3 of DQ-12 quartz; 12 and 50 mg/m^3 of Min-U-Sil 5 quartz) and duration of exposure ranged from 29 days to 2 years. In the inhalation study with no treatment-related tumours, exposure was 60 mg/m^3 of Sikron F300 quartz for 13 weeks. The following is a description of the neoplastic results in the study also identified as the critical study for non-neoplastic results. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. In the exposed group, 18 animals developed tumours (12 in females, 5 in males), as opposed to 3 and 2 for the control and positive control groups respectively. The majority (10/18) of the tumours observed were adenocarcinomas. The mean mass of particles in the lungs at the end of the exposure period was 0.91 mg/lung.

For the intratracheal instillation studies, doses ranged from 4 to 57 mg/kg-bw (based on 7, 12 or 20 mg/animal of Min-U-Sil (5) quartz or 20 mg/animal of novaculite quartz). Exposure regimes were diverse and included single instillation with observation for up to two years, to weekly instillation for 10 weeks. It is noteworthy that the single intratracheal administration of a 95% pure quartz particles (<5 μm) resulted in an increased incidence of silicotic granulomas after 3 weeks and lung tumours after 11 months. The most common tumours reported across the long term rat studies were adenocarcinomas, however other tumours such as squamous-cell carcinoma, alveolar carcinoma and bronchiole-alveolar adenoma were also reported, and all animals that developed tumours also showed some degree of fibrosis.

Of particular interest is the intratracheal instillation study, investigating the sequence of pathological events leading to lung tumors. An unspecified number of rats/sex/dose received a single intratracheal instillation of various crystalline silica dusts or ferric oxide, allowing direct administration into the bronchial tree. The doses were 12 or 20 mg of Min-U-Sil 5 quartz (MQZ), 12 mg of hydrofluoric-acid-etched Min-U-Sil 5 quartz (HFMQZ), 12 mg of cristobalite, 12 mg of tridymite and 12 mg of ferric oxide suspended in saline. All groups were observed until six months post exposure, except for both MQZ groups, the HFMQZ and the ferric oxide group which were observed up until 17 months post-exposure. Interim sacrifices were conducted at 6, 11 and 17 months. The rat lungs showed a clear progression of effects. The sequence of pathological events were, an initial inflammatory response leading to a marked hyperplasia and hypertrophy of alveolar cells after one month, and at six months hyperplasia was evident but no lung tumours were observed. In this study, lung tumours were observed starting at the 11 month sacrifice with a 17% and 42% incidence in males and females (based on 3/18 males and 8/19 females), respectively, and at 17 months incidences were 32% and 59% (based on 6/19 males and 10/17 females, respectively). No lung tumours were found in ferric oxide treated rats. Similar studies have also been conducted in hamsters and mice. Although treated mice and hamsters showed treatment related signs (inflammation or fibrosis), no tumours were observed in hamsters. No increase in the incidence of lung tumours was seen in mice treated with quartz; however silicotic granulomas and lymphoid cuffing around airways but no fibrosis were seen in the lungs of quartz-treated mice.

Human epidemiology data

There is an extensive dataset of human studies investigating the link between crystalline silica exposure and cancer. IARC (1997) identified over 50 epidemiological studies based on occupational exposure to dust containing respirable crystalline silica. Main industry sectors from which the human data is derived include gold mines, foundries, granite/stone industry, pottery workers and refractory brick workers. From the least confounded studies, it was noted that lung cancer tended to increase with the following parameters: cumulative

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exposure; duration of exposure; peak intensity of exposure; presence of radiographically defined silicosis; and length of follow-up time from date of silicosis diagnostic. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics).

Since the 1997 IARC report, a large number of epidemiological studies have been published, with the more recent studies being updates from supplementary follow-up of results from previously assessed case-control studies cohorts, new results based on refined exposure assessments or adjustment for confounders or meta-analyses of the pooled data from these epidemiology studies

In a meta-analysis of the data from 10 cohort studies of gold, tin and tungsten miners, granite workers, industrial sand, diatomaceous earth and pottery workers with quantitative exposure estimates for crystalline silica were pooled in order to analyse the risk related to lung cancer. The pooled cohort standardized mortality ratio (SMR, against national rates) [See Appendix 1 for definition] was 1.2 (Confidence Interval [CI] 1.1-1.3). The results from the case-control analyses show a statistically significant trend with duration of exposure (odds ratios (ORs) [See Appendix 1] by quintile of cumulative exposure increased from 1.0 to 1.6 [CIs of 0.85 to 2.1] and by quintile of average concentration increased from 1.0 to 1.7 [CIs of 1.1 to 2.3]), supporting the importance of the increasing lung burden of silica in the occurrence of cancer. Overall, the authors concluded that the results support the carcinogenicity conclusion presented by IARC (1997).

To investigate the link between crystalline silica, silicosis and lung cancer, epidemiological data published between 1966 and 2001 were gathered. Over 50 studies were selected and pooled according to type of study and the parameter being linked to lung cancer (i.e. silica exposure, presence of silicosis in subjects). The quality of study, adjustment for confounding factors, co-exposure to other carcinogens and availability of a more recent analysis of a same cohort were taken into consideration in the final selection of the studies. Analysis of the relationship between exposure to silica and lung cancer included 17 cohort and 13 case-control studies. For the analysis of lung cancer versus silicosis, 11 cohort and 5 case-control studies were selected. The third analysis included 6 cohort and 2 case-control studies to evaluate the risk of lung cancer in non-silicotics. A random effect model was used to conduct each meta-analysis. Pooled cancer risk ratios (RRs) were 1.32 (CI 1.23-1.41) for crystalline silica exposure, 2.37 (CI 1.98-2.84) for individuals exposed to silica with confirmed silicosis (Silicotics) and 0.96 (CI 0.81-1.15) for individuals with no evidence of silicosis (non-silicotics) with confirmed exposure to silica, supporting the general observation that silicosis has a stronger temporal relationship with crystalline silica exposure and furthermore support the view that a human silicotic response could be a preliminary stage in the development of cancer.

A more recent meta-analysis included 28 cohort, 15 case-control and two proportionate mortality ratio (PMR) [See Appendix 1] studies from a variety of occupational settings conducted between 1996 and 2005. Risk ratios (RRs) were calculated based on type of study and silicosis status using fixed and random effect models (results presented here are from the random model). RRs for all cohort studies was 1.34 (CI 1.25-1.45), and were 1.69 (CI 1.32-2.16) for silicotics, 1.25 (CI 1.18-1.33) for those with undefined silicosis status and 1.19 (CI 0.87-1.57) for non-silicotics. In the case-control studies, the general RR was 1.41 (CI1.18-1.67), and the same sub-groups as mentioned above resulted in RRs of 3.27 (CI 1.32-8.2), 1.41 (CI1.18-1.70) and 0.97 (CI 0.68-1.38), respectively. The proportionate mortality ratio for the last two studies was 1.24 (CI 1.05-1.47). The authors noted that the association between lung cancer and exposure to crystalline silica was more consistent for silicotics, i.e., those diagnosed with silicosis and RR values split into type of occupational settings in which participants worked.

Based upon the above three meta-analysis studies and the epidemiology studies discussed in IARC (1997), the following can be concluded. Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis. Cancer risk is often more significant in workers exposed to crystalline silica over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours. Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles.

There have been reports of tumours outside of the lungs in persons with high silica exposure; however, these reports are sparse and the data inconsistent and have not been unequivocally linked to exposure to either one of the crystalline forms (quartz or cristobalite). Some of the reported locations are: oesophagus, stomach, liver, skin and bone. Sufficient epidemiological or toxicological data do not currently exist for quantitative assessment of the exposure-response relationship on these other tissues or organs.

Genotoxicity

Potential genotoxicity has been assessed in multiple *in vitro* and *in vivo* assays. Table 1 below gives a brief summary of the positive results observed in each type of assay.

Table 1. Summary of positive results over total number of results for each assay and each category (all studies

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conducted with crystalline silica: quartz, except where indicated).

Assay	Animal data		Human data		Positives/Total	
	In vitro	In vivo	In vitro	In vivo[d]	In vitro	In vivo
Rec Assay	0/1				0/1	
DNA strand break	1/1	2/2	5/5[b]	1/1	6/6	3/3
Sister chromatid exchange	0/1		0/1[c]	1/1	0/2	1/1
Micronucleus	2/3	0/1	2/2[b]	1/1	4/5	1/2
Chromosome aberration	0/1			1/1	0/1	1/1
Aneuploidy/polyploidy	0/3				0/3	
Cell transformation	4/4				4/4	
Hprt mutation	1/2	2/2[a]	1/1[b]		2/3	2/2
Oxidative DNA damage		4/5	2/2		2/2	4/5
DNA binding		1/1				1/1
p53 activation		0/1				0/1

a. one assay conducted with crystalline silica: cristobalite
b. one assay conducted with "ultrafine crystalline silicon dioxide".
c. crystalline silica: tridymite
d. crystalline silica dust (subtypes not provided).

All the *in vivo* human genotoxicity studies are based on three independent studies that used blood samples from workers from diverse occupational settings with confirmed exposures to crystalline silica dust; however, quantification of exposure was not provided. After stratification by smoking status, sister chromatid exchange remained statistically significant in both smokers and non-smokers although the frequency was higher in smokers. For the chromosome aberration assay conducted as part of the same study (blood samples from workers in the stone crusher industry), the increased frequency was no longer significant after stratification. In the DNA damage study of foundry and pottery workers and the micronucleus assay of workers involved in sandblasting and related jobs, results were positive when compared to controls. However, in both studies, smoking status influenced the results, contributing to the increased DNA damage observed since results were greater in smokers versus non-smokers, and the frequency of micronuclei in nasal epithelial cells was higher in smokers (p=0.002) but when using peripheral blood lymphocytes did not differ statistically between smokers and non-smokers who were similarly exposed to silica dust,

The role of *in situ* generation of reactive oxygen species (ROS) and reactive nitrogen species (RNS) has been well established in the following types of DNA damage: small scale insertions, DNA base pair deletion, base modification, chromosomal change/loss, microsatellite instability, DNA strand break, 8-hydroxydeoxyguanosine (8-OHdG) mutation and point mutations. ROS and RNS generation is postulated to be (a part of) the DNA damage mechanism for crystalline silica. Studies are described below to support this hypothesis.

DNA was exposed *in vitro* to various crystalline silica dusts, to H_2O_2, or to both. Results show that DNA damage was limited when dust or H_2O_2 were administered alone but increased with the co-exposure. When the reactive oxygen scavenger, dimethylsulfoxide, was added to the test system, DNA strand break was inhibited, data supporting the viewpoint that it is the presence of radicals generated in response to quartz and cristobalite that causes the DNA damage and not quartz or cristobalite themselves.

Hprt mutation assays in rat alveolar epithelial cells, both *in vitro* and *in vivo,* were positive in response to quartz. The positive results *in vivo* were seen only in the presence of significant inflammatory responses in the treated animals. Also, in a parallel *in vitro* experiment, rat alveolar epithelial cells were incubated with the bronchoalveolar lavage fluid from the rats exposed to quartz. Both macrophage and neutrophil enriched lavage cells induced mutation in the exposed alveolar epithelial cells. Addition of catalase (an enzyme which inactivates H_2O_2) before incubation inhibited the increase in *hprt* mutation.

Rats were exposed to either crystalline or amorphous silica in a manner to induce the same level of

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inflammation in the lungs. The inflammatory response was assessed by measuring the proportion of neutrophils in the bronchiolar lavage fluid. The actual concentrations were 3 and 50 mg/m^3 for crystalline and amorphous silica respectively. The animals were exposed for 13 weeks. *Hprt* mutation frequency was measured in the alveolar epithelial cells at the end of the exposure period. Mutation frequency was greatly increased only in the crystalline silica treated rats; no treatment related increase was found in the rats treated with the amorphous form.

In an 8-OHdG assay conducted to monitor DNA damage by reactive oxygen species, female rats were exposed to 0, 0.3, 1.5 and 7.5 mg/animal of quartz via intratracheal instillation. Effects were observed 90 days post-exposure. A clear dose-response relationship was identified between quartz exposure and various inflammation markers (differential cell count, protein, lung surfactant lipids and tumour necrosis factor alpha). Inflammation was present starting at the lowest dose. However, 8-OHdG showed a statistically significant increase starting at 1.5 mg/animal only. Similarly, in another study, 8-OHdG and DNA strand breaks were observed at concentrations of or above 10 ug/m^3 in rat lung epithelial cells.

In the aim of investigating the role of ROS in lung carcinogenesis, rat lung epithelial cells were incubated with polymorphonuclear (PMN) leukocytes (involved in the inflammatory process and responsible for the release of certain ROS) or hydrogen peroxide. Statistically significant increases in 8-OHdG were observed in the presence of PMN or hydrogen peroxide in a dose-response manner.

In a series of experiments which used *in vitro* stimulation of macrophages with crystalline silica and *in vivo* intranasal instillation of crystalline silica in mice, it was demonstrated that that the chronic fibrosis seen in a murine model of silicosis *in vivo* is dependent on the presence of adaptor molecule ASC and Nalp3 inflammazome. These data support a potential mode of action whereby silica triggers cellular responses that in turn activate alveolar macrophages, resulting in an inflammatory response and silicosis. In mice deficient in Nalp3 inflammazome, the development of inflammation and collagen deposition was significantly reduced compared with normal mice 3 months after the initial intranasal instillation of silica.

Analysis of Lung Tumour Data

The weight of evidence for both rats and humans indicates that fibrotic and silicotic lesions in the lung result from inhalation exposure to crystalline silica and that lung cancer is secondary to those lesions in the lung. Although the mechanism of induction for the lung tumours has not been fully elucidated, there is sufficient supportive mode of action evidence from the data presented to demonstrate that a threshold approach to risk assessment is appropriate based on an understanding of the key events in the pathogenesis of crystalline silica induced lung tumours. The body of evidence include the following:

- In experimental studies, all rats that developed tumours also showed fibrosis.
- Adenocarcinomas, the most common type of tumour identified in rats, are commonly associated with fibrosis and deeply scarred lung tissue.
- Experimental rat studies showed a clear progression of the effects from initially mild inflammation, followed by fibrosis over-time, leading eventually to lung tumours.
- Tumours are not present in all treated species dosed in the same way.
- The tumours, both in rats and humans, are concentrated in the lungs only, although other organs are indirectly exposed.
- In human studies, cancer risk is often more significant in workers exposed over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours.
- Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles
- Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis.
- For genotoxicity, in vitro results were mostly mixed and in vivo results were mostly positive. However, the vast majority of the positive genotoxicity assay results can be explained by the generation of reactive oxygen species, as demonstrated experimentally, where ROS scavenging prevents the genotoxicity.
- *In vivo*, macrophage deficient mice (macrophages produce ROS in response to crystalline silica) do not develop silicosis nor do they develop tumours and the Nalp3 inflammazome, a key player in the macrophage initiated inflammatory response, is required for the development of pulmonary fibrosis after

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inhalation of silica.

- Though inhalation exposure to crystalline silica in multiple occupational settings is clear, the increase in risk, based on the several recent meta-analyses of the multiple human epidemiological studies, remains low.

It is worth noting that where aggressive engineering controls have been made to reduce silica dust levels in the workplace (Sweden), silicosis has been eliminated. By corollary, existing exposures outside of the workplace in such areas do not pose a risk for silicosis to the general population.

The respirable forms of quartz and cristobalite possess properties indicating a hazard for human health (repeated dose toxicity, carcinogenicity and genotoxicity). The mode of action in the lungs involves irritation, inflammation and reactive species formation, leading to silicosis, and eventually to tumour formation.

Exposure

Uses

Consistent with oxygen and silicon being the two most abundant elements in the Earth's crust, silicon-oxide minerals, including quartz are ubiquitous in the natural environment. In particular, as a component of sand, quartz may find use in a diverse array of applications. Several high volume uses include, but are not limited to, the use of sand as a filling material for the construction of roads and in general building activities, the use of sand and gravel aggregates as abrasives on roads in winter and the use of fly-ash, which may contain 4-14% quartz and 0.5-1% cristobalite, as a cement additive. These abrasives when used on winter roads are usually mixed with road salts and may be sand only, stone dust, sand and gravel aggregates, or pre-treated sand. They are used mainly by rural municipalities or in areas where cold temperatures diminish the efficiency of salts for de-icing. Quantities of abrasives used in Canada were 5.73×10^9 kg, 4.59×10^9 kg, and 4.93×10^9 kg for 2007, 2008 and 2009, respectively.

Industrial sand, high purity silica sand products with closely controlled sizing are expected to contain quartz and cristobalite, include lump silica (2-3mm up to 15 cm or more), silica sand (75µm to 2-3mm) and silica flour (less than 75µm). Lump silica may be used in the production of silicon alloys, silica bricks, and the linings of certain types of pulverizers (eg. ball mills and tube mills).

Silica sand may be used in the manufacture of glass and glass fibres, silicate chemicals and silicon carbide, the hydraulic fracturing of wells, foundry moulding, and for sandblasting. Silica flour may find use in the ceramics and cement industries, as a filler and extender in rubber and coatings, and as an abrasive in soaps.

Natural clays, such as bentonite and fuller's earth, are used in cat litters for their high water absorbance capacities. Quartz is a natural component of these clays, and consequently, it may be present in cat litter products. High purity α-quartz is a piezoelectric material, which means that application of a voltage induces a distortion in the crystal shape and vice versa. This ability to interconvert electrical and mechanical energy has led to the use of quartz crystals in electronic devices requiring precise timing control, for example telephones, radios, watches and computers.

According to a survey conducted in Canada, quartz and cristobalite are also used in abrasives, adsorbents, filter products (diatomaceous earth), grout and cement. These substances reportedly also find use as fillers, which add bulk and improve wear resistance, in paints and coatings, adhesives, sealants, polymer films, caulking, epoxy resins and silicones. Also, quartz is listed as an ingredient in 60 cosmetic products in Canada. The types of products include anti-wrinkle preparation, eye and face makeup, lipstick, hair dyes, shampoos and grooming products, as well as skin cleansers, moisturizers and tanning preparations.

Natural Sources

In Canada, quartz naturally occurs in many types of rock formations. Those with high silicon dioxide content (95% SiO_2 or more) include vein and massive intrusion bodies, quartz pebbles, silica sand, sandstone and quartzite. Sandstone is a sedimentary rock mostly composed of quartz grains cemented by a bonding material such as clay, calcite or iron oxide. Quartzite is a hard, compact, metamorphosed sandstone made of grains of quartz firmly bonded with a siliceous cement. Mineral aggregates (e.g., sand and gravel) have variable silicon dioxide content. Quartz is also found as crystals, aggregates or discrete particles in certain igneous rocks (e.g., granites and pegmatites), soils, sediments, air and surface water. This omnipresence is consistent with the fact that silicon is the second most abundant chemical element on Earth.

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Cristobalite is naturally produced in the ashes of volcanic eruptions, and by combustion metamorphism which is a local phenomenon of spontaneous combustion of naturally occurring substances such as bituminous rocks, coal or oil. It may be found in cavities in volcanic rocks and in thermally metamorphosed sandstones and may also be a transient stage in the diagenesis of diatomaceous shale with the result that soils made of these geologic formations may be rich in cristobalite. Unlike quartz, the natural occurrence of cristobalite is limited to specific geographic regions and mineral types.

Anthropogenic Sources

Natural quartz is isolated from ore via beneficiation, which involves milling or grinding the material into particles that are separated into desired mineral and waste. The materials obtained are either used directly or further purified. In Canada, in 2006, 2.146×10^{9} kg of pure quartz were mined, and 2.385×10^{11} kg of sand and gravel aggregates were produced. The proportion of quartz in silica sand deposits and gravel aggregates will vary from one site to another.

Cristobalite can form from silica melts during the preparation of silica glass; quartz is not obtained from melts but is manufactured at elevated temperature and pressure via a hydrothermal process. Cristobalite also forms during the calcination[2] of diatomaceous earth.

Human Exposure Estimate

Ambient air

The exposure assessment is focussed on respirable quartz and cristobalite, which in ambient air comprises a component of total particulate matter (PM). In Canada, data on the concentrations of silicon in PM was available and used as a surrogate for quartz and cristobalite. This approach is conservative because the measured silicon includes all silicon-containing substances and therefore represents the upper limit for quartz and cristobalite in ambient air.

The National Air Pollution Surveillance (NAPS) Program measured concentrations in $\mu g/m^3$ of silicon in PM with aerodynamic radii less than 2.5 µm ($PM_{2.5}$ (dichot)), and from 2.5 to 10 µm (PM_{10} (dichot)) (the total particulate matter with aerodynamic radii less than 10 µm (PM_{10}) is obtained by adding these values) in Canada. In 2009, as part of the NAPS Program, silicon concentrations were determined on over 1600 samples of $PM_{2.5}$(dichot) and over 1500 samples of PM_{10}(dichot) at 24 urban locations across Canada. An estimate of exposure to quartz and cristobalite can be obtained by assuming that all the silicon in the PM is represented stoichiometrically as SiO_2, and multiplying the reported concentration of silicon by 2.14 to obtain a value for silica.

The intake of respirable quartz and cristobalite by the general population of Canada is estimated using a range covering the lowest 50^{th} percentile SiO_2 concentration in PM_{10}, measured in Pt. Petre, ON, (0.12 $\mu g/m^3$) to the highest 50^{th} percentile concentration in PM_{10} measured in Calgary, AB (2.1 $\mu g/m^3$). The 50^{th} percentile SiO_2 concentrations ranged from 0.1 to 2.1 $\mu g/m^3$ across the survey sites; the top of this range is quite close to the average of the maximum values for the 24 sites (3.7 $\mu g/m^3$). The outdoor data were used to represent the indoor levels, because information on indoor silicon concentrations was not available, and the range of PM_{10} measured indoors is generally lower than the outdoor range. Thus, this approach conservatively overestimates indoor exposure in homes.

The highest exposure group based on these calculations is children ages 0.5 to 4 years with an estimated daily intake ranging from 0.07 to 5.26 µg/kg-bw per day; the estimated daily intake decreases with age due to changes in the ratio of inhalation rates to body weights; the daily intake of adults, 20-59 years old, is estimated to range from 0.03 to 2.00 µg/kg-bw per day.

Consumer Products

Exposure to respirable quartz from the use of cosmetic products, which contained quartz as an ingredient, was considered low because they are not formulated for spray application, the loose powders were reported to contain less than 0.1% quartz, and in these products the substance is not expected to be associated with other components of the formulation and not available in a free form.

For consumer Do It Yourself (DIY) activities around the home, the highest mean breathing zone concentration of particles from sanding dry wall (median cut-point of 10µm) of 6.31 mg/m^3, was used to derive an upper-

[2] Calcinations: Heat treating a substance, but without fusion, to bring about change in its physical or chemical constitution.

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bound exposure estimate ranging from 2 to10 µg/kg-bw per event.

Quartz is used to formulate a large number of paints and coatings. To estimate potential inhalation exposure to quartz from these products, the spray painting of wall paints with an airless spray gun was considered appropriate as a conservative scenario. Exposure to respirable paint particles was estimated using data from controlled a laboratory study in which walls of poorly ventilated test rooms were painted by professional painters using an airless sprayer to apply interior latex paint. The maximum concentration of 13% quartz in paint in Canada was used to estimate exposure. The upper-bound estimate of exposure to quartz, based on the maximum concentration of 13% quartz in paint in the Canadian market and the maximum concentration of respirable paint particles measured in these controlled studies when recommended personal protective equipment is used, is 0.954 µg/kg-bw per event.

Inhalation of ambient air containing quartz and cristobalite is the dominant pathway of chronic exposure (excluding that from DIY activities) for the general population. Because SiO_2 makes up only approximately 5% of PM_{10}, silicon concentrations (expressed as SiO_2) measured in the Canadian NAPS survey of 24 urban locations were considered most relevant to the estimation of exposure by the general population. Quartz and cristobalite comprise only a portion of the total SiO_2 in PM_{10}, therefore, the use of the total silicon concentration to represent the upper bound crystalline silica concentrations results in an overestimation of exposure.

Appendix 1: Definitions of Epidemiological Terms in the ITAP

SMR (Standardized Mortality Ratio): The ratio (x 100) of observed to expected deaths in a study population. Expected deaths are calculated by applying a set of standard age-specific mortality rates to the age distribution of the study population. Standardized ratios are only useful for comparisons. They have no intrinsic meaning.

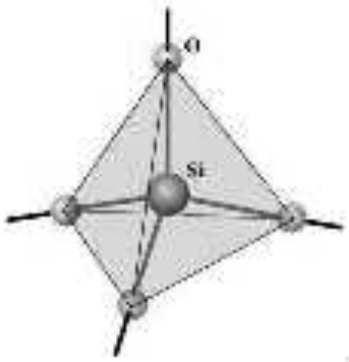
OR (Odds Ratio): In epidemiological case-control studies, a relative measure of disease occurrence. The odds in favour of a particular disease occurring in an exposed group are divided by the odds in favour of its occurring in an unexposed group. If the condition being studied is rare, the odds ratio is a close approximation to the relative risk.

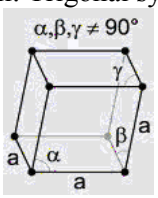
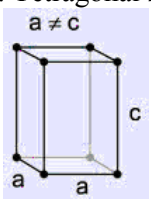
RR (Risk Ratio): The probability of the occurrence of a disease in a group that has been exposed to some environmental, medicinal, microbial, or toxic influence, relative to its probability in a randomly selected population.

PMR (Proportionate Mortality Ratio): Proportionate mortality is the proportion of deaths in a specified population over a period of time attributable to different causes. Each cause is expressed as a percentage of all deaths, and the sum of the causes must add to 100%. These proportions are not mortality rates, since the denominator is all deaths, not the population in which the deaths occurred. Thus, proportionate mortality ratio is a measure of the frequency of occurrence of the proportionate mortality in a defined population during a specified interval of time.

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INITIAL TARGETED ASSESSMENT PROFILE (Human Health)

CAS No.	Quartz: CAS RN 14808-60-7 Cristobalite: CAS RN 14464-46-1
Chemical Name	Quartz and Cristobalite
Structural Formula	Molecular Formula: SiO_2 

Unit Cell: Trigonal symmetry	Unit Cell: Tetragonal symmetry
	
Quartz: CAS RN 14808-60-7	Cristobalite: CAS RN 14464-46-1

SUMMARY CONCLUSIONS OF THE TARGETED ASSESSMENT

NOTE: The present assessment is targeted to address the following human health endpoints: repeated dose toxicity and carcinogenicity via the inhalation route of exposure, and genotoxicity. It cannot be considered as a full SIDS Initial Assessment. Summary information on exposure is also reported here. Other endpoints for human health and the environment included in the Canadian screening assessment but have not been presented to OECD member countries, and thus are not included in this profile.

The final screening assessment will be published under the responsibility of the Government of Canada.

Rationale for Targeting the Assessment

The Government of Canada "categorized" or prioritized all 23,000 chemical substances on its Domestic Substances List (DSL) from 1999 to September 2006, as required by its *Canadian Environmental Protection Act, 1999* (CEPA 1999). Additional details may be found at http://www.chemicalsubstanceschimiques.gc.ca/about-apropos/categor/index-eng.php. Using information from Canadian industry, academic research and other countries, Government of Canada scientists applied a set of rigorous tools to the 23,000 chemical substances on the DSL. They were categorized to identify those that were: **inherently toxic** to humans or to the environment and that might be **persistent** and/or **bioaccumulative**; and substances to which people might have **greatest potential for exposure**. During this priority-setting exercise, distinct approaches were taken for identifying substances of likely concern for human health and the environment, and subsequent assessment activities may have focused on either human health or ecological endpoints. Through categorization, the Government of Canada has identified approximately 4,000 of the 23,000

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chemical substances on the DSL as priorities for further assessment, research and/or measures to control their use or release. Quartz and cristobalite were identified at that time, applying the categorization criteria, as high priorities for human health risk because they were considered to pose greatest potential for exposure and their respirable forms are classified by the International Agency for Research on Cancer as carcinogenic to humans (quartz and cristobalite) and by the National Toxicology Program as known human carcinogens (crystalline silica). These substances did not meet the ecological categorization criteria for bioaccumulation potential or inherent toxicity to aquatic organisms.

Under the Canadian legislation a determination of whether one or more of the criteria of the CANADIAN ENVIRONMENTAL PROTECTION ACT (CEPA) 1999, section 64 are met is based upon an assessment of potential risks to the environment and/or to human health associated with exposures in the general environment. For humans, this includes, but is not limited to, exposures from ambient and indoor air, drinking water, foodstuffs, and the use of consumer products. A conclusion under CEPA 1999 on the substances in the Chemicals Management Plan (CMP) Challenge is not relevant to, nor does it preclude, an assessment against the hazard criteria specified in the Controlled Products Regulations, which is part of the regulatory framework for the Workplace Hazardous Materials Information System [WHMIS] for products intended for workplace use.

Physical-chemical properties

The silicon dioxide group represents a polymorphic category containing a large number of forms identical in composition but with different atomic arrangements which afford different chemical properties. There are two sub-categories within this group: crystalline silica, to which the present substances quartz and cristobalite belong, and non-crystalline or amorphous silica. The key distinction between these sub-categories is that in crystalline substances, the building blocks are arranged in regular, repeating 3-dimensional pattern having long range order, whereas amorphous materials do not display long range order. In all forms of silica, (crystalline and non-crystalline), the silicon atom is tetrahedral and bound to four neighbouring oxygen atoms.

Quartz and cristobalite are solid at room temperature, existing normally as colourless or white crystals. The melting points for quartz and cristobalite are 1400-2000 ^{o}C and 1713-1728 ^{o}C, respectively and for both compounds, the boiling point is 2230^{o}C. Even though no experimental data were available, their vapour pressure and Henry's Law constant are likely negligible. Log K_{ow} (octanol-water partition coefficient) and log K_{oc} (organic carbon-water partition coefficient) are not applicable to these substances. The densities range from 2500-2700 kg/m^3 for quartz and 2300-2380 kg/m^3 for cristobalite.

The very similar physico-chemical properties of quartz and cristobalite reflect their closely related crystal forms. The solubility of crystalline silicates decreases as a function of silica tetrahedral packing density and long-range crystal order. For example, cristobalite has a more open framework structure than quartz and its density is lower, therefore, its solubility is higher. The water solubility of these minerals is also function of temperature, pH, particle size, and the presence of a disrupted surface layer. This may explain the variability of solubility values reported by many authors. The most probable solubility value for quartz is approximately 3.8 mg Si/L, or 6.4 mg/L expressed as the SiO_2 species, while the solubility of cristobalite is approximately 8.7 mg Si/L, or 18 mg SiO_2/L. The kinetics of dissolution of these substances is slow due to the high activation energy required to hydrolyse the Si-O-Si bond.

Human Health Targeted Endpoints

The majority of the studies described here have been reviewed by the International Agency for Research on Cancer (IARC 1997). However, additional data relevant to the screening assessment were identified up to August 2010.

Repeated dose toxicity/non-neoplastic effects (development of silicosis).

Studies on animals

Significant short-term and subchronic studies have demonstrated adverse effects in the lungs, while one of the 6 studies showed effects on the spleen in mice. Rats were exposed to 0, 10 or 100 mg/m^3 of cristobalite via inhalation for 6 hours/day during 3 days. Animals were observed 3 months after exposure. Elevated levels of granulocytes and elevated markers of cytotoxicity from the lung lavage fluid were noted in all exposed groups. Another study of similar duration (9 days) conducted in mice also identified a LOAEC of 10 mg/m^3. Effects observed included minimal interstitial thickening, accumulations of mononuclear cells and slight lymphoid tissue hypertrophy in the lungs.

In a 4-week inhalation study, female rats were exposed to 0, 0.1, 1 or 10 mg/m^3 of quartz 6 hours/day, 5 days/week. Bronchoalveolar lavage fluid was evaluated at 1, 8, and 24 weeks after exposure. Elevated levels of

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granulocytes and significant elevation of markers of cytotoxicity (Lactate dehydrogenase [LDH] and β-glucuronidase [β-glu]) were observed at 1 mg/m^3 and higher. The increased levels of LDH and β-glu were only significant at 24 weeks after exposure. A LOAEC of 1 mg/m^3 was identified at 24 weeks.

Male rats (4 animals per dose) were exposed to 0 or 3 mg/m^3 of cristobalite via inhalation for 6 hours/day, 5 days/week during 13 weeks. Pulmonary inflammation and fibrosis were observed in the exposed group at the end of treatment. When mice were similarly exposed to 5 mg/m^3 of quartz for 6 hours/day, 5 days/week for 15 or 27 weeks, the authors observed increased spleen weight and formation of plaque in the spleen.

In two separate studies, in which rats or hamsters were exposed to quartz via inhalation for at least 6 months, LOAECs of 2 and 3 mg/m^3 were identified, respectively. All the effects observed were related to inflammation and fibrosis of the lung tissue.

Several chronic studies investigated exposure of the respirable forms (i.e. accumulated via inhalation in the lung tissues) of quartz and cristobalite to rats, mice and hamsters. The following is a description of the study in which the lowest non-neoplastic LOAEC was determined. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz, containing 74% of respirable quartz, through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. The mean mass of particle at the end of the exposure period was 0.91 mg/lung. The LOAEC identified was 0.74 mg/m^3 (adjusted for 74% respirable quartz) based on lipoproteinosis, multifocal, inflammatory cell infiltrate and alveolar hyperplasia.

Human epidemiology data

In humans, the lowest observed adverse effect level was identified in a U.S. cohort study. The study was conducted on 3330 gold miners (all are males), who had an average of 9 years underground exposure during the period 1940 to 1965. The cohort was followed up through 1990. Silicosis[1] was identified through death certificates or chest X-rays. A job-exposure matrix together with work history was used to estimate individual exposure. The total silica content in the respirable dust in the mine was estimated at 13% and the median crystalline silica exposure was 0.05 mg/m^3. In this sub population of miners, 170 cases of silicosis were identified. The best predictor for risk of silicosis was cumulative exposure, which varied from less than 1% for a 0.5 mg/m^3-year exposure to 68-84% when exposed to more than 4 mg/m^3-year (based on the average daily dust exposure during the workday each year and summed over time for each miner). The main limitations identified by the authors include the limited number of radiographic surveys, the potential bias from death certificates

[1] Silicosis: Lung disease caused by inhalation of crystalline silica dust, and resulting in inflammation and scarring in forms of nodular lesions in the upper lobes of the lungs. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics). It does not follow that a history of exposure to silica necessarily results in silicosis (Nonsilicotics). The typical "Silicotic" lung nodule is shown in Figure 1.

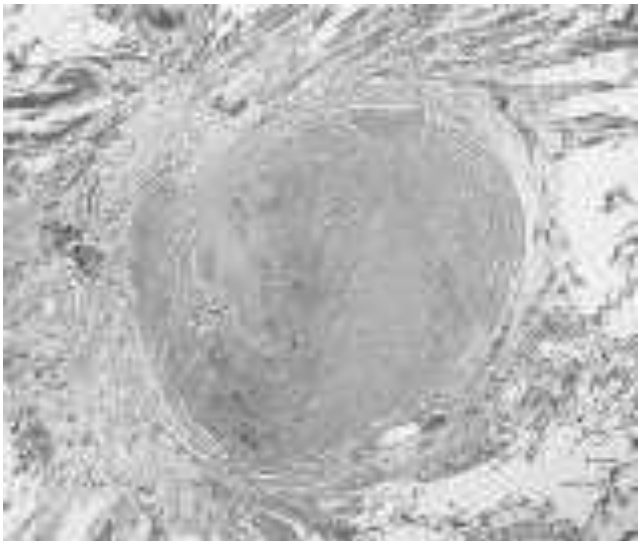


Figure 1. Silicotic nodule characterised by a central zone of hyalinised collagen with a whorled appearance and peripheral dust-containing macrophages (Rees and Murray, 2007).

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(relying on death certificates instead of relying on repeated x-rays, which were lacking for each miner, may have underestimated the number of cases) and the fact that the conversion of dust counts to

gravimetric measurements may not be accurate based on the estimation of 13% silica content in the respirable dust (although based on a relatively large number of samples (n = 82) collected in two different surveys, there was broad range of content in these samples (1% to 48%, SD = 9), and the percentage of respirable quartz may have differed in earlier years, but data were lacking for these years).

Two other human studies have identified similar LOAECs based on the critical endpoint of radiographic confirmed silicosis. A LOAEC of 0.053 mg/m^3 (mean exposure) was identified in a cross sectional study of South African gold miners and a LOAEC of 0.064 mg/m^3 (mean exposure) was derived in a mining community population-based random sample survey in Colorado.

Carcinogenicity studies

Studies on animals

Experimental studies conducted in rats have shown clear and consistent increases in lung tumours after chronic inhalation exposure. In the nine rat studies identified, five were inhalation studies and four were intratracheal instillation studies. All studies except one inhalation study showed increased incidence of lung tumours. For the inhalation studies with treatment related tumours, concentrations ranged from 1 to 50 mg/m^3 (1, 6, and 30 mg/m^3 of DQ-12 quartz; 12 and 50 mg/m^3 of Min-U-Sil 5 quartz) and duration of exposure ranged from 29 days to 2 years. In the inhalation study with no treatment-related tumours, exposure was 60 mg/m^3 of Sikron F300 quartz for 13 weeks. The following is a description of the neoplastic results in the study also identified as the critical study for non-neoplastic results. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. In the exposed group, 18 animals developed tumours (12 in females, 5 in males), as opposed to 3 and 2 for the control and positive control groups respectively. The majority (10/18) of the tumours observed were adenocarcinomas. The mean mass of particles in the lungs at the end of the exposure period was 0.91 mg/lung.

For the intratracheal instillation studies, doses ranged from 4 to 57 mg/kg-bw (based on 7, 12 or 20 mg/animal of Min-U-Sil (5) quartz or 20 mg/animal of novaculite quartz). Exposure regimes were diverse and included single instillation with observation for up to two years, to weekly instillation for 10 weeks. It is noteworthy that the single intratracheal administration of a 95% pure quartz particles (<5 μm) resulted in an increased incidence of silicotic granulomas after 3 weeks and lung tumours after 11 months. The most common tumours reported across the long term rat studies were adenocarcinomas, however other tumours such as squamous-cell carcinoma, alveolar carcinoma and bronchiole-alveolar adenoma were also reported, and all animals that developed tumours also showed some degree of fibrosis.

Of particular interest is the intratracheal instillation study, investigating the sequence of pathological events leading to lung tumors. An unspecified number of rats/sex/dose received a single intratracheal instillation of various crystalline silica dusts or ferric oxide, allowing direct administration into the bronchial tree. The doses were 12 or 20 mg of Min-U-Sil 5 quartz (MQZ), 12 mg of hydrofluoric-acid-etched Min-U-Sil 5 quartz (HFMQZ), 12 mg of cristobalite, 12 mg of tridymite and 12 mg of ferric oxide suspended in saline. All groups were observed until six months post exposure, except for both MQZ groups, the HFMQZ and the ferric oxide group which were observed up until 17 months post-exposure. Interim sacrifices were conducted at 6, 11 and 17 months. The rat lungs showed a clear progression of effects. The sequence of pathological events were, an initial inflammatory response leading to a marked hyperplasia and hypertrophy of alveolar cells after one month, and at six months hyperplasia was evident but no lung tumours were observed. In this study, lung tumours were observed starting at the 11 month sacrifice with a 17% and 42% incidence in males and females (based on 3/18 males and 8/19 females), respectively, and at 17 months incidences were 32% and 59% (based on 6/19 males and 10/17 females, respectively). No lung tumours were found in ferric oxide treated rats. Similar studies have also been conducted in hamsters and mice. Although treated mice and hamsters showed treatment related signs (inflammation or fibrosis), no tumours were observed in hamsters. No increase in the incidence of lung tumours was seen in mice treated with quartz; however silicotic granulomas and lymphoid cuffing around airways but no fibrosis were seen in the lungs of quartz-treated mice.

Human epidemiology data

There is an extensive dataset of human studies investigating the link between crystalline silica exposure and cancer. IARC (1997) identified over 50 epidemiological studies based on occupational exposure to dust containing respirable crystalline silica. Main industry sectors from which the human data is derived include gold mines, foundries, granite/stone industry, pottery workers and refractory brick workers. From the least confounded studies, it was noted that lung cancer tended to increase with the following parameters: cumulative

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exposure; duration of exposure; peak intensity of exposure; presence of radiographically defined silicosis; and length of follow-up time from date of silicosis diagnostic. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics).

Since the 1997 IARC report, a large number of epidemiological studies have been published, with the more recent studies being updates from supplementary follow-up of results from previously assessed case-control studies cohorts, new results based on refined exposure assessments or adjustment for confounders or meta-analyses of the pooled data from these epidemiology studies

In a meta-analysis of the data from 10 cohort studies of gold, tin and tungsten miners, granite workers, industrial sand, diatomaceous earth and pottery workers with quantitative exposure estimates for crystalline silica were pooled in order to analyse the risk related to lung cancer. The pooled cohort standardized mortality ratio (SMR, against national rates) [See Appendix 1 for definition] was 1.2 (Confidence Interval [CI] 1.1-1.3). The results from the case-control analyses show a statistically significant trend with duration of exposure (odds ratios (ORs) [See Appendix 1] by quintile of cumulative exposure increased from 1.0 to 1.6 [CIs of 0.85 to 2.1] and by quintile of average concentration increased from 1.0 to 1.7 [CIs of 1.1 to 2.3]), supporting the importance of the increasing lung burden of silica in the occurrence of cancer. Overall, the authors concluded that the results support the carcinogenicity conclusion presented by IARC (1997).

To investigate the link between crystalline silica, silicosis and lung cancer, epidemiological data published between 1966 and 2001 were gathered. Over 50 studies were selected and pooled according to type of study and the parameter being linked to lung cancer (i.e. silica exposure, presence of silicosis in subjects). The quality of study, adjustment for confounding factors, co-exposure to other carcinogens and availability of a more recent analysis of a same cohort were taken into consideration in the final selection of the studies. Analysis of the relationship between exposure to silica and lung cancer included 17 cohort and 13 case-control studies. For the analysis of lung cancer versus silicosis, 11 cohort and 5 case-control studies were selected. The third analysis included 6 cohort and 2 case-control studies to evaluate the risk of lung cancer in non-silicotics. A random effect model was used to conduct each meta-analysis. Pooled cancer risk ratios (RRs) were 1.32 (CI 1.23-1.41) for crystalline silica exposure, 2.37 (CI 1.98-2.84) for individuals exposed to silica with confirmed silicosis (Silicotics) and 0.96 (CI 0.81-1.15) for individuals with no evidence of silicosis (non-silicotics) with confirmed exposure to silica, supporting the general observation that silicosis has a stronger temporal relationship with crystalline silica exposure and furthermore support the view that a human silicotic response could be a preliminary stage in the development of cancer.

A more recent meta-analysis included 28 cohort, 15 case-control and two proportionate mortality ratio (PMR) [See Appendix 1] studies from a variety of occupational settings conducted between 1996 and 2005. Risk ratios (RRs) were calculated based on type of study and silicosis status using fixed and random effect models (results presented here are from the random model). RRs for all cohort studies was 1.34 (CI 1.25-1.45), and were 1.69 (CI 1.32-2.16) for silicotics, 1.25 (CI 1.18-1.33) for those with undefined silicosis status and 1.19 (CI 0.87-1.57) for non-silicotics. In the case-control studies, the general RR was 1.41 (CI1.18-1.67), and the same sub-groups as mentioned above resulted in RRs of 3.27 (CI 1.32-8.2), 1.41 (CI1.18-1.70) and 0.97 (CI 0.68-1.38), respectively. The proportionate mortality ratio for the last two studies was 1.24 (CI 1.05-1.47). The authors noted that the association between lung cancer and exposure to crystalline silica was more consistent for silicotics, i.e., those diagnosed with silicosis and RR values split into type of occupational settings in which participants worked.

Based upon the above three meta-analysis studies and the epidemiology studies discussed in IARC (1997), the following can be concluded. Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis. Cancer risk is often more significant in workers exposed to crystalline silica over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours. Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles.

There have been reports of tumours outside of the lungs in persons with high silica exposure; however, these reports are sparse and the data inconsistent and have not been unequivocally linked to exposure to either one of the crystalline forms (quartz or cristobalite). Some of the reported locations are: oesophagus, stomach, liver, skin and bone. Sufficient epidemiological or toxicological data do not currently exist for quantitative assessment of the exposure-response relationship on these other tissues or organs.

Genotoxicity

Potential genotoxicity has been assessed in multiple *in vitro* and *in vivo* assays. Table 1 below gives a brief summary of the positive results observed in each type of assay.

Table 1. Summary of positive results over total number of results for each assay and each category (all studies

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conducted with crystalline silica: quartz, except where indicated).

Assay	Animal data		Human data		Positives/Total	
	In vitro	In vivo	In vitro	In vivo[d]	In vitro	In vivo
Rec Assay	0/1				0/1	
DNA strand break	1/1	2/2	5/5[b]	1/1	6/6	3/3
Sister chromatid exchange	0/1		0/1[c]	1/1	0/2	1/1
Micronucleus	2/3	0/1	2/2[b]	1/1	4/5	1/2
Chromosome aberration	0/1			1/1	0/1	1/1
Aneuploidy/polyploidy	0/3				0/3	
Cell transformation	4/4				4/4	
Hprt mutation	1/2	2/2[a]	1/1[b]		2/3	2/2
Oxidative DNA damage		4/5	2/2		2/2	4/5
DNA binding		1/1				1/1
p53 activation		0/1				0/1

a. one assay conducted with crystalline silica: cristobalite
b. one assay conducted with "ultrafine crystalline silicon dioxide".
c. crystalline silica: tridymite
d. crystalline silica dust (subtypes not provided).

All the *in vivo* human genotoxicity studies are based on three independent studies that used blood samples from workers from diverse occupational settings with confirmed exposures to crystalline silica dust; however, quantification of exposure was not provided. After stratification by smoking status, sister chromatid exchange remained statistically significant in both smokers and non-smokers although the frequency was higher in smokers. For the chromosome aberration assay conducted as part of the same study (blood samples from workers in the stone crusher industry), the increased frequency was no longer significant after stratification. In the DNA damage study of foundry and pottery workers and the micronucleus assay of workers involved in sandblasting and related jobs, results were positive when compared to controls. However, in both studies, smoking status influenced the results, contributing to the increased DNA damage observed since results were greater in smokers versus non-smokers, and the frequency of micronuclei in nasal epithelial cells was higher in smokers (p=0.002) but when using peripheral blood lymphocytes did not differ statistically between smokers and non-smokers who were similarly exposed to silica dust,

The role of *in situ* generation of reactive oxygen species (ROS) and reactive nitrogen species (RNS) has been well established in the following types of DNA damage: small scale insertions, DNA base pair deletion, base modification, chromosomal change/loss, microsatellite instability, DNA strand break, 8-hydroxydeoxyguanosine (8-OHdG) mutation and point mutations. ROS and RNS generation is postulated to be (a part of) the DNA damage mechanism for crystalline silica. Studies are described below to support this hypothesis.

DNA was exposed *in vitro* to various crystalline silica dusts, to H_2O_2, or to both. Results show that DNA damage was limited when dust or H_2O_2 were administered alone but increased with the co-exposure. When the reactive oxygen scavenger, dimethylsulfoxide, was added to the test system, DNA strand break was inhibited, data supporting the viewpoint that it is the presence of radicals generated in response to quartz and cristobalite that causes the DNA damage and not quartz or cristobalite themselves.

Hprt mutation assays in rat alveolar epithelial cells, both *in vitro* and *in vivo,* were positive in response to quartz. The positive results *in vivo* were seen only in the presence of significant inflammatory responses in the treated animals. Also, in a parallel *in vitro* experiment, rat alveolar epithelial cells were incubated with the bronchoalveolar lavage fluid from the rats exposed to quartz. Both macrophage and neutrophil enriched lavage cells induced mutation in the exposed alveolar epithelial cells. Addition of catalase (an enzyme which inactivates H_2O_2) before incubation inhibited the increase in *hprt* mutation.

Rats were exposed to either crystalline or amorphous silica in a manner to induce the same level of

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inflammation in the lungs. The inflammatory response was assessed by measuring the proportion of neutrophils in the bronchiolar lavage fluid. The actual concentrations were 3 and 50 mg/m^3 for crystalline and amorphous silica respectively. The animals were exposed for 13 weeks. *Hprt* mutation frequency was measured in the alveolar epithelial cells at the end of the exposure period. Mutation frequency was greatly increased only in the crystalline silica treated rats; no treatment related increase was found in the rats treated with the amorphous form.

In an 8-OHdG assay conducted to monitor DNA damage by reactive oxygen species, female rats were exposed to 0, 0.3, 1.5 and 7.5 mg/animal of quartz via intratracheal instillation. Effects were observed 90 days post-exposure. A clear dose-response relationship was identified between quartz exposure and various inflammation markers (differential cell count, protein, lung surfactant lipids and tumour necrosis factor alpha). Inflammation was present starting at the lowest dose. However, 8-OHdG showed a statistically significant increase starting at 1.5 mg/animal only. Similarly, in another study, 8-OHdG and DNA strand breaks were observed at concentrations of or above 10 ug/m^3 in rat lung epithelial cells.

In the aim of investigating the role of ROS in lung carcinogenesis, rat lung epithelial cells were incubated with polymorphonuclear (PMN) leukocytes (involved in the inflammatory process and responsible for the release of certain ROS) or hydrogen peroxide. Statistically significant increases in 8-OHdG were observed in the presence of PMN or hydrogen peroxide in a dose-response manner.

In a series of experiments which used *in vitro* stimulation of macrophages with crystalline silica and *in vivo* intranasal instillation of crystalline silica in mice, it was demonstrated that that the chronic fibrosis seen in a murine model of silicosis *in vivo* is dependent on the presence of adaptor molecule ASC and Nalp3 inflammazome. These data support a potential mode of action whereby silica triggers cellular responses that in turn activate alveolar macrophages, resulting in an inflammatory response and silicosis. In mice deficient in Nalp3 inflammazome, the development of inflammation and collagen deposition was significantly reduced compared with normal mice 3 months after the initial intranasal instillation of silica.

Analysis of Lung Tumour Data

The weight of evidence for both rats and humans indicates that fibrotic and silicotic lesions in the lung result from inhalation exposure to crystalline silica and that lung cancer is secondary to those lesions in the lung. Although the mechanism of induction for the lung tumours has not been fully elucidated, there is sufficient supportive mode of action evidence from the data presented to demonstrate that a threshold approach to risk assessment is appropriate based on an understanding of the key events in the pathogenesis of crystalline silica induced lung tumours. The body of evidence include the following:

- In experimental studies, all rats that developed tumours also showed fibrosis.
- Adenocarcinomas, the most common type of tumour identified in rats, are commonly associated with fibrosis and deeply scarred lung tissue.
- Experimental rat studies showed a clear progression of the effects from initially mild inflammation, followed by fibrosis over-time, leading eventually to lung tumours.
- Tumours are not present in all treated species dosed in the same way.
- The tumours, both in rats and humans, are concentrated in the lungs only, although other organs are indirectly exposed.
- In human studies, cancer risk is often more significant in workers exposed over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours.
- Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles
- Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis.
- For genotoxicity, in vitro results were mostly mixed and in vivo results were mostly positive. However, the vast majority of the positive genotoxicity assay results can be explained by the generation of reactive oxygen species, as demonstrated experimentally, where ROS scavenging prevents the genotoxicity.
- *In vivo*, macrophage deficient mice (macrophages produce ROS in response to crystalline silica) do not develop silicosis nor do they develop tumours and the Nalp3 inflammazome, a key player in the macrophage initiated inflammatory response, is required for the development of pulmonary fibrosis after

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inhalation of silica.

- Though inhalation exposure to crystalline silica in multiple occupational settings is clear, the increase in risk, based on the several recent meta-analyses of the multiple human epidemiological studies, remains low.

It is worth noting that where aggressive engineering controls have been made to reduce silica dust levels in the workplace (Sweden), silicosis has been eliminated. By corollary, existing exposures outside of the workplace in such areas do not pose a risk for silicosis to the general population.

The respirable forms of quartz and cristobalite possess properties indicating a hazard for human health (repeated dose toxicity, carcinogenicity and genotoxicity). The mode of action in the lungs involves irritation, inflammation and reactive species formation, leading to silicosis, and eventually to tumour formation.

Exposure

Uses

Consistent with oxygen and silicon being the two most abundant elements in the Earth's crust, silicon-oxide minerals, including quartz are ubiquitous in the natural environment. In particular, as a component of sand, quartz may find use in a diverse array of applications. Several high volume uses include, but are not limited to, the use of sand as a filling material for the construction of roads and in general building activities, the use of sand and gravel aggregates as abrasives on roads in winter and the use of fly-ash, which may contain 4-14% quartz and 0.5-1% cristobalite, as a cement additive. These abrasives when used on winter roads are usually mixed with road salts and may be sand only, stone dust, sand and gravel aggregates, or pre-treated sand. They are used mainly by rural municipalities or in areas where cold temperatures diminish the efficiency of salts for de-icing. Quantities of abrasives used in Canada were 5.73×10^9 kg, 4.59×10^9 kg, and 4.93×10^9 kg for 2007, 2008 and 2009, respectively.

Industrial sand, high purity silica sand products with closely controlled sizing are expected to contain quartz and cristobalite, include lump silica (2-3mm up to 15 cm or more), silica sand (75µm to 2-3mm) and silica flour (less than 75µm). Lump silica may be used in the production of silicon alloys, silica bricks, and the linings of certain types of pulverizers (eg. ball mills and tube mills).

Silica sand may be used in the manufacture of glass and glass fibres, silicate chemicals and silicon carbide, the hydraulic fracturing of wells, foundry moulding, and for sandblasting. Silica flour may find use in the ceramics and cement industries, as a filler and extender in rubber and coatings, and as an abrasive in soaps.

Natural clays, such as bentonite and fuller's earth, are used in cat litters for their high water absorbance capacities. Quartz is a natural component of these clays, and consequently, it may be present in cat litter products. High purity α-quartz is a piezoelectric material, which means that application of a voltage induces a distortion in the crystal shape and vice versa. This ability to interconvert electrical and mechanical energy has led to the use of quartz crystals in electronic devices requiring precise timing control, for example telephones, radios, watches and computers.

According to a survey conducted in Canada, quartz and cristobalite are also used in abrasives, adsorbents, filter products (diatomaceous earth), grout and cement. These substances reportedly also find use as fillers, which add bulk and improve wear resistance, in paints and coatings, adhesives, sealants, polymer films, caulking, epoxy resins and silicones. Also, quartz is listed as an ingredient in 60 cosmetic products in Canada. The types of products include anti-wrinkle preparation, eye and face makeup, lipstick, hair dyes, shampoos and grooming products, as well as skin cleansers, moisturizers and tanning preparations.

Natural Sources

In Canada, quartz naturally occurs in many types of rock formations. Those with high silicon dioxide content (95% SiO_2 or more) include vein and massive intrusion bodies, quartz pebbles, silica sand, sandstone and quartzite. Sandstone is a sedimentary rock mostly composed of quartz grains cemented by a bonding material such as clay, calcite or iron oxide. Quartzite is a hard, compact, metamorphosed sandstone made of grains of quartz firmly bonded with a siliceous cement. Mineral aggregates (e.g., sand and gravel) have variable silicon dioxide content. Quartz is also found as crystals, aggregates or discrete particles in certain igneous rocks (e.g., granites and pegmatites), soils, sediments, air and surface water. This omnipresence is consistent with the fact that silicon is the second most abundant chemical element on Earth.

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Cristobalite is naturally produced in the ashes of volcanic eruptions, and by combustion metamorphism which is a local phenomenon of spontaneous combustion of naturally occurring substances such as bituminous rocks, coal or oil. It may be found in cavities in volcanic rocks and in thermally metamorphosed sandstones and may also be a transient stage in the diagenesis of diatomaceous shale with the result that soils made of these geologic formations may be rich in cristobalite. Unlike quartz, the natural occurrence of cristobalite is limited to specific geographic regions and mineral types.

Anthropogenic Sources

Natural quartz is isolated from ore via beneficiation, which involves milling or grinding the material into particles that are separated into desired mineral and waste. The materials obtained are either used directly or further purified. In Canada, in 2006, 2.146×10^{9} kg of pure quartz were mined, and 2.385×10^{11} kg of sand and gravel aggregates were produced. The proportion of quartz in silica sand deposits and gravel aggregates will vary from one site to another.

Cristobalite can form from silica melts during the preparation of silica glass; quartz is not obtained from melts but is manufactured at elevated temperature and pressure via a hydrothermal process. Cristobalite also forms during the calcination[2] of diatomaceous earth.

Human Exposure Estimate

Ambient air

The exposure assessment is focussed on respirable quartz and cristobalite, which in ambient air comprises a component of total particulate matter (PM). In Canada, data on the concentrations of silicon in PM was available and used as a surrogate for quartz and cristobalite. This approach is conservative because the measured silicon includes all silicon-containing substances and therefore represents the upper limit for quartz and cristobalite in ambient air.

The National Air Pollution Surveillance (NAPS) Program measured concentrations in $\mu g/m^3$ of silicon in PM with aerodynamic radii less than 2.5 µm ($PM_{2.5}$ (dichot)), and from 2.5 to 10 µm (PM_{10} (dichot)) (the total particulate matter with aerodynamic radii less than 10 µm (PM_{10}) is obtained by adding these values) in Canada. In 2009, as part of the NAPS Program, silicon concentrations were determined on over 1600 samples of $PM_{2.5}$(dichot) and over 1500 samples of PM_{10}(dichot) at 24 urban locations across Canada. An estimate of exposure to quartz and cristobalite can be obtained by assuming that all the silicon in the PM is represented stoichiometrically as SiO_2, and multiplying the reported concentration of silicon by 2.14 to obtain a value for silica.

The intake of respirable quartz and cristobalite by the general population of Canada is estimated using a range covering the lowest 50^{th} percentile SiO_2 concentration in PM_{10}, measured in Pt. Petre, ON, (0.12 $\mu g/m^3$) to the highest 50^{th} percentile concentration in PM_{10} measured in Calgary, AB (2.1 $\mu g/m^3$). The 50^{th} percentile SiO_2 concentrations ranged from 0.1 to 2.1 $\mu g/m^3$ across the survey sites; the top of this range is quite close to the average of the maximum values for the 24 sites (3.7 $\mu g/m^3$). The outdoor data were used to represent the indoor levels, because information on indoor silicon concentrations was not available, and the range of PM_{10} measured indoors is generally lower than the outdoor range. Thus, this approach conservatively overestimates indoor exposure in homes.

The highest exposure group based on these calculations is children ages 0.5 to 4 years with an estimated daily intake ranging from 0.07 to 5.26 µg/kg-bw per day; the estimated daily intake decreases with age due to changes in the ratio of inhalation rates to body weights; the daily intake of adults, 20-59 years old, is estimated to range from 0.03 to 2.00 µg/kg-bw per day.

Consumer Products

Exposure to respirable quartz from the use of cosmetic products, which contained quartz as an ingredient, was considered low because they are not formulated for spray application, the loose powders were reported to contain less than 0.1% quartz, and in these products the substance is not expected to be associated with other components of the formulation and not available in a free form.

For consumer Do It Yourself (DIY) activities around the home, the highest mean breathing zone concentration of particles from sanding dry wall (median cut-point of 10µm) of 6.31 mg/m^3, was used to derive an upper-

[2] Calcinations: Heat treating a substance, but without fusion, to bring about change in its physical or chemical constitution.

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bound exposure estimate ranging from 2 to10 µg/kg-bw per event.

Quartz is used to formulate a large number of paints and coatings. To estimate potential inhalation exposure to quartz from these products, the spray painting of wall paints with an airless spray gun was considered appropriate as a conservative scenario. Exposure to respirable paint particles was estimated using data from controlled a laboratory study in which walls of poorly ventilated test rooms were painted by professional painters using an airless sprayer to apply interior latex paint. The maximum concentration of 13% quartz in paint in Canada was used to estimate exposure. The upper-bound estimate of exposure to quartz, based on the maximum concentration of 13% quartz in paint in the Canadian market and the maximum concentration of respirable paint particles measured in these controlled studies when recommended personal protective equipment is used, is 0.954 µg/kg-bw per event.

Inhalation of ambient air containing quartz and cristobalite is the dominant pathway of chronic exposure (excluding that from DIY activities) for the general population. Because SiO_2 makes up only approximately 5% of PM_{10}, silicon concentrations (expressed as SiO_2) measured in the Canadian NAPS survey of 24 urban locations were considered most relevant to the estimation of exposure by the general population. Quartz and cristobalite comprise only a portion of the total SiO_2 in PM_{10}, therefore, the use of the total silicon concentration to represent the upper bound crystalline silica concentrations results in an overestimation of exposure.

Appendix 1: Definitions of Epidemiological Terms in the ITAP

SMR (Standardized Mortality Ratio): The ratio (x 100) of observed to expected deaths in a study population. Expected deaths are calculated by applying a set of standard age-specific mortality rates to the age distribution of the study population. Standardized ratios are only useful for comparisons. They have no intrinsic meaning.

OR (Odds Ratio): In epidemiological case-control studies, a relative measure of disease occurrence. The odds in favour of a particular disease occurring in an exposed group are divided by the odds in favour of its occurring in an unexposed group. If the condition being studied is rare, the odds ratio is a close approximation to the relative risk.

RR (Risk Ratio): The probability of the occurrence of a disease in a group that has been exposed to some environmental, medicinal, microbial, or toxic influence, relative to its probability in a randomly selected population.

PMR (Proportionate Mortality Ratio): Proportionate mortality is the proportion of deaths in a specified population over a period of time attributable to different causes. Each cause is expressed as a percentage of all deaths, and the sum of the causes must add to 100%. These proportions are not mortality rates, since the denominator is all deaths, not the population in which the deaths occurred. Thus, proportionate mortality ratio is a measure of the frequency of occurrence of the proportionate mortality in a defined population during a specified interval of time.

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Toxicity Profile

2-Butoxyethanol
(CAS No. 111-76-2)

2-Butoxyethanol has been reviewed by U.S. EPA (2010) and an oral RfD and inhalation RfC is available in IRIS. An EU Risk Assessment Report is also available on 2-butoxyethanol (2006), an the information in this toxicity profile has been obtained from this report.

Toxicokinetics/Metabolism

Uptake of EGBE by the oral route is rapid and is assumed to be complete (100% absorption). In toxicokinetic studies involving radiolabeled EGBE, the forestomach, liver and kidneys were the organs where most of the radiolabel was found. The major metabolite of EGBE is butoxy acetic acid (BAA). EGBE is metabolized to butoxy aldehyde (BAL) by alcohol dehydrogenases, which is then further metabolized to BAA by aldehyde dehydrogenases. The metabolism of EGBE to BAA appears to be a saturable process. The other metabolites of EGBE are (in order of magnitude): the glucuronide conjugate of EGBE (a competing pathway to BAA formation and whose percentage increases relative to dose), the sulfate-conjugate of EGBE and ethylene glycol. Elimination is rapid and occurs mainly by urinary excretion. EGBE does not accumulate in tissues, and the metabolic profile does not change after repeated exposures compared to acute exposures.

The *in vitro* dermal uptake studies, measuring the rate of absorption of liquid EGBE through human skin, gave results that varied by a factor of 25 (0.064 mg/cm^2/hr for the lowest and 1.66 mg/cm^2/hr for the highest). *In vitro*, rate of absorption is highly dependent on the concentration of the aqueous solution of EGBE used. *In vivo*, in one study, an estimation of the skin penetration gave results in the following range: 7 to 96 nmol/min/cm^2 (0.008 mg/cm^2/hr to 0.0114 mg/cm^2/hr) for pure liquid EGBE. Another study performed with liquid EGBE has showed that greater absorption was found with EGBE 50% in water than neat EGBE (dermal flux 1.34 mg/cm^2/hr and 0.26 mg/cm^2/hr, respectively). This is consistent with data available *in vitro* and in animals. In the EU RAR, where required, a permeation rate of 0.63 mg/cm^2/hr will be used. This is the upper figure from the *in vivo* data and is consistent with the *in vitro* data.

PBPK models has been developed for EGBE and can be used to derive animal to human toxicokinetic extrapolation factors for the inhalation route. These factors are based on the toxokinetics of BAA since this is the metabolite that causes the critical toxic effects.

Acute Toxicity

The oral LD_{50} values are >1,000 mg/kg, and the dermal LD_{50} for rabbits (the most sensitive species) is approximately 500 mg/kg. The 4-hour LC_{50} in rats is approximately 450 ppm (2,214 mg/m^3), with higher values seen in other species.

Suicide cases suggest that the LOEL in humans is about 400 mg/kg. It should be noted that this is a worst case estimation of the LOEL derived from McKinney *et al.* (2000) in which the possible range of exposure was between 400 and 1200 mg/kg.

EGBE causes hematotoxicity *in vivo* in rats, and that the metabolite BAA is considered responsible for this effect. The rat, mouse, hamster and baboon are very sensitive to the hemolytic effects of EGBE; whereas the dog, guinea pig, pig, cat, rabbit and humans (30-times less sensitive than rats) are resistant to EGBE-induced hematoxicity. The hemolysis from EGBE exposure is due to a decrease of erythrocyte deformability due to erythrocyte swelling (this also explains the formation of thrombosis). Newly formed erythrocytes are more resistant than old ones.

Irritation

EGBE is moderately irritating to the skin of rabbits when applied under occlusive conditions for 4 hours. It is also an irritant or severely irritant to the eyes of rabbits.

Sensitization

EGBE is not a skin sensitizer to guinea pigs. A 10 % (v/v) aqueous solution of EGBE was not sensitizing in a human repeat patch test.

Repeated Dose Toxicity (Oral Studies Only)

Male and female Sherman rats were fed in their diets 0, 0.03, 0.125, 0.5 or 2% EGBE for 90 days. The average daily intakes were 0, 18, 76, 310 or 1,540 mg/kg-day. There were no treatment-related deaths and appetite was not affected. Tests for blood in pooled urine sample after 3 and 6 days of testing from the 0, 0.5 and 2% groups were negative. The mean weight gain was lower in the 2% group compared to controls. Relative kidney and live weights were increased in the 2% group, and relative liver weights were only increased in the 0.5% group. No adverse histopathological effects were observed The NOAEL can be considered to be 0.125 % (76 mg/kg-day) (Mellon Institute of Industrial Research, 1952; EU, 2006).

Male and female DW albino rats were given in their diet 0, 0.01, 0.05, 0.25 or 1.25% EGBE (corresponding to 7, 38, 188 or 919 mg/kg-day for males; and 0, 9, 41, 222, or 976 mg/kg-day for females) for three months. There was one death in the 1.25% group on day 73 of the study. Food consumption was decreased in the 1.25% group (both sexes). There was also a significant decrease of food consumption in the 0.25% males. Body

weight gain was significantly decreased in the 1.25 % animals (both sexes) and in the 0.25% males. Mean liver and kidney weight of males and females were significantly increased in the 1.25% group. The testes were atrophied in the 0.25 and 1.25% males. The NOAEL for this study can be considered to be 0.05%. (Mellon Institute of Industrial Research, 1963; reviewed in EU, 2006).

Rats (CR, COBS, CD-BR) were dosed by oral gavage with 0, 222, 443 or 885 mg/kg-day EBGE, five days/week for 6 weeks. In the high-dose animals, there was mortality (2/10) and significantly decreased body weight gain and food consumption (from days 3 to 20 of the study). Bloody urine, which persisted through the third week of treatment, was observed in the mid- and high-dose group; only one rat in the low-dose group had bloody urine. Other clinical signs in the mid- and high-dose groups were lethargy, unkempt hair coats, piloerection, rales, slight weakness and inactivity. In all treatment groups, there were significant effects on red blood cell (RBC) parameters, indicating hemolytic anemia. No effects were seen on white blood cells (WBC). There was a significant increase of alkaline phosphatase was seen from the mid-dose group. In the high-dose group, there was a significant increase of SGPT and a decrease of glucose. Absolute and relative spleen weights were increased for the middle and high dose of EGBE. Liver weights were slightly increased (only significant for relative weight) in the high-dose group. No effects were seen on testes weight (relative or absolute) at any dose group. Gross pathology showed only enlarged, dark spleens in the mid- and high-dose groups. Histopathological lesions were hyperkeratosis and acanthosis in the stomach epithelium in all treated animals. Hepatomegaly was also seen in 4 out of 10 animals of the high dose group. Hemosiderin deposition was seen in some animals (6/10 and 7/10 in the mid- and high-dose groups, respectively). Thymus atrophy was seen in one animal of the high-dose group. Congestion of the spleen was seen in all treated animals. Extramedulary hematopoiesis was reported for one animal in the high-dose group and hemosiderin deposit in the majority of animals of the mid- and high-dose group animals. The LOAEL for this study is considered to be 222 mg/kg-day based on effects in the spleen and on RBC parameters. A NOAEL was not obtained (Eastman Kodak, 1982).

Male and female F344/N rats were given in their drinking water 0, 750, 1,500, 3,000, 4,500 or 6,000 ppm EGBE for 13 weeks. Based on water consumption, the average daily intake was 0, 69, 129, 281, 367 or 452 mg/kg-day for males; and 0, 82, 151, 304, 363 or 470 mg/kg-day for females. Supplemental groups were included for hematology and clinical chemistry observations at weeks 1 and 3. There was no mortality and no clinical signs of toxicity. Reduced body weight gain was seen in the $\geq$4,500 ppm animals. There were reductions in drinking water consumption in the higher dose groups (both sexes), this being clearly concentration-related in females, from a mean of 18.8 mL/day in the control group to 10.7 mL/day in the 6,000 ppm group. A markedly macrocytic and mildly hypochromic anemia was observed at each time point and reticulocyte counts were moderately increased in weeks 1 and 13. For males there was a decrease in erythrocyte counts at all time points in the $\geq$3,000 ppm groups, while in females the decrease occurred in the $\geq$1,500 ppm groups. A consistent thrombocytopenia was observed at all time points in $\geq$4,500 ppm males and females; it also occurred in the 3,000 ppm females at week 13. The most consistent blood chemistry observation was an

increase in alkaline phosphatase, particularly in the high dose groups. This observation is consistent with mild cholestasis. Thymus weights were significantly reduced in 4,500 ppm males of the 4,500 ppm and the 6,000 ppm males and females. Other organ weight changes were found, but these appeared to be secondary to body weight gain reduction (spleen was not weighed). Histopathological effects were seen in the liver, spleen and bone marrow of both male and female rats. The liver changes were primarily centrilobular hepatocellular degeneration and centrilobular Kupffer cell pigmentation. These changes were present in the majority of dosed rats, but they were more prevalent in the $\geq$3,000 ppm animals and were slightly more severe in females. In addition, the cytoplasm of hepatocytes of treated rats was more eosinophilic and lacked the ampholytic-to-basophilic granularity typical of the controls. In the spleen there was an increase in hematopoiesis and deposition of hemosiderin. In bone marrow there was an hyperplasia characterized by an increase of hematopoietic cells and decrease in marrow fat cells. All of these lesions were present in the majority of dosed rats, but they were more prominent in the $\geq$3,000 ppm animals. Testis weights were unaffected by treatment, but the size of the uterus in the $\geq$4,500 ppm groups were reduced. Changes in uterine weight were considered by the authors to be secondary to the reduction in body weight gain rather than a direct effect of EGBE. Sperm concentration was slightly decreased in all treated males (not dose-related); all other sperm measurements were similar to controls. Estrous cycle length was unaffected by treatment, although the $\geq$4500 ppm females spent more time in diestrous than the other groups. This correlated with the smaller uterine size, which was attributed to a secondary consequence of reduced body weight gain. The LOAEL for this study is 750 ppm (69 and 82 mg/kg-day for males and females, respectively). A NOAEL was not obtained (NTP, 1993).

Male and female B6C3F$_1$ mice were given in their drinking water 0, 750, 1,500, 3,000, 4,500 or 6,000 ppm EGBE for 14 weeks. Based on water consumption, the average daily intake was estimated to be 0, 118, 223, 553, 676 or 694 mg/kg-day for males; and 0, 185, 370, 676, 861 or 1,306 mg/kg-day for females. There was no mortality and no significant clinical signs of toxicity. Reduction in body weight gain was seen in the $\geq$3,000 ppm males and females. Water consumption did not appear to be affected by treatment. Organ weight changes were considered secondary to body weight gain reduction. No treatment-related gross or microscopic lesions in male or female mice were observed. The NOAEL for this study is 223 and 370 mg/kg-day for males and females, respectively. However, this study did not include hematology measurements (NTP, 1993).

Genotoxicity

Below are the conclusions from the EU Risk Assessment Report on 2-butoxyethanol.

EGBE is not mutagenic in bacteria. One report showed a significant response in *S. typhimurium* strain TA97a (Hoflack *et al.*, 1995). This finding could not be substantiated by Gollapudi e*t al.* (1996). The metabolites butoxy aldehyde (BAL) and butoxy acetic acid (BAA) are also not mutagenic to bacteria. No mutagenic activity was observed in

two of three *in vitro* mammalian cell mutation assays; the other study, which was poorly reported, showed a positive finding at very high concentrations. The same study also reported a positive finding with a very high concentration of BAL, whereas another study showed not effects at slightly lower concentrations. No *in vitro* mammalian cell mutation assays have been conducted with BAA.

Inconsistent findings have been reported for SCE induction with EGBE. Inhibition of gap-junctional intercellular communication was reported in a single study with EGBE and its two major metabolites. A significant response was seen in a single assay for UDS induction with a technique that is now considered to be invalid.

EGBE has not been shown to induce chromosomal aberrations in a number of mammalian cell culture studies, or in one study with BAL or BAA. Weak aneugenic effects were seen in one study with EGBE and BAL, but not with BAA. *In vitro* studies with long exposure to BAL, and to a much less extent with EGBE itself, appear to induce micronuclei from aneuploidy rather than from chromosomal breakage.

There is no evidence for micronucleus induction in bone marrow cells or interaction with DNA in several organs of rats from *in vivo* exposure. The possibility of non-disjunction occurring and not being detected in these assays appears to be remote, because BAA produced no evidence of aneugenicity in vitro. BAA is rapidly formed *in vivo* and is by far the most prevalent blood metabolite of EGBE; thus, exposure of possible target cells to either EGBE or BAL at high concentrations is brief. Overall, the evidence suggests that EGBE does not pose a significant mutagenic potential *in vivo*.

Carcinogenicity

Male and female F344/N rats were exposed by inhalation to 0, 31.2, 62.5 or 125 ppm (0, 151, 302 or 604 mg/m^3) EGBE vapor for 6 hours/day, five days/week for 104 weeks (NTP, 2000). For hematological and bone marrow analyzes, additional groups of animals were exposed to 0, 62.5 or 125 ppm for evaluation at 3, 6 and 12 months; and to 31.2 ppm for 3 months (hematological examination only) and 6 months. Survival of exposed male and female rats was similar to the control animals, and no clinical signs were attributed to EGBE exposure. Body weights of male and female rats in the low- and mid-dose groups and the high-dose males were generally similar to the controls throughout the study. Body weights of the high-dose female rats were generally lower than those of the controls from week 17 until the end of the study. The incidence of benign or malignant pheochromocytoma (combined) of the adrenal medulla in females exposed to 125 ppm EGBE was not significantly increased compared to the chamber controls, but it did exceed the historical control range. There was only one malignant phaeochromocytoma, which occurred in the 125 ppm group. It was concluded that there was no evidence for carcinogenicity in male rats and equivocal evidence for carcinogenicity in female rats.

Male and female B6C3F$_1$ mice were exposed by inhalation to 0, 62.5, 125 or 250 ppm (0, 302, 604 or 1,208 mg/m^3) EGBE vapor for 6 hours/day, five days/week for 104 weeks (NTP, 2000). For hematological and bone marrow analyzes, additional groups of animals were exposed to 0, 62.5, 125 or 250 ppm for evaluation at 3, 6 and 12 months. Survival of male mice exposed to 125 or 250 ppm was significantly less than that of the controls, whereas survival in all other treated groups was similar to the controls. No clinical signs were attributed to EGBE. Body weights of exposed male mice were generally less than the controls during the last 25 weeks of the study. Body weights of the high-dose females were generally lower than the controls from week 30 until the end of the study, the difference being about 20% for much of that time. Body weights of the low- and mid-dose groups were generally lower than the controls from about week 60 until the end of the study. There was a positive trend in the incidences of forestomach squamous cell papilloma and squamous cell papilloma or carcinoma combined in female mice. The incidences were significantly increased in the 250 ppm group, in which the only squamous cell carcinoma occurred. These incidences exceeded the historical control range for female mice. There was no significant increase in the incidence of these neoplasms in male mice, but they did exceed the historical control range for male mice. Again, there was one squamous cell carcinoma, but in the 125 ppm group.

There was a positive trend in the incidence of hemangiosarcomas in male male mice, which was statistically significant in the 250 ppm group. The incidence at 250 ppm also exceeded the historical control range for this tumor in male mice. There was also a positive trend in the incidence of hepatocellular carcinomas, which was statistically significant in the 250 ppm group. There was, however, no change in the incidence of hepatocellular adenomas and carcinomas combined, because of a reduced incidence of hepatocellular adenomas in the treated groups. In female mice there was a single haemangiosarcoma, in the 62.5 ppm group, which was considered to be an incidental finding. Furthermore, the incidences of hepatocellular adenomas were reduced in the 125 and 250 ppm groups of female mice and there was no change in the incidence of hepatocellular carcinomas. The NOAEC for tumorigenicity in mice is 125 ppm, based on an increased incidence of hemangiosarcomas in males and squamous cell papillomas or carcinomas in females at 250 ppm.

Proposed Mode of Action (MOA) for Forestomach and Liver Hemangiosarcomas in Female and Male Mice from EGBE Exposure

The EU Risk Assessment Report (2006) evaluated the MOA for the forestomach and liver hemangiosarcomas in female and male mice and the relevancy of these tumors for human health risk assessment using the IPCS Human Relevance Framework.

I. Postulated Mode of Action for the Induction of Tumours of the Forestomach in Female Mice

"The proposed mechanism of action for production of tumours in the forestomach is the local generation, as well as accumulation of cytoxic metabolite(s) that induce a sustained, compensatory cell proliferation, neoplasia arising out of this proliferating cell population.

The neoplasia was mainly papillomas, a single squamous cell carcinoma arising in the highest dose group of female mice."

II. Postulated Mode of Action for the Induction of Hamangiosarcomas of the Liver in Male Mice

"The proposed mechanism of action for production of haemangiosarcomas of the liver is the deposition of haemosiderin in relevant cell-types, possibly including endothelial cells from which haemangiosarcomas arise, and the generation of cytotoxic reactive oxygen species that either induce genetic changes by this secondary mechanism or sustained cell proliferation within the endothelial target tissue, neoplasia arising out of this proliferating cell population."

III. Summary

"EGBE is carcinogenic in male mice, where it causes a low incidence of haemangiosarcomas, and female mice, where is causes an increased incidence of forestomach tumours. It is not carcinogenic in rats. Genotoxicity is not an important toxicological property of this chemical and it is unlikely that the low, variable and uncertainly defined genotoxic activity can be the cause of the carcinogenic responses. Hypotheses have been proposed and supported by experiment data in an attempt to explain the carcinogenic responses…In the case of forestomach tumors, the argument that they arise in a tissue subject to sustained abuse and consequent repair is clear. It is likely that this finding is in reality not sex specific but merely due to chance that the low level incidence in females rose above the level of statistical significance but it did not do so in males. In the case of the haemangiosarcomas, data from experiments with other chemicals show that mice are more susceptible to haemangiosarcoma development than are rats, and male mice are more sensitive than female mice, but the database in support of the hypothesis that life-long exposure of the liver to Kupffer cell pigmentation is a pre-requisite for an increase in liver haemangiosarcoma rates in male mice is small, after exclusion of doubtful examples. With the rejection of genotoxicity as a possible mechanism, strong evidence for a potential source of reactive oxygen species within the liver, and a mode of action where each step has at least some supporting data, it is reasonable to presume that these may play a role in the neoplasia."

"With regard to human relevance, the mechanism proposed for the induction of haemangiosarcomas strongly suggests that EGBE is not likely to be a carcinogenic hazard under conditions of normal handling and use, because human erythrocytes are demonstrably more resistant to haemolysis than are rodent erythrocytes. The mechanism proposed for the induction of forestomach tumours would also point to a lack of human relevance under conditions of normal handling and use. As stated recently (IARC, 2003), while people do not possess forestomachs, they do have comparable squamous epithelial tissues in the oral cavity and the upper two-thirds of the oesophagus. Thus, in principle, carcinogens targeting the forestomach squamous epithelium in rodents are relevant for man. However, the relevance for man is probably low for agents that have no demonstrable genotoxicity and that are solely carcinogenic for the forestomach squamous

epithelium in rodents after oral administration. Consequently, for these agents, the mode of carcinogenic action could be specific to the experimental animals (IARC, 2003). EGBE satisfies only some of these conditions. On the other hand, there are proposed mechanisms that are supported by experimental evidence to show how this chemical, even when inhaled, can accumulate in the forestomach contents, where it can remain for many hours to cause damage directly or after its metabolism to BAA."

"In conclusion, given the species and sex specificity of the neoplastic responses and the current evidence supporting the hypothesis that the more likely mechanism of action is based on haematotoxicity, then EGBE is unlikely to be a human carcinogen."

Reproductive Toxicity

Male and female Swiss CD-1 mice were given in their drinking water 0 0.5, 1.0 or 2.0 % EGBE (equivalent to daily intakes of 0, 720, 1340 and 2050 mg/kg-day) during a continuous breeding phase (CBP) with a 7-day pre-mating period and a 98-day cohabitation period (Morrissey *et al*., 1988,1989; Heindel *et al.*, 1990). There were significant adverse reproductive effects in the females at very high dose levels ($\geq$1,340 mg/kg) which also caused severe toxicity, including death. Under the conditions of the study, the NOAEL for reproductive toxicity of EGBE (fertility) was considered to be 720 mg/kg-day. For developmental toxicity, a NOAEL could not be derived. There was a very slight decrease in pup weight was observed at 720 mg/kg-day. No NOAEL or LOAEL can be determined for systemic parental toxicity because this kind of study is not designed to assess systemic toxicity although it is of note that there were effects (reduced fluid consumption) even at the lowest dose of 720 mg/kg-day.

There were no macroscopic nor microscopic effects on the reproductive organs in the repeated dose toxicity studies at doses which does not result in severe general toxicity.

Developmental Toxicity (Oral Studies Only)

A developmental toxicity study was conducted by oral gavage using Fischer 344 rats with the purpose of determining whether the exposure of pregnant rats to EGBE during critical periods of cardiovascular development adversely affected the structure of the fetal heart and great vessels. Pregnant rats were dosed on GD 9-11 with 0, 30, 100 or 200 mg/kg EGBE, with some animals sacrificed on GD 12 and others sacrificed on GD 20. Other group of pregnant rats were dosed on GD 11-13 with 0, 30, 100 or 300 mg/kg EGBE, with some animals sacrificed on GD 14 and the others sacrificed on GD 20. At doses of $\geq$100 mg/kg on GD 9-11 and GD 11-13, there was marked body weight reduction and/or weight gain, increased kidney and spleen weights, and severe hematotoxicity. The hematotoxicity was characterized by a large reduction in circulating red blood cells, hematocrit and hemoglobin, which occurred 24 hours post-treatment. The observed embryo/fetal effects included increased resorptions, non-live implants, and adversely affected implants per litter in the 200 mg/kg dose group of the GD 9 – 11 treated dams,

and decreased platelet count but no embryolethality in the 300 mg/kg dose group of the GD 11-13 treated dams. EGBE treatment did not increase malformations, including cardiovascular malformations. Increased fetal lethality did occur in the 200 mg/kg dose group when given during GD 9-11, but there were no increased malformations. Increased platelet count was also seen in the fetuses of the 300 mg/kg dose group given during GD 11-13. The maternal NOAEL for this study is 30 mg/kg-day. The developmental NOAEL is 100 mg/kg-day when EGBE is given on GD 9–11, and the NOAEL is 300 mg/kg-day when EGBE is given on GD 11–13 (Sleet *et al.*, 1991).

Pregnant CD-mice were dosed by oral gavage with 0, 350, 650, 1,000, 1,500 or 2,000 mg/kg EGBE during GD 8 to 14. Maternal toxicity was evident in the dams at dosed of ≥650 mg/kg. There were hemolytic effects (≥650 mg/kg) and mortality (≥1,500 mg/kg). At 1,000 and 1,500 mg/kg, increased resorption rates and numerically reduced number of viable fetuses were observed at 1,000 and 1,500 mg/kg. Cleft palates were seen in 4/43 fetuses (in one litter) at 1,000 mg/kg/day and 1/25 at 1,500 mg/kg. The NOAELs for maternal and developmental toxicity are 350 and 650 mg/kg-day, respectively (Wier *et al.*, 1987).

A subsequent reproduction study was conducted which followed a Chernoff modification study design with treatment of the pregnant mice at 650 or 1,000 mg/kg-day between GD 8 and 14; the animals were allowed to give birth and the offspring were observed until PND 22. Hemolytic effects and reduction in body weight were seen in the dams at 1,000 mg. There were no adverse developmental effects including pup growth or survival. The NOAELs for maternal and developmental toxicity are 650 and 1,000 mg/kg/day, respectively.

In another Chernoff assay, fifty mated CD-1 mice were dosed by oral gavage with 1,180 mg/kg-day EGBE (in corn oil) from GD 7 to 14, then allowed to litter and to rear pups to PND 3. Nineteen of the dams died (20%), maternal weight gain was reduced and there were only 24 viable litters (77 %) from the surviving dams compared with 97 % in the controls. There was no external malformations, pup survival to PND was unaffected, and there was no other evidence of developmental toxicity (Schuler *et al.*, 1984).

Key Study/Critical Effect for Screening Criteria

An oral RfD was derived by U.S. EPA (2010) based on the findings of the NTP chronic inhalation studies, the rationale being the limited oral database and because the critical endpoint, hemosiderin pigmentation, was more pronounced in the chronic inhalation study (NTP, 2000) versus the available subchronic oral study (NTP, 1993). The following information on the NTP chronic studies was obtained from IRIS:

"In this chronic study, animals were exposed to EGBE 6 hours/day, 5 days/week at concentrations of 0, 31, 62.5, and 125 ppm (0, 150, 302, and 604 mg/m^3) for groups of 50 F344/N rats and 0, 62.5, 125, and 250 ppm (0, 302, 604, and 1,208 mg/m^3) for groups of 50 B6C3F$_1$ mice. The researchers stated that the highest exposure was selected to

produce a 10-15% depression in hematologic indices. They reported that no effect on survival was observed in rats, but survival was statistically significantly decreased in male mice exposed to 125 or 250 ppm, compared with chamber controls (54, 52, and 78% respectively). Although statistics were not reported for mean body weights, the rats exposed to 31 and 62.5 ppm had similar mean body weights to the control rats. Mean body weights of the exposed mice were generally less than for controls, with females experiencing greater and earlier reductions. From week 17 to the end of the study, the mean body weights of 125 ppm female rats were generally less than those of controls. Non-neoplastic effects in rats included hyaline degeneration of the olfactory epithelium in males (13/48, 21/49, 23/49, 40/50) and females (13/50, 18/48, 28/50, 40/49) and Kupffer cell pigmentation in the livers of males (23/50, 30/50, 34/50, 42/50) and females (15/50, 19/50, 36/50, 47/50). The severity of the olfactory lesion was not affected by exposure. The Kupffer cell pigmentation is a result of hemosiderin accumulation and is a recognized secondary effect of the hemolytic activity of EGBE."

"Statistically significant effects observed in mice included forestomach ulcers and epithelial hyperplasia, hematopoietic cell proliferation and hemosiderin pigmentation in the spleen, Kupffer cell pigmentation in the livers, and bone marrow hyperplasia (males only). Hyaline degeneration of the olfactory epithelium (females only) was increased relative to chamber controls but was not statistically significant. As in the rats, the Kupffer cell pigmentation was considered a secondary effect of the hemolytic activity of EGBE. Bone marrow hyperplasia, hematopoietic cell proliferation, and hemosiderin pigmentation in the spleen were also attributed to the primary hemolytic effect; it was followed by regenerative hyperplasia of the hematopoietic tissue. The forestomach lesions did not appear to be related to the hemolytic effect of EGBE. Incidences of ulcer were significantly increased in all exposed female groups, as well as males exposed to 125 ppm. Incidences of epithelial hyperplasia, usually focal, were significantly increased in all exposed groups of males and females. The hyperplasia was often associated with ulceration, particularly in the females, and consisted of thickness of the stratified squamous epithelium and sometimes the keratinized layer of the forestomach. Ulceration consisted of a defect in the forestomach wall that penetrated the full thickness of the epithelium and frequently contained accumulations of inflammatory cells and debris."

"Using the same exposure levels described above, additional groups of rats (27/gender/exposure group) and mice (30/gender/exposure group) in the 2-year study were examined at 3, 6, and 12 months (8-10 animals/time point) for hematologic effects. Nine male and nine female rats were exposed to 31 ppm EGBE, specifically to evaluate hematology at 3 months and to receive a total evaluation at 6 months. Animals were continuously exposed, as described above, until their sacrifice at 3, 6, or 12 months. As in the 14-week study, inhalation of EGBE by both species resulted in the development of exposure-related hemolytic effects, inducing a responsive anemia. In rats, the anemia was persistent and did not progress or ameliorate in severity from 3 months to the final blood collection at 12 months. Statistically significant ($p < 0.05$) decreases in automated and manual hematocrit (Hct) values, hemoglobin (Hb) concentrations, and red blood cell (RBC) counts occurred at 3, 6, and 12 months in the 125 ppm female mice and the 250 ppm male and female mice. Statistically significant decreases in these same endpoints

were also observed in 62.5 ppm females at 6 months and in 125 ppm males at 6 and 12 months (decreases in Hct were observed only at 3 and 6 months). Mean cell volume (MCV) was increased in female mice at the highest duration (12 months) and exposure (250 ppm) levels. Reticulocyte counts were increased significantly in the 125 ppm females at 3 and 6 months and in the 125 ppm males at 6 months of exposure."

U.S. EPA used a route to route extrapolation from the NTP (2000) study for the derivation for the RfD. The dose metric used for animal-to-human and route-to-route (inhalation-to-oral) extrapolation for the derivation of the RfD is the area under the curve (AUC) of BAA at 12 months in arterial blood. This dose metric was used for dose-response modeling of chronic inhalation data to derive the point of departure (POD) of 133 µmol-hour/L, expressed as a BMDL based on animal data. The corresponding human BMDL was then back-calculated using the human PBPK model (Corley *et al.*, 1994; Corley *et al.*, 1997) to obtain an equivalent human oral drinking water dose ($BMDL_{HED}$) of 1.4 mg/kg-day. A simplifying assumption was used that the entire dose of drinking water EGBE was consumed over a 12-hour period each day.

U.S. EPA Oral Reference Dose (RfD) = 1.4/100 = 0.1 mg/kg/day

Drinking water guidance value = 0.5 ppm

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Toxicity Profile

Ethanol
(CAS No. 64-17-5)

Ethanol has been reviewed in the OECD-SIDS program (OECD, 2004a,b).

Acute Toxicity

Ethanol has a low order of acute toxicity by all routes of exposure. The lowest well-conducted acute oral LD_{50} value is 8,300 mg/kg in mice, and an inhalation 1-hour LC_{50} value of >60,000 ppm (114,000 mg/m^3) in mice.

Irritation

Ethanol is a moderate eye irritant but it is not a skin irritant.

Sensitization

Ethanol is not a sensitizer.

Repeated Dose Toxicity

There are numerous repeat dose toxicity studies on ethanol by the oral route. Many of these studies were designed to increase our understanding of the risks associated with alcoholic beverages. Thus, these studies were carried out by the oral route and at high doses. The selected studies were considered appropriate for risk assessment purposes.

In a 90-day study, male and female Sprague-Dawley rats were fed a diet containing 0, 1, 2, 3, 4, 5 or 10% ethanol. The 2% dose was calculated to be equivalent to 2,400 mg/kg/day. There were no deaths and no clinical signs of noted. Weight gain throughout the study was unaffected by treatment, but the final weights decreased with dose. Food and water consumption in the 10% group was reduced relative to controls. There was no treatment-related effect on serum liver enzymes and kidney clinical chemistry findings were minimal. In the liver, centrilobular steatosis increased in severity with dose as did the frequency and severity of Mallory bodies (hyaline) and acidophilic degeneration and necrosis. Most liver findings were absent or mild at 2% ethanol but became more significant at $\geq$3%. The NOAEL for this study has been established to at 2% (2,400 mg/kg/day).

In an NTP 90-day study, F344/N rats and $B6C3F_1$ mice were given in their drinking water 0 or 5% ethanol in drinking water. Based on the water consumption data in the

study and averaged body weights over the exposure period, this equated to doses of at least 4,000 mg/kg in rats and 7.500 mg/kg in mice. Male rats showed minor changes to organ weights and hematology and clinical chemistry parameters (these were not considered to be adverse changes); female rats showed minor clinical chemistry changes and increased length of estrus cycle, as well as liver nodules. The male mice showed increased organ weights, fatty changes to the liver, and a decrease in sperm concentration.

In the NTP two-year bioassay, B6C3F$_1$ mice were given in their drinking 0, 2.5% and 5% ethanol Concentrations of 2.5% and 5% ethanol resulted in average daily consumption of approximately 100 and 180 mg ethanol for males and 80 and 155 mg for females. There was a marginal exposure-related increase in survival of the males, but no effect on the survival of the females. Water consumption was reduced with increasing concentrations of ethanol which was more marked in males than females. No further information was given on non-neoplastic effects.

Genotoxicity

The balance of evidence is that ethanol is not genotoxic. Negative results from a number of bacterial mutation assays appear to be reliable. Of the mammalian cell mutation assays a weak mutagenic effect in mouse lymphoma cells occurred only at very high ethanol concentrations. *In vivo* tests for chromosome aberrations in both rats and Chinese hamsters have given negative results. There is very little evidence to suggest that ethanol is genotoxic in somatic cells and it may have a very limited capacity to induce genetic changes *in vivo* but under very specific circumstances and at very high doses achievable in humans only by deliberate oral ingestion.

Carcinogenicity

Evidence of the carcinogenicity of ethanol is confined to epidemiological studies assessing the impact of alcoholic beverage consumption. These do not indicate any such hazard exists from potential exposure to ethanol in the work place or from the use of ethanol in consumer products.

Reproductive/Developmental Toxicity

The lowest reported NOAEL for fertility by the oral route was 2,000 mg/kg in rats, equivalent to a blood alcohol concentration of 1,320 mg/L, although this was based on a significant increase in the number of small pups rather than a direct effect on fertility; such direct effects are not seen until much higher doses. Many studies exist examining the developmental end point for ethanol. However, most use very high doses and few are individually robust enough to allow a NOAEL to be established. However, the collective weight of evidence is that the NOAEL for developmental effects in animals is high,

typically >6,400mg/kg, compared to maternally toxic effects at 3,600 mg/kg. The potential for reproductive and developmental toxicity exists in humans from deliberate over-consumption of ethanol. Blood ethanol concentrations resulting from ethanol exposure by any other route are unlikely to produce reproductive or developmental effects.

Key Study/Critical Effect for Screening Criteria

The lowest reported NOAEL is approximately 2,400 mg/kg/day from a 90-day dietary study with rats.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (subchronic to chronic)

Oral RfD = 2,400/1,000 = 2.4 mg/kg/day

Drinking water guidance value = 8.4 ppm

References

OECD (2004a). IUCLID Data Set for Ethanol (CAS No. 64-17-5), UNEP Publications.

OECD (2004b). Screening Information Dataset (SIDS) Initial Assessment Report for Ethanol (CAS No. 64-17-5), UNEP Publications.

Toxicity Profile

Guar Gum
(CAS No. 9000-30-0)

Guar gum (CAS No. 9000-30-0) is the milled endosperm of the leguminous plant *Cyanopsis tetragonolobus*. Structurally, it is a galactomannan consisting of a main chain of D-mannose with a side chain of D-galactose at approximately every second mannose unit. The mannose units are β-(l-4) linked, and the single D-galactose units are joined to the main chain by α-(1-6) linkages. The estimated molecular weight of guar gum cranges from 200,000 to 300,000 daltons (Glickman, 1969).

Guar gum is approved for use as a food additive by the U.S. Food and Drug Administration and is on the list of substances "generally recognized as safe" (CFR 1974).

Acute Toxicity

The oral LD_{50} is 8,100 mg/kg for mice and 9,400 mg/kg for rats (Bailey and Morgareidge, 1948).

Irritation

No data were found.

Sensitization

There are reports of respiratory sensitization in workers exposed occupationally to guar gum dusts (Maio, 1986).

Repeat Dose Toxicity Studies

F344 rats and B6C3F_1 mice were given diets containing 0, 6,300, 12,500, 25,000, 50,000 or 100,000 ppm guar gum for 13 weeks (NTP, 1982). Mean body weights were decreased in male rats (100,000 ppm group) and in female mice (50,000 and 100,000 ppm). A dose-related decrease in feed consumption was observed for male and female rats; male and female mice were comparable or higher than that of controls. There were no compound-related clinical signs or histopathological effects.

F344 rats and B6C3F_1 mice were given diets containing 0, 25,000 ppm or 50,000 ppm guar gum for 103 weeks (NTP, 1982). Mean body weights of the high-dose females were

lower than those of the controls after week 20 for mice and week 40 for rats. No compound-related clinical signs or adverse effects on survival were observed. Feed consumption by dosed rats and mice of either sex was lower than that of controls. There were no non-neoplastic histopathological effects in either rats or mice that were treatment-related.

Genotoxicity

Guar gum was not mutagenic to *Salmonella typhimurium* TA 1530 or G-46 when tested without metabolic activation; however, it was mutagenic to *Saccharomyces cerevisiae* D-3 (Green, 1977). Guar gum also was reported to cause chromosomal aberrations in human embryonic lung cells WI-38 (Green, 1977). No *in vivo* genotoxicity studies have been conducted on guar gum.

Carcinogenicity

F344 rats and B6C3F_1 mice were given diets containing 0, 25,000 ppm or 50,000 ppm guar gum for 103 weeks (NTP, 1982). There were increased incidences of adenomas of the pituitary in male rats and pheochromocytomas of the adrenal in female rats that were statistically significant, but these differences were considered to be unrelated to guar gum administration. When pituitary adenomas or carcinomas and when pheochromocytomas or malignant pheochromocytomas are combined, the statistical differences disappear. Hepatocellular carcinomas occurred in treated male mice at incidences that were significantly lower than that in controls. The combined incidence of male mice with either hepatocellular adenomas or carcinomas was also significantly lower in the high-dose group. It was concluded that under conditions of this bioassay, guar gum was not carcinogenic for F344 rats or B6C3F_1 mice.

Reproductive Toxicity

No data were found.

Developmental Toxicity

Female rabbits were given daily (6 hours/day) dermal administration of 0, 2, 10 and 50 mg/kg guar gum during gestational days 6 through 18 (IRDC, 1988). Mortalities included 2 deaths at 50 mg/kg and 1 death at 10 mg/kg. A single animal was killed in extremis. A dose-related increase in dermal irritation (including erythema, edema, and desquamation) was observed in animals receiving 10 and 50 mg/kg. The number of early resorptions was significantly increased and the number of viable fetuses was correspondingly decreased at 50 mg/kg/day ($p<0.05$). The frequency of fetal malformations and variations in the treated groups was comparable to that of the control

group at all dose levels. The NOEL for this study is 2 mg/kg/day.

Key Study/Critical Effect for Screening Criteria

The key studies for the determination of a drinking water guidance value is the NTP two-year chronic bioassays. The LOAELs are based on decreased mean body weights in female mice and rats fed 50,000 ppm guar gum in diet for 103 weeks. The NOAELs for these studies are 25,000 ppm guar gum.

Rat: NOAEL (mg/kg/day) = 25,000 ppm * 0.05 = 1,250 mg/kg/day

Mouse: NOAEL (mg/kg/day) = 25,000 ppm * 0.13 = 3,250 mg/kg/day

Where 0.05 and 0.13 are the fraction of body weight that rats and mice, respectively, consume per day as food (U.S. EPA).

The lowest NOAEL of 1,250 mg/kg/day for the rat will be used to derive a drinking water guidance value.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD = 1,250/100 = 12.5 mg/kg/day

Drinking water guideline = 44 ppm

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Toxicity Profile

Hydrochloric acid
(CAS No. 7647-01-0)

Hydrochloric acid has been reviewed in the OECD-SIDS program (OECD, 2002a,b).

Hydrochloric acid (HCl) or hydrogen chloride is readily dissociated in water into hydrated protons and chloride ion.

Acute Toxicity

The oral LD_{50} value of hydrogen chloride is reported to be 238 to 277 mg/kg for female rats (Hoechst AG, 1966), and 900 mg/kg for rabbits (Loewy and Munzer, 1923). The lethal dose by dermal exposure is >5,010 mg/kg for rabbits (Monsanto, 1976). The LC_{50} values for HCl are reported to be 23.7 - 60.9 mg/L/5min, 5.7- 7.0 mg/L/30min and 4.2 4.7 mg/L/60min for rats; and 20.9 mg/L/5min, 3.9 mg/L/30min and 1.7 mg/L/60min for mice (Darmer *et al.*, 1974; Hartzell *et al.*, 1990; MacEwean *et al.*, 1974).

Irritation

Concentrations >3.3% cause skin irritation, and concentrations >17% cause corrosion in animal studies (OECD, 2002a,b). An aqueous solution (4%) of hydrogen chloride was slightly irritating (Agner and Serup, 1988), and a 10% solution was determined to be 'Irritating to skin' for the EU Dangerous Preparations Directive, in human volunteer experiments (York *et al.*, 1996).

0.1 mL of 10% aqueous solution of HCl was highly irritating to the eyes of rabbits (Jacobs, 1992); 0.03 mL or more of 5% HCl was corrosive to the eyes of rabbits (Griffith *et al.*, 1980); 0.1 mL of a 3.3% aqueous solution of HCL was slightly irritating the eyes of rabbits (Hoechst AG, 1966); and 0.1 mL of a 0.33% aqueous solution of HCl was not irritating to the eyes of rabbits. (Hoechst AG, 1966).

Sensitization

Hydrogen chloride is not a skin sensitizer to guinea pigs and humans (Gad *et al.*, 1986).

Repeated Dose Toxicity

Rats were fed diets containing 280 to 1,250 mmol/kg hydrochloric acid (10.2 to 45.6 mg/kg) for 7-12 weeks. There was increased water intake in all treated groups. All

animals fed diet containing 937 mmol/kg and above for 9 weeks, and half of the animals fed diet containing 900 mmol/kg for 12 weeks died. Also at doses ≥937 mmol/kg, there was decreased body weight, food consumption, blood pH, femur length, rate of ash in bone (Upotn and L'Estrange, 1977). In another study with rats, hydrochloric acid was administered via drinking water at pH 2-3 (study duration not provided). Decreased protein levels in urine and decreased urine volumes were observed in the treatment groups (Clausing and Gottschalk, 1989).

Genotoxicity

While consistent negative results have been obtained in the bacterial systems, positive results have been obtained in the non-bacterial systems (OECD, 2002a,b). The positive results were observed at high concentrations, but they were considered to be artifacts due to the low pH. Positive results were obtained in a sex-linked recessive lethal study with *D. melanogaster*; only one dose level was tested (Stumm-Tegethoff, 1966) There are no mammalian studies on *in vivo* mutagenicity with hydrogen chloride

Carcinogenicity (Oral Studies only)

A ten-month study has been conducted using mice (Dyer *et al.*, 1946). Because the methods such as strain used, duration and dose of administration, presence of co-administration substance, were not appropriate, it cannot be used for the assessment of carcinogenicity of hydrochloric acid.

Reproductive Toxicity

No reliable studies were identified by the oral route.

Developmental Toxicity

No reliable studies were identified by the oral route.

Key Study/Critical Effect for Screening Criteria

The Australian drinking water guideline value for pH may apply to hydrochloric acid.

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Toxicity Profile

2-Propanol or Isopopranol
(CAS No. 67-63-0)

Acute Toxicity

The acute oral LD_{50} has been reported as 4,700 mg/kg, 5,300 mg/kg, 5,500 mg/kg, and 5,8400 mg/kg in rats; 4,500 mg/kg in mice; and 5,030 mg/kg, 7,800 mg/kg, and 7,900 mg/kg in rabbits (31, 272, 274, 275, 144, 35 Kimura et al., 1971; WHO, 1990; Smyth and Carpenter, 1948; Lehman and Chase, 1994; Munch and Schwartze, 1925; Munch, 1972). The acute dermal LD_{50} in rabbits has been reported to be 12,900 mg/kg (Smyth and Carpenter, 1948). The acute inhalation 8-h LC_{50} in rats was 19,000 ppm in females and 22,500 ppm in males (Laham *et al.*, 1980). Exposure of rats to 16,000 ppm for 8 h resulted in four deaths out of six animals (Smyth and Carpenter, 1948).

Irritation

Isopropanol applied to the intact or abraded skin of rabbits and guinea pigs produced negligible irritation (Nixon *et al.*, 1975). Liquid isopropanol is moderately irritating to the eyes of rabbits (Griffith *et al.*, 1980; WHO, 1990). Isopropanol produced little irritation when tested on the skin of six human subjects (Bevan, 2012).

Sensitization

There have been reports of isolated cases of dermal irritation and/or skin sensitization (Bevan, 2012). Except for three case reports, the positive reactions were observed on patch testing patients with contact dermatitis due to ethanol. These patients also had a positive reaction to ethanol.

Repeated Dose Toxicity (Oral Studies only)

In a drinking water study, rats ingested 0.5 to 10% of isopropanol for 27 weeks and showed decreased body weight gain but no gross or microscopic tissue abnormalities (Lehman and Chase, 1975). Increased formation of hyaline droplets in the proximal tubules was reported in male rats given 1–4% isopropanol in drinking water for 12 weeks (Pilegaard and Ladefoged, 1993). In another study, daily application of a 50% solution to the heads of rats for 187 days produced no apparent injury to the skin (Boughton, 1944). Isopropanol was administered in drinking water to three dogs for 7 months. The alcohol concentration was 4% from the end of the first month until the conclusion of the experiment. Tolerance to the alcohol developed as manifested by an increased degree of neuromuscular coordination at similar blood levels in habituated versus control animals

and by increased elimination of the alcohol. The only significant histopathological changes were noted in the kidneys of one dog that died (Lehman *et al.*, 1945).

Genotoxicity

All genotoxicity assays conducted so far with isopropanol have been negative (OECD, 1997a,b; Bevan, 2012). Isopropanol was not mutagenic in the *Salmonella* microsomal assay using the spot test, in strains TA98, TA100, TA1535, and TA1537 with and without S9 from the livers of Aroclor-induced rats (Abbondandolo *et al.*, 1980). Isopropanol was not mutagenic in *Salmonella* strains TA97, TA98, TA100, TA102, TA104, TA1535, TA1537, and TA1538 with and without metabolic activation, when tested using a plate-incorporation modification of this assay (Zeiger *et al.*, 1992).

Isopropanol was inactive in mutagenicity tests in *Neurospora crassa* (Brockman *et al.*, 1984) and isopropanol did not enhance adenovirus (SA7) transformation using Syrian hamster embryo cells (Heidelberger *et al.*, 1983). Isopropanol was inactive in a sister chromatid exchange assay with and without S9 metabolic activation (von der Hude *et al.*, 1987). Isopropanol was inactive in an *in vitro* CHO/HGPRT gene mutation assay and in an *in vivo* bone marrow micronucleus assay in mice (Kapp, Jr. *et al.*, 1993).

Carcinogenicity

No carcinogenicity studies have been conducted by the oral route.

CD-1 mice were exposed by inhalation to 0, 500, 2500, or 5000 ppm of isopropanol vapor for 6 h/day, 5 days/week for 18 months. An additional group of mice (all exposure levels) were assigned to a recovery group which were exposed to isopropanol for 12 months and then retained until study termination at 18 months. There was no increased frequency of neoplastic lesions in any of the isopropanol-exposed animals. Nonneoplastic lesions were limited to the testes (males) and the kidney. In the testes, enlargement of the seminal vesicles occurred in the absence of associated inflammatory or degenerative changes. The kidney effects included tubular proteinosis and/or tubular dilatation. The incidence of testicular and kidney effects was not increased in the isopropanol-exposed recovery animals (Burleigh-Flayer *et al.*, 1997).

Fischer 344 rats were exposed to 0, 500, 2500, or 5000 ppm of isopropanol vapor for 6 h/day, 5 days/week for 24 months. The mortality rates for all male rats were 82, 83, 91, and 100% for the 0-, 500-, 2500-, and 5000-ppm groups, respectively. The corresponding values for the female rats were 54, 48, 55, and 69%. The main cause of death for the 5000-ppm rats (both sexes), as well as for much of the mortality of the 2500-ppm male rats, was chronic progressive nephropathy. Isopropanol exposure resulted in impaired kidney function, as indicated by various urine chemistry changes in male (2500- and 5000-ppm) and female (5000-ppm) rats. Animals in these groups also exhibited histopathological effects in the kidneys which appeared to be an exacerbated form of

chronic progressive nephropathy. The only neoplastic lesion noted was increased interstitial (Leydig) cell adenomas in male rats. The frequency of these tumors, although elevated above the control animals, was within the historical control range of the testing facility and within the range reported for control animals from the National Toxicology Program carcinogenicity studies (Burleigh-Flayer *et al.*, 1997).

The carcinogenic potential of isopropanol was evaluated via inhalation using three strains of mice. Male mice were exposed to 7.5 ppm of isopropanol for 3 to 7 h/day, 5 days/week for 5 to 8 months. Animals were killed at either 8 or 12 months. There was no significant increase in the number of lung tumors observed. Similarly, no increases in lung tumors were observed in the same strains of mice that received subcutaneous injections of isopropanol once weekly for 20 to 40 weeks (Weil *et al.*, 1952).

Reproductive Toxicity

In a two-generation reproductive toxicity study, Sprague–Dawley rats were dosed by oral gavage with 0, 100, 500, or 1,000 mg/kg isopropanol. There were seven parental deaths that were considered treatment-related: two high-dose F_0 females, two F_1 high-dose females, one mid-dose F_0 female, and two low-dose F_1 males. Lactation body weight gain was increased in the 500- and 1000-mg/kg females in both generations, and liver and kidney weights were increased in the 500- and 1,000-mg/kg groups in both sexes. Centrilobular hepatocyte hypertrophy was noted in some 1,000 mg/kg F_1 males. There were some kidney effects in the 500- and 1000-mg/kg F_0 males and in all treated F_1 male rats. The kidney effects were characterized by an increased number of hyaline droplets in the convoluted proximal tubular cells, epithelial degeneration and hyperplasia, and proteinaceous casts. Increased mortality occurred in the high-dose F_1 offspring during the early postnatal period; no other clinical signs of toxicity were observed in the offspring from either generation. Offspring body weight, however, in the 1,000-mg/kg group was reduced during the early postnatal period. There was significant mortality in the F_1 weanlings (18/70) before the selection of the F_1 adults. A statistically significant reduction was observed in the F_1 male mating index of the 1,000-mg/kg group (73 versus 97% in the controls). There were no other treatment-related effects on reproduction, including fertility and gestational indices, or histopathology of the reproductive organs (Bevan *et al.*, 1995). A benchmark dose level of 420 mg/kg/day (lower bound on dose associated with a 5% response rate for the decrease in the male mating index was calculated (Allen *et al.*, 1998).

In a one-generation reproductive/embryotoxicity study, male and female Wistar rats were given 0, 0.5%, 1.0% or 2.0% isopropanol in their drinking water. The calculated intakes for males were 383, 686 and 1107 mg/kg-day (pre-mating) and 347, 625 and 1030 mg/kg-day (18 weeks of treatment). The calculated intakes for females were 456, 835 and 1206 mg/kg-day (premating); 668, 1330 and 1902 mg/kg-day (gestation); and 1053, 1948 and 2768 mg/kg-day (postpartum). An immediate, statistically significant dose-dependent decrease occurred in water intake in the male rats. Intake was reduced ~5-14% (1% group; premating period) and ~30% (2% group; days 7-11 to end of study).

Overall mean feed consumption was significantly lower in treated versus control animals. Male body weights (2% only) were reduced throughout the study. Water consumption was initially reduced in the 1% and 2% females, but the 2% group recovered to only ~70% of the control values (premating); it continued to be reduced during the gestation and lactation period. Mean maternal body weights were reduced (all treated groups) at the start of gestation, with partial recovery during the gestation period except for the 2% group. Overall weight gain during gestation in these groups were similar to the controls. Following parturition from PND 4 onward, the 2% dams had significantly lower body weights. There were no infertile males in any group, and no treatment-related effect on female fertility or on length of gestation. The number of pups/litter on GD 1 was reduced in the 2% group; because it was not replicated in the embryotoxicity portion, an increase in pup mortality during partuition or GD 0, followed by cannibalism of the dead pups by the dam was suggested. No macroscopic abnormalities were seen in females; nor was there any treatment-related histopathological changes seen in the reproductive tissue in the 2% parental animals. Absolute kidney weight and relative kidney, liver, and spleen weights were increased in the 2% F0 males; increased absolute liver and kidney weights and relative liver weights in the 2% F0 females. In the embryotoxicity portion, there was a statistically significant increase in the total number of preimplantation losses in the 2% animals. Whole body edema was seen in 40% of the fetuses in 3/8 litters in the 2% group. No macroscopic abnormalities of the viscera of these fetuses were detected, and the incidence of edema was not related to gender. In the one-generation portion, postnatal pup survival and in the average pup weight (by PND 7) were decreased in the 2% group. F1 generation animals of both sexes showed increased relative liver weights at all dose levels, and the 2% males had higher relative kidney weights. A slight but significant decrease in absolute brain weight and increase in relative empty cecum weights in both sexes of the 2% F1 generation group. No treatment-related gross abnormalities were observed in the F1 generation animals at necropsy (BIBRA, 1988).

The effects of isopropanol (2.5% in drinking water) on the reproduction and growth of rats was assessed in a multigenerational study. No reproductive toxicity was observed (Lehman *et al.*, 1945).

Isopropanol was administerd as a 3% solution in drinking water to Wistar rats. Reduced parental body weight gain, food, and water consumption was observed in the treated animals compared with the controls. Fertility, litter size, and pup weights at postnatal days 4 and 21 were reduced in treated animals compared with the controls. In the second generation, the isopropanol concentration was reduced to 2%, and there were essentially no effects (Gallo *et al.*, 1977).

Developmental Toxicity

Isopropanol was given at concentrations of 0, 0.5%, 1.25% or 2.5% in the drinking water to female Wistar rats on GD 6 to 16. The calculated intakes of isopropanol during GD 6-16 were 596, 1242 and 1605 mg/kg/day. There was an immediate reduction in water intake in the 2.5% dose group, and this was statistically significant throughout the

treatment period when compared to controls. A smaller reduction in water intake was also seen in the 1.25% females (statistically significant during GD 6-9), with no change in the 0.5% females. Palatability of the drinking water may have been the problem since water intake significantly increased the first day following the end of the treatment period for all dose groups. Feed consumption patterns paralleled the water consumption during and after treatment in the mid- and high-dose groups. Overall, mean body weights of the 2.5% females were lower than the controls from GD 7 to termination. Effects on weight gain in the 0.5% and 1.25% females were limited to a failure to gain weight during the first (0.5%) and second (1.25%) day of treatment. There were no treatment-related effects in postimplantation loss, mean number of implantation sites or live fetuses. There was a slight dose-dependent decrease in mean litter weight and a significant decrease in mean fetal weight in the 1.25% and 2.5% groups. A statistically significant increase in variations was observed, indicative of a lower degree of ossification in the treated animals There was a dose-dependent decrease in the number of fetuses with the 4^{th} sacral arch and a dose-dependent increase in the number of fetuses with less than 2 caudal arches. The sternum also showed reduced ossification because there were increased numbers of fetuses with small, absent, or incompletely ossified sternebrae (BIBRA, 1987).

In a rat developmental study, female Sprague–Dawley rats were dosed by oral gavage with either 0, 400, 800, or 1200 mg/kg of isopropanol during gestational days 6 to 15. Two dams (8%) died at 1200 mg/kg and one dam (4%) died at 800 mg/kg. At 1200 mg/kg, maternal body weights were reduced throughout gestation (GS 0-20; 89.9% of control value), associated with reduced gravid uterine weight. There were no other treatment-related effects on the dams. Fetal body weights per litter were also significantly reduced at the 800 and 1200 mg/kg dose levels, but there were no teratogenic effects. There were no adverse maternal or developmental effects at 400 mg/kg (Tyl *et al.*, 1994).

In a rabbit developmental study, female New Zealand white rabbits were dosed by oral gavage with either 0, 120, 240, or 480 mg/kg of isopropanol during gestational days 6 to 18. At 480 mg/kg, isopropanol was unexpectedly toxic to pregnant female rabbits, resulting in the deaths of four does (26%). Maternal body weights were significantly reduced during treatment (gestational days 6–18) and were associated with reduced maternal food consumption during this period. Profound clinical signs were noted at 480 mg/kg and included flushed and/or warm ears, cyanosis, lethargy, and labored respiration. No adverse maternal effects were noted at 120 or 240 mg/kg. There were no developmental or teratogenic effects at any dose tested (Tyl *et al.*, 1994).

Isopropanol was given by oral gavage to Sprague–Dawley rats from gestational days 6 to 21 in doses of 0, 200, 700, or 1200 mg/kg. The dams were allowed to deliver, litters were culled on postnatal day (PND) 4, pups were weaned on PND 22, and their dams were killed. Weaned pups were assessed for day of testes descent or vaginal opening, motor activity, auditory startle, and active avoidance. The pups were killed on PND 68. Some of the pups were taken from each dose group and were perfused in situ for pathological examination of the central nervous system. There were no biologically significant findings in the behavioral tests, no changes in organ weights, and no pathological

findings of note. Thus, there was no evidence of developmental neurotoxicity from isopropanol exposure (Bates *et al.*, 1994).

Key Study/Critical Effect for Screening Criteria

The benchmark dose level of 420 mg/kg/day from the two-generation reproductive toxicity study will be used to derive a drinking water guidance value for 2-propanol.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral Reference Dose = 420/100 = 4 mg/kg/day

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Toxicity Profile

Magnesium chloride
(CAS No. 7786-30-3)

Acute Toxicity

The oral LD_{50} of magnesium chloride hexahydrate in rats is >2,000 mg/kg. The dermal LD_{50} of magnesium chloride hexahydrate in rats is >2,000 mg/kg.

Irritation

Magnesium chloride hexahydrate was applied topically to the EPISKIN-SMätissue for 15 min followed by a 42 hour post-incubation period and immediate determination of cytotoxic effects via MTT reduction assay. The test item showed no irritant effects.

Single ocular instillation of magnesium chloride hexahydrate to rabbits at a dose of 0.1 g produced irritant effects, which were fully reversible within 6, 4 and 2 days post-instillation in animal no. 1, 2 and 3, respectively. Based on these findings, magnesium chloride hexahydrate is not an eye irritant.

Sensitization

Magnesium chloride hexahydrate was not a skin sensitizer when tested in guinea pigs.

Repeated Dose Toxicity

In an OECD 422 study, Wistar rats at dosages of 250, 500 and 1,000 mg/kg magnesium chloride hexahydrate revealed no major toxicological findings. The cause of death of animals during the conduct of the study could not be determined (a plausible cause may be gavage error or regurgitation). The NOAEL for this study is 1,000 mg/kg/day.

Groups of 50 male and 50 female $B6C3F_1$ mice were given magnesium hexahydrate at dose levels of 0, 0.5% and 2% in the diet for 96 weeks, after which all animals received the control diet for 8 weeks and were then necropsied. In the 2% females, a decrease in body weight was observed. However, survival rates did not differ between the treatment and control groups for males or females and clinical signs and urinary, hematological or serum clinical chemistry parameters showed no treatment-related effects. Therefore, this change was considered not to be of biological significance. The NOAEL for female and male mice was 2% in feed, which corresponded to 3,930 and 2,810 mg/kg/day, respectively.

Genotoxicity

Magnesium chloride was not genotoxic in the *in vitro* mouse lymphoma assay and in the *in vitro* chromosomal aberration assay using human lymphocytes.

Carcinogenicity

Male and female $B6C3F_1$ mice were given in their fed 0, 0.5% or 2% magnesium chloride hexahydrate for 96 weeks, after which all animals received the control diet for 8 weesk and were then necropsied. Tumors were mainly found in the skin/subcutis, liver and lymphatic system. With the exception of a significant decrease in the incidence of liver tumors among the 2% males, there were no differences in the tumor incidences between the treated and control animals.

Reproductive/Developmental Toxicity

In an OECD 422 study, Wistar rats at dosages of 0, 250, 500 or 1,000 mg/kg showed no treatment-related reproductive or developmental effects. The NOAEL for this study is 1,000 mg/kg/day.

Key Study/Critical Effect for Screening Criteria

The Australian drinking water guideline value for chloride may apply to magnesium chloride.

Reference

ECHA REACH database: http://apps.echa.europa.eu/registered/registered-sub.aspx

Toxicity Profile

Magnesium nitrate
(CAS No. 10377-60-3)

Acute Toxicity

The acute oral LD_{50} in rats is >5,000 mg/kg.

Irritation

No studies are available.

Sensitization

Magnesium nitrate is not a skin sensitizer based on results of a Local Lymph Node Assay (LLNA).

Repeat Dose Toxicity Studies

No studies are available.

Genotoxicity

Magnesium nitrate hexahydrate is not mutagenic in the *Salmonella typhimurium* reverse mutation assay and in the *Escherichia coli* reverse mutation assay.

Carcinogenicity

No data are available.

Reproductive Toxicity

No data are available.

Developmental Toxicity

No data are available.

Key Study/Critical Effect for Screening Criteria

The Australian drinking water guidance value for nitrates may apply to magnesium nitrate.

Reference

ECHA REACH database: http://apps.echa.europa.eu/registered/registered-sub.aspx

Toxicity Profile

Polypropylene glycol
(CAS No. 25322-69-4)

Acute Toxicity

Acute oral toxicity studies on PPGs of various molecular weights (300-3,900) have indicated LD_{50} values (rats) ranging from 500 to >40,000 mg/kg. In acute dermal toxicity studies, doses of PPG 1025 (20 ml/kg) and PPG 2025 (20 ml/kg) did not cause death to rabbits. Two of five rabbits dosed with 20 ml/kg PPG 425 and one of five dosed with 10 ml/kg PPG 425 died.

Irritation

Skin irritation was not noted after PPG 425, PPG 1025, or PPG 2025 was applied once to the skin of rabbits or when applied a total of eight times to the same area within 4 h. PPGs 425, 1025, and 2025 were classified as harmless agents in rabbits in another ocular irritation study; PPG 1200 induced slight, transient ocular irritation in an albino rabbit.

Sensitization

Neither skin irritation nor sensitization reactions were observed in 300 subjects who received continuous and repeated dermal applications of undiluted PPG 2000.

Repeated Dose Toxicity

PPG 2000 was administered to rats over a period of 100 days. Concentrations of 0.1, 0.3, 1.0, and 3.0% were administered in oral doses of 50 to 1,500 mg/kg/day. There were no adverse effects noted at concentrations of 0.1 to 1.0%. Slight decreases in growth were observed after the administration of 3% PPG 2000.

In a 90-day study, PPG 2000 was administered orally to rats in doses ranging from 275 to 501 mg/kg/day. There was no evidence of adverse histopathologic, hematologic, or clinical chemistry effects in any of the animals tested. Body weight effects (not specified) were noted at the highest dose tested. Similar results were reported for dogs that received doses of PPG 2000 ranging from 526 to 810 mg/kg/day.

PPG 1200 was fed to three groups of four pure bred beagle dogs for 90 days. Each group consisted of two male and two female dogs. The three groups ingested PPG 1200 at concentrations of 0.1, 0.3, and 1.0 % in the diet, respectively; six beagles in the control group were fed diets without PPG. At the highest “no effect level” (0.3%), average daily

consumption doses were 79 and 99 mg/kg for two male dogs and 90 and 123mg/kg for two female dogs. Data based on the following analyses did not indicate adverse effects at any of the concentrations tested: demeanor, feed consumption, hematologic parameters, clinical chemistry determinations, urinalysis, organ weights, organ/body weight and organ/brain weight ratios, or gross and microscopic examination of tissues and organs. Similar results were reported when three groups of 50 rats were dosed with 0.1, 0.3, and 1.0% PPG 1200, respectively, according to the same procedure.

PPG 750 was administered to rats over a period of 100 days. Concentrations of 0.1 and 1% were administered at doses of 50 and 500 mg/kg/day. PPG 750 (0.1%) did not induce any adverse effects. However, in the group dosed with 1% PPG 750, there was a slight increase in liver and kidney weights; there were no histological changes. Neither of the doses resulted in a central nervous system stimulatory effect.

Genotoxicity

No data are available.

Carcinogenicity

No data are available.

Reproductive/Developmental Toxicity

No data are available.

Key Study/Critical Effect for Screening Criteria

Several rat subchronic toxicity studies indicate a NOAEL of 1% PPG in diet (500 mg/kg/day). In one study, it was reported that there was a slight increase in liver and kidney weights (no data are provided to determine if the change in organ weights were statistically significant). Nevertheless, these organ weight changes may not be considered adverse since there were no accompanying histopathologic changes.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (subchronic to chronic)

Oral RfD = 500/1,000 = 0.5 mg/kg/day

Drinking water guidance value = 1.75 ppm

References

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Benzenesulfonic acid, 4-ethyenyl-, sodium salt, homopolymer
(CAS No. 25704-18-1)

Acetic acid ethenyl ester, polymer with ethanol
(CAS No. 25213-24-5)

Vinylidene chloride/methacrylate copolymer
(CAS No. 25038-72-6)

Polyvinyl acetate, partially hydrolyzed
(CAS No. 30443-60-5) THIS IS NOT THE CORRECT CASRN

All of the these substances are polymers.

Mammalian toxicity data was located for only for acetic acid, ethenyl ester, polymer with ethanol (CAS No. 25213-24-5) on a supplier's MSDS. However, all of the polymers listed above are expected to exhibit similar toxicity profiles.

As polymers, they are not expected to be absorbed by the oral, dermal or inhalation routes of exposure due to their large molecular weights. They are also expected to be stable in biological media and resistant to metabolism.

This polymers are expected to be essentially acutely non-toxic by the oral, dermal and inhalation routes of exposure. The oral LD_{50} in rats for CAS No. 25213-24-5 was reported to be >11,000 mg/kg. Under certain conditions, dusts may be formed, which is to be considered as a nuisance dust. The polymers are expected to be non-irritating and not dermal sensitizers. No irritation or sensitization was observed in guinea pigs from CAS No. 25213-24-5.

These polymers are not expected to exhibit any systemic toxicity.

Reference

DuPont (2006). MSDS for "ELVANOL" 60-30, revised 27-Oct-2006.

Toxicity Profile

Sodium carbonate
(CAS No. 497-19-8)

Sodium carbonate has been reviewed in the OECD-SIDS program (OECD, 2002a,b).

Sodium carbonate is a strong alkaline compound with a pH of 11.6 for a 0.1M aqueous solution. The pKa of carbonate (CO_3^{2-}) is 10.33, which means that at a pH of 10.33 both carbonate and bicarbonate are present in equal amounts.

In water, sodium carbonate dissociates into sodium ion (Na^+) and carbonate (CO_3^{2-}). The carbonate ions will react with water, resulting in the formation of bicarbonate and hydroxide, until an equilibrium is established.

Sodium carbonate is used in many countries (*e.g.* U.S. and EU) as a food additive. It is regarded as a 'Generally Recognised as Safe' (GRAS) substance in food with no limitation other than current good manufacturing practice.

Acute Toxicity

An acute oral LD_{50} of sodium carbonate monohydrate in rats is 2,800 mg/kg, and the acute dermal LD_{50} is >2,000 mg/kg. These studies were done with sodium carbonate monohydrate but due to the relatively low water content of sodium carbonate monohydrate, the toxicity of sodium carbonate is not expected to be significantly different. The LC_{50}s for guinea pigs, mice and rats were 800, 1,200 and 2,300 mg/m , respectively, when male animals were exposed for 2 hours to sodium combustion products containing mainly sodium carbonate.

Irritation

Skin irritation studies have been performed with solid sodium carbonate and a 50 % solution of sodium carbonate with both animals and human volunteers. Erythema and edema were not observed for the intact skin. Thus, sodium carbonate has little to no skin irritation potential.

The available eye irritation tests show differing results. Studies using a dose of 0.1 ml sodium carbonate monohydrate and sodium carbonate (anhydrous) resulted in a classification of irritating and highly irritating, respectively. However, based on a study with a dose of 0.1 g sodium carbonate it was not classified as an ocular irritant. Overall, the results indicat that sodium carbonate is irritating to the eyes.

Sensitization

No data are available.

Repeated Dose Toxicity

No animal data are available on repeated dose toxicity studies by the oral route. Carbonate would be neutralized in the stomach by the low pH of the gastric juice and would not be available for uptake into the body.

Genotoxicity

The available *in vitro* mutagenicity test with sodium carbonate was negative.

Carcinogenicity

No data are available.

Reproductive/Developmental Toxicity

Aqueous solutions of sodium carbonate were administered daily via oral intubation to pregnant mice at doses ranging from 3.4 to 340 mg/kg during days 6-15 of gestation. There was no effect on implantation or on the survival of dams and fetuses. There were no significant differences in soft and skeletal tissue anomalies between treated and control animals. Negative results were reported for rats and rabbits for daily doses from 2.45 to 245 mg/kg and 1.79 to 179 mg/kg, respectively.

Key Study/Critical Effect for Screening Criteria

The Australian drinking water screening value for sodium (180 ppm, aethestic) and pH may apply to sodium carbonate.

References

OECD (2002a). IUCLID Data Set for Sodium carbonate (CAS No. 497-19-8), UNEP Publications.

OECD (2002b). Screening Information Dataset (SIDS) Initial Assessment Report for Sodium carbonate (CAS No. 497-19-8), UNEP Publications.

Toxicity Profile

Sodium hydroxide
(CAS No. 1310-73-2)

Sodium hydroxide (NaOH) has been reviewed in the OECD-SIDS program (OECD, 2002a,b).

Sodium hydroxide (NaOH) is present in the environment as sodium (Na^+) and hydroxyl ions (OH^-). Sodium is a normal constituent of the blood and an excess is excreted in the urine. A significant amount of sodium is taken up via the food because the normal uptake of sodium via food is 3.1-6.0 g per day according to Fodor *et al.* (1999). Exposure to NaOH could potentially increase the pH of the blood. However, the pH of the blood is regulated between narrow ranges to maintain homeostasis (pH of 7.4 to 7.5) by urinary excretion of bicarbonate and via exhalation of carbon dioxide.

Acute Toxicity

An oral LD_{50} of a 1-10% solution of NaOH in rabbits was reported to be 325 mg/kg (expressed as 100% NaOH). Mortality was also observed when 1% NaOH was dosed, but in this case, the applied volume was relatively high (24 mL per kg body weight).

Irritation

A NaOH solution of 8% can be considered corrosive based on animal data. Human data indicate that concentrations of 0.5 to 4% were irritating. In two different studies a concentration of 0.5% was irritating for only 55 and 61% of the volunteers, respectively. Thus, it is assumed that a concentration, which is slightly lower than 0.5%, is the non-irritating concentration.

The available animal data on eye irritation showed that the non-irritant level was 0.2-1.0 %, while the corrosive concentration was 1.2 % or >2%.

Sensitization

Male volunteers were exposed on the back to sodium hydroxide concentrations of 0.063 – 1.0% (induction). After 7 days the volunteers were challenged to a concentration of 0.125%. The irritant response correlated well with the concentration of NaOH, but an increased response was not observed when the previously patch tested sites were re-challenged. Based on this study sodium hydroxide has no skin sensitization potential.

Repeated Dose Toxicity

No animal data are available on repeated dose toxicity studies by oral, dermal, inhalation or by other routes for NaOH. It is not useful to study the repeated dose toxicity of hydroxide via an oral study because at high concentrations the substance is corrosive or irritating, while at low concentrations the hydroxide will be neutralized in the stomach by gastric juice, which has a very low pH.

Genotoxicity

Both the *in vitro* and the *in vivo* genotoxicity tests are negative.

Carcinogenicity

No carcinogenicity studies on sodium hydroxide were identified.

Reproductive Toxicity

No valid studies were identified regarding toxicity to reproduction in animals after oral, dermal or inhalation exposure to NaOH. It is not useful to study the reproduction/developmental toxicity of hydroxide via an oral study because at high concentrations the substance is corrosive or irritating, while at low concentrations the hydroxide will be neutralized in the stomach by gastric juice, which has a very low pH.

Developmental Toxicity

No valid studies were identified regarding developmental toxicity in animals after oral, dermal or inhalation exposure to NaOH. It is not useful to study the reproduction/developmental toxicity of hydroxide via an oral study because at high concentrations the substance is corrosive or irritating, while at low concentrations the hydroxide will be neutralized in the stomach by gastric juice, which has a very low pH.

Key Study/Critical Effect for Screening Criteria

The Australian drinking water guideline value for pH may apply to sodium hydroxide.

Reference

OECD (2002). IUCLID Data Set for Sodium hydroxide (CAS No. 1310-73-2), UNEP Publications.

OECD (2002). Screening Information Dataset (SIDS) Initial Assessment Report for Sodium hydroxide (CAS No. 1310-73-2), UNEP Publications.

Toxicity Profile

Talc
(CAS No. 61789-40-0)

Talc refers to both mineral talc and industrial mineral products that are marketed under the name talc and contain proportions of mineral talc that range from about 35% to almost 100%. Industrial talc generally refers to products that contain abundant minerals other than talc; cosmetic talc now normally contains >98% talc but the content may have been lower in the past. Pharmaceutical talc contains >99% talc. Talcum powder is cosmetic-grade talc.

Talc is a mineral composed of hydrated magnesium silicate with the chemical formula $Mg_3Si4O_{10}(OH)_2$ or $H_2Mg_3(SiO_3)_4$. Talc is not soluble in water.

The U.S. Food and Drug Administration (FDA) regulates talc and states that it is generally recognized as safe for use in color additives in foods, drugs and cosmetics, and in paper, paper products, cotton and cotton fabrics that come into contact with food. The Food Chemical Codex (2003) provides specifications for food-grade talc, including the statement that "talc derived from deposits that are known to contain associated asbestos is not food grade." Under the voluntary guidelines initiated in 1976, the Cosmetic, Toiletry, and Fragrances Association stated that all cosmetic talc should contain at least 90% platy talc (hydrated magnesium silicate) that is free from detectable amounts (<0.5%) of fibrous, asbestos minerals.

Toxicokinetics (Oral)

The absorption and disposition of ^{3}H-labeled talc in rats, mice, and guinea pigs administered a single oral dose was studied by Phillips *et al.* (1978). The oral doses were 50 mg/kg for rats, 40 mg/kg for mice, and 25 mg/kg for guinea pigs. In rats, mice, and guinea pigs, more than 95% of the dose was excreted in the feces 3 to 4 days after dosing. Less than 2% of the radioactivity was recovered in the urine. This radioactivity probably reflected contamination of urine samples with feces. No radioactivity was found in the liver or kidneys of these animals. This information suggests that talc is not absorbed from the gastrointestinal tract following oral exposure.

Acute Toxicity

No data were located.

Repeated Dose Toxicity/Carcinogenicity

Male and female Wistar rats were given in their diet 0 or 50 mg/kg of commercial talc [characteristics unspecified] for the life of the animals (average survival was 702 and 649 days, respectively). There was no significant difference in the talc-fed animals compared with control animals (Gibel *et al.*, 1976).

Male and female Wistar-derived rats were given in their diet 100 mg Italian talc (grade 00000; ready milled; mean particle size, 25 μm; containing 92% talc, 3% chlorite, 1% carbonate minerals and 0.5–1% quartz) per rat per day for 5 months (talc-containing diet was actually given for 101 days) and were then maintained on basal diet for life (average survival, 614 days). No differences in tumor incidence were noted between treated animals and control animals (eight/sex for an average survival of 641 days) (Wagner *et al.*, 1977).

In humans and experimental animals, the effects of talc are dependent on the route of exposure, and the dose and properties of the talc. Talc pneumoconiosis was somewhat more prevalent and severe among miners exposed to talc containing asbestiform minerals and/or asbestos than among those exposed to talc without such contaminants. However, the role of quartz and asbestos in the observed pneumoconiosis could not be ruled out. Among drug users, intravenous injection of talc present as a filler in the drugs resulted in microembolization in a variety of organs and alterations in pulmonary function. In animal studies, talc has been shown to cause granulomas and mild inflammation when inhaled. Observations of the effects that occurred in the lungs of rats exposed by inhalation to talc suggested that the operative mechanisms may be similar to those identified for carbon black, and talc is known to cause the release of cytokines, chemokines and growth factors from pleural mesothelial cells.

IARC: There is *inadequate evidence* in humans for the carcinogenicity of inhaled talc not containing asbestos or asbestiform fibres. There is *limited evidence* in experimental animals for the carcinogenicity of talc not containing asbestos or asbestiform fibres. Inhaled talc not containing asbestos or asbestiform fibres is *not classifiable as to its carcinogenicity (Group 3).*

Genotoxicity

The IARC (1987) review of talc included unpublished results from a 1974 study conducted by Litton Bionetics that showed no mutagenic activity for talc *in vitro* or *in vivo.* Talc did not induce mutations in *Salmonella typhimurium* strains TA1530 or HisG46, or in the yeast, *Saccharomyces cerevisiae.* No chromosomal aberrations were observed in human fibroblasts treated with talc *in vitro. In vivo* tests conducted in rats gave negative results for induction of chromosomal aberrations in bone marrow cells and dominant lethal mutations in germinal cells.

Three samples of respirable talc failed to elicit significant unscheduled DNA synthesis (10, 20 and 50 μg/cm^2, 24 hours), sister chromatid exchange or aneuploidy (2, 5, 10 and 15 μg/cm^2, 48 hours) in rat pleural mesothelial cells, in contrast to various positive controls. The three samples, *i.e.* Spanish talc (No. 5725), Italian talc (No. 5726) and French talc (No. 7841), contained 90–95% talc; the remaining contents were chlorite and dolomite. Electron microscopy analysis revealed that talc particles were taken up by the rat pleural mesothelial cells, but no aneuploidy was observed in metaphases (Endo-Capron *et al.*, 1993).

Reproductive Toxicity

No data are available.

Developmental Toxicity

No teratologic effects were observed in hamsters, rats, mice, or rabbits after oral administration of talc. The doses used were 1,600 mg/kg for rats and mice on days *6* through 15 of gestation; 1,200 mg/kg for hamsters on day 6 through 10 of gestation; and 900 mg/kg for rabbits on days 6 through 18 of gestation.

Key Study/Critical Effect for Screening Criteria

There are no adequate studies for which to derive a oral reference dose. Talc is poorly absorbed from the gastrointestinal tract, if at all, and the limited data available by the oral route indicate that talc is essentially non-toxic by the oral route of exposure.

References

Endo-Capron, S., Renier, A., Janson, X. *et al*. (1993). In vitro response of rat pleural mesothelial cells to talc samples in genotoxicity assays (sister chromatid exchanges and DNA repair). Toxicol. In Vitro 7: 7-14.

Gibel, W., LOhs, K., Horn, K.H., Wildner, G.P., and Hoffman, F. (1976) Experimental study on carcinogenic activity of asbestos filters (Ger.). Arch. Geschwulstforsch. 46: 437-442.

IARC (1987) IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Volume 42, International Agency for the Research on Cancer, World Health Organization, Lyon, France; cited in NTP (1993).

IARC (2010). IARC Monographs on the Evaluation of Carcinogenic Risks to Humans: Carbon Black, Titanium Dioxide, and Talc, Volume 93, International Agency for the Research on Cancer, World Health Organization, Lyon, France.

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Phillips, J.C., Young, P.J., Hardy, K., and Gangolli, S.D. (1978). Studies on the absorption and disposition of 'H-labelled talc in the rat, mouse, guinea-pig and rabbit. Food Cosmet. Toxicol. 16: 161-163.

Wagner, J.C., Berry, G., Cooke, T.J., Hill, R.J., Pooley, F.D., and Skidmore, J.W. (1977). Animal experiments with talc. In: Inhaled Particles (W.H. Walton and B. McGovern, Eds.), Vol. IV, Part 2, pp. 647-654, Pergamon Press, Oxford.

Toxicity Profile

Tetramethylammonium chloride
(CAS No. 75-57-0)

Surrogates:
Didecyldimethylammonium chloride
(CAS No. 7173-51-5)
Dodecyltrimethylammonium chloride
(CAS No. 112-00-5)

No data could be located on tetramethylammonium chloride. Toxicity data are available for didecyldimethylammonium chloride (DDAC) and dodecyltrimethyl-ammonium chloride (DTAC). Thus, these two substances have been used as surrogates for the alkylated quaternary chloride.

Acute Toxicity

The oral LD_{50} of 100% DDAC has been reported to be 84 mg/kg in rats and 268 mg/kg in mice. The oral LD_{50} of a 5-25% solution of DDAC in rats was reported to be 1,190 mg/kg (595 to 297 mg a.i./kg). The acute dermal LD_{50} of a 80% solution of DDAC in rats is 3,342 mg/kg (2674 mg a.i./kg).

The acute oral LD_{50} of DTAC (24.7% aq. soln.) in rats is 490 mg/kg. The acute oral LD_{50} of DTAC (37.35% aq. soln.) in rats is 560 mg/kg.

Irritation

DDAC is a severe skin and eye irritant to rabbits.

Sensitization

DDAC is not a dermal sensitizer to guinea pigs or to humans.

Repeatd Dose Toxicity

Mice were given in their diet 0, 100, 300, 600, 1,000 or 3,000 ppm DDAC for 89-90 days. For the lowest four dose groups, these doses correspond to mean intake levels of approximately 18, 52, 107, and 182 mg/kg for males, and 23, 68, 134, and 224 mg/kg for females. High mortality in the 3,000 ppm groups prohibited calculation of daily intakes. Treatment of mice with 3,000 ppm DDAC in the diet for several days resulted in virtually

100% mortality in both sexes, with only one male surviving to termination of the study. Death was attributed to treatment-related severe wasting and dehydration resulting from gastrointestinal effects. Treatment with 1,000 ppm DDAC produced a 5% decrease in body weight in males with associated decreases in body weight gain. Similar depressed body weight in females from this group was assumed to be related to DDAC exposure. No other changes were observed in males or females in the other dose groups. The NOEL for this study is 600 ppm (107 and 134 mg/kg/day for males and females, respectively).

Rats were given in their diet 0, 100, 300, 600, 1,000 or 3,000 ppm DDAC for 89-90 days. For the lowest four dose groups, these doses correspond to mean intake levels of approximately 6, 18, 37, and 61 mg/kg for males, and 8, 22, 44, and 74 mg/kg for females. High mortality in the 3,000 ppm group prohibited calculation of mean daily intakes. Dietary exposure to 3,000 ppm DDAC resulted in 80% mortality in both sexes. The three rats of each sex of this group that survived to the end of the study exhibited markedly reduced body weights, fluid- or gas-filled intestines at necropsy, and inflammation of the beginning of the large intestines (typhlitis). Pathological changes in clinical chemistry included decreased serum glucose and protein concentrations in both sexes, decreased albumin and globulin concentrations in females, and increased erythrocyte count and hemoglobin and hematocrit concentrations in males. Administration of 1,000 ppm of less of DDAC resulted in no treatment-related effects. The NOEL for this study is 61 and 74 mg/kg/day for males and females, respectively.

Male and female beagle dogs were given DDAC in their diet at doses of 0, 5, 15 and 50 mg/kg for 90 days. There was marked decrease in body weight gain, food consumption and food efficiency in the 50 mg/kg dose group. Clinical chemistry, hematology, urinalysis, and pathological results did not reveal any treatment-related effects. The NOAEL for this study is 15 mg/kg/day.

Beagle dogs were dosed orally with 0, 3, 10, or 30 mg/kg DDAC for 52 weeks. During the first four and a half weeks of the study, several dogs in the 30 mg/kg group showed potentially life threatening decreases in body weight and food consumption. The dose was therefore decreased to 20 mg/kg/day. In some cases, depressions in weight and food consumption were so severe that the dogs in this group were removed from treatment completely during study days 31-36, and then reinstated at the 20 mg/kg/day. Administration of 3 or 20 mg/kg/day was not associated with mortality, changes in organ weights, gross pathological findings, ophthalmologic changes, or microscopic changes in selected organs and tissues. The 20 mg/kg/day dose was associated with decreases in mean erythrocyte counts; hemoglobin and hematocrit values; and mean total cholesterol, total protein, and albumin values. The 10 and 20 mg/kg/day doses were associated with an increased incidence of emesis, salivation, and soft/mucoid/liquid feces compared to controls. The NOEL for systemic toxicity was considered to be 10 mg/kg/day.

Sprague-Dawley rats were given in their diet 0, 300, 750, or 1,500 ppm DDAC for at least 104 weeks. These doses corresponded to approximate DDAC intakes of 13, 32, and 64 mg/kg/day for males, and 16, 41, and 83 mg/kg/day for females. Treatment-related

decreases in body weight and food consumption in both males and females were observed in the 1,500 ppm group. In addition, possible treatment-related microscopic changes including hyperplasia of bile ducts in female rats and changes in mesenteric lymph nodes in male and female rats related to blood in the sinuses were observed in the 1,500 ppm group. No treatment-related effects were seen in the type of incidence of clinical signs, survival, palpable masses, clinical pathology, organ weights, gross anatomic pathology, or ophthalmology. The NOEL for toxicity was considered to be 750 ppm (32 and 41 mg/kg/day for males and females, respectively).

CD-1 mice were administered in their diet 0, 100, 500, or 1,000 ppm DDAC for at least 78 weeks. The approximate mean intake levels were 15, 76.3, and 155.5 mg/kg/day for males and 18.6, 93.1, and 193.1 mg/kg/day for females. Treatment-related findings included decreased body weights and body weight gains in both male and females from the 1,000 ppm groups. There were no treatment-related clinical signs of toxicity, increases in palpable masses, changes in food consumption, differences in organ weights or observations at necropsy or differences in histopathological findings. The NOEL for this study was considered to be 500 ppm (76.3 and 93.1 mg/kg/day for males and females, respectively).

Genotoxicity

Several studies evaluating the mutagenicity of DDAC have all given negative results. DDAC was not mutagenic to several strains of *S. typhimurium* in a bacterial reverse mutation assay with or without metabolic activation. DDAC was tested in the CHO/HGPRT forward mutation assay and was not mutagenic in the presence or absence of metabolic activation. DDAC did not induce chromosomal aberrations in CHO cells with or without metabolic activation. In the *in vitro* rat primary hepatocyte unscheduled DNA synthesis (UDS) assay, DDAC did not induce significant increases in UDS. No chromosomal damage was observed in the bone marrow of rats in an *in vivo* cyogenetics assay.

DTAC (24.7% aq. soln.) was not mutagenic to bacteria in a reverse mutation assay with or without metabolic activation. DTAC (24.7% aq. soln.) was not mutagenic in a mouse lymphoma assay with or without metabolic activation. DTAC was inactive in a rat primary hepatocyte UDS assay. DTAC was not genotoxic when given by oral gavage in a rat bone marrow micronucleus assay.

Carcinogenicity

Sprague-Dawley rats received DDAC in their diet at concentrations of 0, 300, 750 or 1,500 ppm for at least 104 weeks. These doses corresponded to approximate mean DDAC intakes of 13, 32, and 64 mg/kg/day for males, and 16, 41, and 83 mg/kg/day for females. DDAC was not considered to be carcinogenic under the conditions of this study.

CD-1 mice were administered in the diet 0, 100, 500, or 1,000 ppm DDAC for at least 78 weeks. The approximate mean intake levels were 15, 76.3, and 155.5 mg/kg/day for males, and 18.6, 93.1, and 193.1 mg/kg/day for females. DDAC was not considered to be carcinogenic under the conditions of this study.

Reproductive Toxicity

A two-generation reproductive toxicity study has been conducted with DDAC. Sprague-Dawley rats were given in their diet 0, 300, 750 or 1,500 ppm for two generations. Results indicate that continuous exposure to DDAC in the diet for two generations resulted in no adverse reproductive effects. Parental toxicity was observed at 1,500 ppm (~112.6 mg/kg/day), limited to body weight reduction, weight gain depression, and decreased food consumption. Postnatal toxicity at 1,500 ppm was indicated by reduced pup body weights. Based on decreased body weight/weight gain and food consumption, the parental Toxicity NOAEL = 750 ppm (56 mg/kg/day); LOAEL = 1500 ppm (113 mg/kg/day). Based on decreased pup body weight/weight gain, the reproductive toxicity NOAEL = 750 ppm (56 mg/kg/day); LOAEL = 1500 ppm (113 mg/kg/day).

Developmental Toxicity

Female NZ rabbits were given by oral gavage 0, 1.0, 3.0 or 10 mg/kg/day of DDAC during GD 6-18. Four of the 16 does in the highest group died prior to GD 13. One doe at 10 mg/kg and 2 does at 1.0 mg/kg delivered early and were removed from the study. Nonlethal indications of maternal toxicity were evident at 3 and 10 mg/kg, as evidenced by reduced weight gain and clinical signs during the treatment period. Developmental toxicity, including increased incidences of fetal mortality and reduced fetal body weight per litter, were observed only at the highest dose. No teratogenicity was observed at any dose level. The NOEL for maternal toxicity is 1 mg/kg/day, and the NOEL for developmental toxicity is 3 mg/kg/day.

Female Sprague-Dawley rats were given by oral gavage 0, 1, 10 or 20 mg/kg DDAC during GD 6-15. No females died, aborted, delivered early, or were removed early from the study. Maternal toxicity was indicated at 10 and 20 mg/kg by characteristic clinical signs of audible respiration. Reductions in body weight and food consumption were also observed at 20 mg/kg during the treatment period. No evidence of developmental toxicity including teratogenicity was observed at any dose level. The NOEL for maternal toxicity was 1 mg/kg/day. The NOEL for developmental toxicity is >20 mg/kg/day.

Key Study/Critical Effect for Screening Criteria

The lowest NOAEL was 10 mg/kg/day for dogs in the one-year chronic toxicity study. The LOAEL of 20 mg/kg/day was based on increased incidence of clinical signs in males and females, and decreased total cholesterol levels in females.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral Reference Dose = 20/100 = 0.2 mg/kg/day

Drinking water guidance value = 0.7 ppm

References

Henderson, N.D. (1992). A Review of the Environmental Impact and Toxic Effects of DDAC. Prepared for: BC Environment, Ministry of Environment, Lands and Parks, Victoria, British Columbia. Found as Appendix B of the Robust Summaries for the Fatty Nitrogen Derived (FND) Cationics Category in the U.S. HPV Chemical Challenge Program.

U.S. EPA (2006). Reregistration Eligibility Decision for Aliphatic Alkyl Quaternaries (DDAC), EPA739-R-06-008, Office of Prevention, Pesticides and Toxic Substances (OPPTS), U.S. Environmental Protection Agency, August 2006 (docket #EPA-HQ-OPP-2006-0338).

U.S. HPVIS (FND Cationics Category): http://www.epa.gov/chemrtk/hpvis/index.html

Santos

APPENDIX F.2 HALLIBURTON WATER AND GUAR BASED SYSTEMS

Toxicity Profile

Acetic acid
(CAS No. 64-19-7)

Acetic acid dissociates in aqueous media to H^+ and the acetate anion ($CH_3CO_2^-$). It is naturally occurring as the acid in apple cider vinegar and other fruit-derived products. It and several of its salts are commonly used as food additives (*e.g.*, as flavor enhancers) and are listed as Generally Recognized as Safe (GRAS) by the U.S. Food and Drug Administration (FDA).

pH: 2.5 at 50 g/L and 20°C
pK_a: 4.76 @ 20°C

Acute Toxicity

The oral LD_{50} in rats is 4,950 mg/kg, and the dermal LD_{50} in rabbits is 1,060 mg/kg. The 4-hour LC_{50} in rats is 11.4 mg/L.

Irritation

In the EU, acetic acid is classified as a skin and eye irritant at concentrations <25%. At ≥25%, it is classified as corrosive to the skin.

Sensitization

No data are available.

Repeated Dose Toxicity

In an 8-month study, rats dosed with 60 mg/kg acetic acid (three times per week) developed hyperplasia in the esophagus and forestomach.

Genotoxicity

Acetic acid was not mutagenic to *Salmonella typhimurium* strains TA 98, TA 100, TA 1535, TA 1537, and TA 1538 in an *in vitro* bacterial mutation assay with or without metabolic activation. Acetic acid (in media adjusted to a pH of 8.5) was also not genotoxic in an *in vitro* chromosomal aberration test using Chinese Hamster Ovary cells with or without metabolic activation.

Carcinogenicity

No adequate carcinogenicity studies have been conducted on acetic acid.

Reproductive Toxicity

No studies could be located.

Developmental Toxicity

There were no effects on implantations or on maternal or fetal survival in mice, rats, or rabbits at doses up to 1,600 mg/kg.

Key Study/Critical Effect for Screening Criteria

There are no repeat dose toxicity studies that were considered adequate for human health risk assessment. The only study reported on the toxicity of acetic acid by oral gavage showed effects of irritation (probably due to the pH of acetic acid) at the site of contact in the gastrointestinal tract. No systemic effects were reported.

The Joint FAO/WHO Expert Committee on Food Additives (JECFA) has maintained a group ADI of "not limited" for acetic acid and its potassium and sodium salts.

The Australian drinking water guidance value for pH may apply to acetic acid.

References

ECHA REACH: http://apps.echa.europa.eu/registered/registered-sub.aspx

JECFA: http://apps.who.int/ipsc/database/evaluations/chemical.aspx?chemID=4785

U.S. EPA HPVIS database: http://www.epa.gov/chemrtk/hpvis/index.html

Toxicity Profile

Alkylated Quaternary chloride

Surrogates:
Didecyldimethylammonium chloride
(CAS No. 7173-51-5)
Dodecyltrimethylammonium chloride
(CAS No. 112-00-5)

No data could be located on this alkylated quaternary chloride. Toxicity data are available for didecyldimethylammonium chloride (DDAC) and dodecyltrimethyl-ammonium chloride (DTAC). Thus, these two substances have been used as surrogates for the alkylated quaternary chloride.

Acute Toxicity

The oral LD_{50} of 100% DDAC has been reported to be 84 mg/kg in rats and 268 mg/kg in mice. The oral LD_{50} of a 5-25% solution of DDAC in rats was reported to be 1,190 mg/kg (595 to 297 mg a.i./kg). The acute dermal LD_{50} of a 80% solution of DDAC in rats is 3,342 mg/kg (2674 mg a.i./kg).

The acute oral LD_{50} of DTAC (24.7% aq. soln.) in rats is 490 mg/kg. The acute oral LD_{50} of DTAC (37.35% aq. soln.) in rats is 560 mg/kg.

Irritation

DDAC is a severe skin and eye irritant to rabbits.

Sensitization

DDAC is not a dermal sensitizer to guinea pigs or to humans.

Repeatd Dose Toxicity

Mice were given in their diet 0, 100, 300, 600, 1,000 or 3,000 ppm DDAC for 89-90 days. For the lowest four dose groups, these doses correspond to mean intake levels of approximately 18, 52, 107, and 182 mg/kg for males, and 23, 68, 134, and 224 mg/kg for females. High mortality in the 3,000 ppm groups prohibited calculation of daily intakes. Treatment of mice with 3,000 ppm DDAC in the diet for several days resulted in virtually 100% mortality in both sexes, with only one male surviving to termination of the study. Death was attributed to treatment-related severe wasting and dehydration resulting from

gastrointestinal effects. Treatment with 1,000 ppm DDAC produced a 5% decrease in body weight in males with associated decreases in body weight gain. Similar depressed body weight in females from this group was assumed to be related to DDAC exposure. No other changes were observed in males or females in the other dose groups. The NOEL for this study is 600 ppm (107 and 134 mg/kg/day for males and females, respectively).

Rats were given in their diet 0, 100, 300, 600, 1,000 or 3,000 ppm DDAC for 89-90 days. For the lowest four dose groups, these doses correspond to mean intake levels of approximately 6, 18, 37, and 61 mg/kg for males, and 8, 22, 44, and 74 mg/kg for females. High mortality in the 3,000 ppm group prohibited calculation of mean daily intakes. Dietary exposure to 3,000 ppm DDAC resulted in 80% mortality in both sexes. The three rats of each sex of this group that survived to the end of the study exhibited markedly reduced body weights, fluid- or gas-filled intestines at necropsy, and inflammation of the beginning of the large intestines (typhlitis). Pathological changes in clinical chemistry included decreased serum glucose and protein concentrations in both sexes, decreased albumin and globulin concentrations in females, and increased erythrocyte count and hemoglobin and hematocrit concentrations in males. Administration of 1,000 ppm of less of DDAC resulted in no treatment-related effects. The NOEL for this study is 61 and 74 mg/kg/day for males and females, respectively.

Male and female beagle dogs were given DDAC in their diet at doses of 0, 5, 15 and 50 mg/kg for 90 days. There was marked decrease in body weight gain, food consumption and food efficiency in the 50 mg/kg dose group. Clinical chemistry, hematology, urinalysis, and pathological results did not reveal any treatment-related effects. The NOAEL for this study is 15 mg/kg/day.

Beagle dogs were dosed orally with 0, 3, 10, or 30 mg/kg DDAC for 52 weeks. During the first four and a half weeks of the study, several dogs in the 30 mg/kg group showed potentially life threatening decreases in body weight and food consumption. The dose was therefore decreased to 20 mg/kg/day. In some cases, depressions in weight and food consumption were so severe that the dogs in this group were removed from treatment completely during study days 31-36, and then reinstated at the 20 mg/kg/day. Administration of 3 or 20 mg/kg/day was not associated with mortality, changes in organ weights, gross pathological findings, ophthalmologic changes, or microscopic changes in selected organs and tissues. The 20 mg/kg/day dose was associated with decreases in mean erythrocyte counts; hemoglobin and hematocrit values; and mean total cholesterol, total protein, and albumin values. The 10 and 20 mg/kg/day doses were associated with an increased incidence of emesis, salivation, and soft/mucoid/liquid feces compared to controls. The NOEL for systemic toxicity was considered to be 10 mg/kg/day.

Sprague-Dawley rats were given in their diet 0, 300, 750, or 1,500 ppm DDAC for at least 104 weeks. These doses corresponded to approximate DDAC intakes of 13, 32, and 64 mg/kg/day for males, and 16, 41, and 83 mg/kg/day for females. Treatment-related decreases in body weight and food consumption in both males and females were observed in the 1,500 ppm group. In addition, possible treatment-related microscopic

changes including hyperplasia of bile ducts in female rats and changes in mesenteric lymph nodes in male and female rats related to blood in the sinuses were observed in the 1,500 ppm group. No treatment-related effects were seen in the type of incidence of clinical signs, survival, palpable masses, clinical pathology, organ weights, gross anatomic pathology, or ophthalmology. The NOEL for toxicity was considered to be 750 ppm (32 and 41 mg/kg/day for males and females, respectively).

CD-1 mice were administered in their diet 0, 100, 500, or 1,000 ppm DDAC for at least 78 weeks. The approximate mean intake levels were 15, 76.3, and 155.5 mg/kg/day for males and 18.6, 93.1, and 193.1 mg/kg/day for females. Treatment-related findings included decreased body weights and body weight gains in both male and females from the 1,000 ppm groups. There were no treatment-related clinical signs of toxicity, increases in palpable masses, changes in food consumption, differences in organ weights or observations at necropsy or differences in histopathological findings. The NOEL for this study was considered to be 500 ppm (76.3 and 93.1 mg/kg/day for males and females, respectively).

Genotoxicity

Several studies evaluating the mutagenicity of DDAC have all given negative results. DDAC was not mutagenic to several strains of *S. typhimurium* in a bacterial reverse mutation assay with or without metabolic activation. DDAC was tested in the CHO/HGPRT forward mutation assay and was not mutagenic in the presence or absence of metabolic activation. DDAC did not induce chromosomal aberrations in CHO cells with or without metabolic activation. In the *in vitro* rat primary hepatocyte unscheduled DNA synthesis (UDS) assay, DDAC did not induce significant increases in UDS. No chromosomal damage was observed in the bone marrow of rats in an *in vivo* cyogenetics assay.

DTAC (24.7% aq. soln.) was not mutagenic to bacteria in a reverse mutation assay with or without metabolic activation. DTAC (24.7% aq. soln.) was not mutagenic in a mouse lymphoma assay with or without metabolic activation. DTAC was inactive in a rat primary hepatocyte UDS assay. DTAC was not genotoxic when given by oral gavage in a rat bone marrow micronucleus assay.

Carcinogenicity

Sprague-Dawley rats received DDAC in their diet at concentrations of 0, 300, 750 or 1,500 ppm for at least 104 weeks. These doses corresponded to approximate mean DDAC intakes of 13, 32, and 64 mg/kg/day for males, and 16, 41, and 83 mg/kg/day for females. DDAC was not considered to be carcinogenic under the conditions of this study.

CD-1 mice were administered in the diet 0, 100, 500, or 1,000 ppm DDAC for at least 78 weeks. The approximate mean intake levels were 15, 76.3, and 155.5 mg/kg/day for males, and 18.6, 93.1, and 193.1 mg/kg/day for females. DDAC was not considered to be carcinogenic under the conditions of this study.

Reproductive Toxicity

A two-generation reproductive toxicity study has been conducted with DDAC. Sprague-Dawley rats were given in their diet 0, 300, 750 or 1,500 ppm for two generations. Results indicate that continuous exposure to DDAC in the diet for two generations resulted in no adverse reproductive effects. Parental toxicity was observed at 1,500 ppm (~112.6 mg/kg/day), limited to body weight reduction, weight gain depression, and decreased food consumption. Postnatal toxicity at 1,500 ppm was indicated by reduced pup body weights. Based on decreased body weight/weight gain and food consumption, the parental Toxicity NOAEL = 750 ppm (56 mg/kg/day); LOAEL = 1500 ppm (113 mg/kg/day). Based on decreased pup body weight/weight gain, the reproductive toxicity NOAEL = 750 ppm (56 mg/kg/day); LOAEL = 1500 ppm (113 mg/kg/day).

Developmental Toxicity

Female NZ rabbits were given by oral gavage 0, 1.0, 3.0 or 10 mg/kg/day of DDAC during GD 6-18. Four of the 16 does in the highest group died prior to GD 13. One doe at 10 mg/kg and 2 does at 1.0 mg/kg delivered early and were removed from the study. Nonlethal indications of maternal toxicity were evident at 3 and 10 mg/kg, as evidenced by reduced weight gain and clinical signs during the treatment period. Developmental toxicity, including increased incidences of fetal mortality and reduced fetal body weight per litter, were observed only at the highest dose. No teratogenicity was observed at any dose level. The NOEL for maternal toxicity is 1 mg/kg/day, and the NOEL for developmental toxicity is 3 mg/kg/day.

Female Sprague-Dawley rats were given by oral gavage 0, 1, 10 or 20 mg/kg DDAC during GD 6-15. No females died, aborted, delivered early, or were removed early from the study. Maternal toxicity was indicated at 10 and 20 mg/kg by characteristic clinical signs of audible respiration. Reductions in body weight and food consumption were also observed at 20 mg/kg during the treatment period. No evidence of developmental toxicity including teratogenicity was observed at any dose level. The NOEL for maternal toxicity was 1 mg/kg/day. The NOEL for developmental toxicity was >20 mg/kg/day.

Key Study/Critical Effect for Screening Criteria

The lowest NOAEL was 10 mg/kg/day for dogs in the one-year chronic toxicity study. The LOAEL of 20 mg/kg/day was based on increased incidence of clinical signs in males and females, and decreased total cholesterol levels in females.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD = 20/100 = 0.2 mg/kg/day

Drinking water guidance value = 0.7 ppm

References

Henderson, N.D. (1992). A Review of the Environmental Impact and Toxic Effects of DDAC. Prepared for: BC Environment, Ministry of Environment, Lands and Parks, Victoria, British Columbia. Found as Appendix B of the Robust Summaries for the Fatty Nitrogen Derived (FND) Cationics Category in the U.S. HPV Chemical Challenge Program.

U.S. EPA (2006). Reregistration Eligibility Decision for Aliphatic Alkyl Quaternaries (DDAC), EPA739-R-06-008, Office of Prevention, Pesticides and Toxic Substances (OPPTS), U.S. Environmental Protection Agency, August 2006 (docket #EPA-HQ-OPP-2006-0338).

U.S. HPVIS (FND Cationics Category), http://www.epa.gov/chemrtk/hpvis/index.html

Toxicity Profile

Amorphous/Non-crystalline Silica
(CAS No. 7631-86-9[1])

Silica Gel
(CAS No. 112926-00-8)

Amorphous silica and silica gel have been reviewed in the OECD-SIDS program (OECD, 2004a,b).

The CAS No. 7631-86-9 is the general CAS No. for silicon dioxide which includes all forms of silicas (*e.g.* also crystalline and natural forms). Only the silica sub-classes, the synthetic amorphous silicas, are the subject of this assessment.

Synthetic amorphous silicas (SAS) are in powder form which have a low water solubility: ≤70 mg/L

Toxicokinetics

After oral ingestion, there is no accumulation of SAS in body tissues. Upon cessation of exposure, rapid elimination occurs. Intestinal resorption appears to be insignificant in animals and humans. In a human study, the small apparent increases in the urine output of human volunteers were remarkably low as compared with the high dose of 2,500 mg SiO_2 applied.

After daily oral administration of 1,500 mg/kg SAS (FK 700) as aqueous suspension to rats for one month, there was no accumulation of SiO_2 in the body: the average SiO_2 content was: 1.5 µg in the liver, 6.4 µg in the kidney, and 5.3 µg in the spleen. The corresponding control values were 1.8, 7.2 and 7.8 µg SiO_2, respectively.

In a similar experiment in rats receiving 20 daily oral doses of 100 mg SAS (HDK V15) per animal (about 500 mg/kg) each, tissue values were slightly increased in liver and kidney: in liver 4.2 µg (control value 1.8 µg), in the spleen 5.5 µg (7.2 µg) and in the kidneys 14.2 µg (7.8 µg).

In 12 human volunteers, no significant increased renal excretion of SiO_2 was found following single oral ingestion of 2,500 mg (AEROSIL 175 and FK 700).

Acute Toxicity

The acute oral administration of various forms of SAS (aqueous suspension or gel) failed to produce signs of toxicity or deaths in treated animals with LD_{50} values greater than the

top doses applied, either by gavage: >3100 to >20000 mg/kg in mice and rats; or in the diet for 24 hours.

Irritation

Synthetic amorphous silicas are not irritating to the skin of rabbits exposed to 0.19 g (one case) or 0.5 g of dry or moistened test item under occlusive conditions for 4 or 24 hours. All products tested as a powder (0.1 g) have shown no or only weak and transient irritating effects on the conjunctivae of the eyes of rabbits with the iris and cornea not affected at all.

Sensitization

No experimental data are available on the synthetic amorphous silicas. Medical surveillance records on workers gave no evidence of skin sensitization over decades of practical experience.

Repeated Dose Toxicity/Carcinogenicity

Fischer rats and B6C3F_1 mice were administered SAS in the diet at levels of 0, 1.25, 2.5, and 5% for 102 weeks. The animals were in good condition throughout and showed high survival. The tumor responses in all organs of SAS-fed rats and mice were not statistically significantly different from the controls. The NOAEL for rats and mice were 2,500 and 6,500 mg/kg/day, respectively.

Genotoxicity

There is no evidence for synthetic amorphous silica to induce mutations either *in vitro* or *in vivo* using standard genotoxicity tests.

Reproductive Toxicity

An early limited one-generation study on rats gave no evidence of adverse effects on reproduction performan*ce* at 500 mg/kg/day, the highest dose tested (NOAEL). But the reliability is poor due to the small group size of animals.

Developmental Toxicity

SAS was examined for embryotoxic and developmental effects during the gestation phase in various animals species, rat, mouse, rabbit and hamster, at oral doses up to 1,600 mg/kg/day. . There were no significant signs of maternal or embryotoxic/developmental toxic effects in any species tested. The number of abnormalities seen in either soft or skeletal tissues of the test groups did not differ from the frequencies occurring spontaneously in the control animals.

Key Study/Critical Effect for Screening Criteria

The lowest NOAEL from the two-year dietary study was 2,500 mg/kg/day for rats.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD = 2,500/100 = 2.5 mg/kg/day

Drinking water guidance value = 0.09 ppm

References

OECD (2004a). IUCLID Data Set for Synthetic Amorphous Silica and Silicates: Silicon Dioxide (CAS No. 7631-86-9, 112945-52-5, 112926-00-8; Silicic Acid, Aluminum Sodium Salt (CAS No. 1344-00-9); Silicic Acid, Calcium Salt (CAS No. 1344-95-2), UNEP Publications.

OECD (2004b). Screening Information Dataset (SIDS) Initial Assessment Report for Synthetic Amorphous Silica and Silicates: Silicon Dioxide (CAS No. 7631-86-9, 112945-52-5, 112926-00-8; Silicic Acid, Aluminum Sodium Salt (CAS No. 1344-00-9); Silicic Acid, Calcium Salt (CAS No. 1344-95-2), UNEP Publications.

Toxicity Profile

1,2-Benzothiazolin-3-one
(CAS No. 2634-33-5)

Acute Toxicity

The rat oral LD_{50} is 670 mg/kg in males and 784 mg/kg in females. The rabbit dermal LD_{50} is >2,000 mg/kg.

Irritation

1,3-Benzothiazolin-2-one is a mild skin irritant and severe eye irritant to rabbits.

Sensitization

1,3-Benzeothiazolin-3-one is a skin sensitizer to guinea pigs.

Repeated Dose Toxicity

Decreased body weight, increased incidence of forestomach hyperplasia, and non-glandular stomach lesions were observed in rats in a rat subchronic oral toxicity study. The NOAEL is 8.42 mg/kg/day.

A dog subchronic oral toxicity study showed effects occurring at lower doses than in rats, and included alterations in blood chemistry (decreased plasma albumin, total protein, and alanine aminotransferase) and increased absolute liver weight. The NOAEL is 5 mg/kg/day.

Genotoxicity

All acceptable mutagenicity studies showed a negative mutagenic response for this chemical.

Carcinogenicity

No carcinogenicity studies are available.

Reproductive Toxicity

In a two-generation reproductive toxicity study, parental toxicity was observed at 500 ppm and was characterized by lesions in the stomach. In pups, toxic effects were reported at 1,000 ppm and consisted of preputial separation in males and impaired growth and survival in both sexes. There was no evidence of increased susceptibility of the offspring.

Developmental Toxicity

Developmental toxicity studies were conducted in rats with maternal effects including decreased body weight gain, decreased food consumption, and clinical toxicity signs (audible breathing, haircoat staining of the anogenital region, dry brown material around the nasal area) as well as increased mortality. Developmental effects consisted of increases in skeletal abnormalities (extra sites of ossification of skull bones, unossified sternebra), but no external or visceral abnormalities.

Key Study/Critical Effect for Screening Criteria

The U.S. EPA Office of Prevention, Pesticides and Toxic Substances (OPPTS) chronic oral reference dose is based on increased incidence of emesis and clinical chemistry alterations at 20 mg/kg/day in a subchronic toxicity study in dogs, with a NOAEL of 5 mg/kg/day.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD = 5/100 = 0.05 mg/kg/day

Drinking water guidance value = 0.2 ppm

Reference

U.S. Environmental Protection Agency, Reregistration Eligibility Decision for 1,2-Benzoisothiazolin-3-one (BIT), Office of Prevention, Pesticides and Toxic Substances, 739-R-05-007, September 2005.

Toxicity Profile

C10-C12 Alcohol Ethoxylates
(CAS No. 67254-71-1)

Alcohol ethoxylates (AE) are a class of non-ionic surfactants that have the basic structure $C_{x-y}AE_n$. The subscript (x-y) following the 'C' indicates the range of carbon chain units. AEs with carbon unit range between C8 to C18 are most commonly used in household detergent products. The hydrocarbon chain can be either linear or branched. AEs also contain an ethylene oxide (E) chain attached to the alcohol. The degree of ethylene oxide polymerization is indicated by the subscript (n) which indicates the average number of ethylene oxide units. In household products the average ethylene oxide chain length commonly ranges between 3 and 12 units.

The toxicity profile of C10-C12 alcohol ethoxylates has been developed from a risk assessment report on alcohol ethoxylates ranging from C8 to C18 prepared by the household cleaning product and chemical industry (HERA, 2009).

Acute Toxicity

The acute oral LD_{50} of C9-11AE2.5 in rats was calculated to be >4,000 mg/kg and <10,000 mg/kg. The acute oral LD_{50} of C7-9AE6 in rats was determined to be <2,000 mg/kg. The acute oral LD_{50} of C9-11AE8 in fasted rats was found to be 1,200 mg/kg. The oral LD_{50} in rats for C12-13AE6.5 is 2,100 mg/kg. The oral LD_{50} in rats for C12-15AE7 is 1,700 mg/kg. For C14-15AE11, the acute oral LD_{50} values were reported to be 720 mg/kg (neat) and 1,800 mg/kg (given as 50% (m/v) solution in corn oil). The oral LD_{50} in rats for C12-15AE11 is >2,00 mg/kg for males and between 1,000 and 2,000 mg/kg for females. The oral LD_{50} in rats for C14-15AE13 is 1,100 and 1,000 mg/kg in two separate studies.

The dermal LD_{50} of C7-9AE6 was >2 g/kg. The dermal LD_{50} values for AEs with an alkyl chain length of 9 – 11 carbon atoms in three different rat studies were determined to be >2,000 mg/kg and >4,000 mg/kg. An acute dermal LD_{50} value of >2,000 mg/kg was determined for C12-14AE3 and C12-14AE6 in two separate studies. The acute dermal LD_{50} of C12-15AE7 was determined to be >2,000 mg/kg.

The acute rat 4 hr-LC_{50} of C9-11AE5 generated as a mist was determined to be >0.22 mg/L. Talmage (1994) reported that alcohol ethoxylates were not acutely toxic to rats at concentrations less than or equal to their saturated vapor concentrations in air. Acute toxic thresholds were reached only when animals were exposed to the undiluted test chemical in the form of a respirable mist or aerosol. Under these conditions, 1- or 4-hour inhalation LC_{50} values ranged from 1.5 to 20.7 mg/L. Some studies reported no mortalities (1-hours LC_{50} -study) occurred at concentrations as high as 52 mg/L.

Irritation

Alcohol ethoxylates with varying alkyl chain lengths and ethoxylation degree were found to be slightly to severely irritating to skin in rabbits and rats. The degree of irritation was dependent on the type of patches used (open application versus full occlusion), the exposure time as well as the concentration of the test material. In humans, AEs are less irritating to skin than in animals. Neat applications of a range AEs in a 4-hr human patch test did not warrant these chemicals to be classified as skin irritants under EU legislation, while the same AEs would have been classified for skin irritation on the basis of animal data.

Alcohol ethoxylates range from mildly to severely irritating to rabbit eyes. Generally, concentration of 0.1% were non-irritating, and concentrations of 1 to 10% ranged from slight to moderately irritating. No relationship could be established between the chemical structures of the tested AEs and their eye irritation responses.

Sensitization

Alcohol ethoxylates should not be considered as skin sensitizers. A substantial amount of skin sensitization studies in guinea pigs following either the Magnusson-Kligman maximization or the Buehler testing protocol are available to evaluate the skin sensitization potential of AEs. Although a mild skin sensitization reaction was observed in a study following the Magnusson-Kligman protocol, the weight of evidence clearly supports the assessment that AEs should not be considered as skin sensitizers. This is further supported by clinical and market data that demonstrate the absence skin sensitization responses to AEs when tested under the conditions of the HRIPT or when used in AE containing consumer products.

Repeated Dose Toxicity

C10AE5 was fed to rats at doses of 0, 125, 250 or 500 mg/kg for 90 days. There were not treatment-related clinical signs, body weight gain, food consumption or feed efficiency. There was a slight increase in absolute liver weights as well as a trend toward a dose-dependent increase in the liver weight/body weight ratio, with a statistically significant increase in the high dose group. However, the histological evaluation did not reveal any indication of hepatotoxicity and therefore the increase in liver weights was not interpreted to be a toxicological effect. It can be considered to be an adaptive response as a result of extensive metabolism of the test compound by the liver. There were no other gross or histopathological changes that were considered treatment-related. The NOAEL for this study can be considered to be 500 mg/kg/day.

Rats were given in their diet 0, 125, 250, 500, 1,000 and 3,000 ppm C9-11AE6 for 90 days. There were no signs of toxicity at any dose level. The NOAEL is 3,000 ppm (approximately 150 mg/kg/day).

Rats were given in their diet 0. 04, 0.2 and 1.0% C9-11AE8 for 90 days. Lower body weight gain and decreased food consumption were noted in the 1% males and females and in the 0.2% females from week 1 through the end of the study. Further statistical analyses revealed a significant decrease in the mean body weight gain noted in the 1% females and the decreases in mean food consumption noted in the 1% males and females. The differences noted in the 0.2% females were not statistically significant. The investigators considered these observations to be the result of poor palatability of the test substance. There were no other treatment-related effects. The NOAEL for this study is 1.0% (about 400 mg/kg/day).

Rats were fed C12-15AE7 in the diet at concentrations of 0%, 0.0313%, 0.0625%, 0.125%, 0.25%, 0.5% and 1.0% for 90 days. Body weight gain was significantly reduced in male and female rats in the 0.25% and higher dose groups, and was associated with marked decreases in food and water consumption. Relative liver weights were significantly increased in the 0.5% and 1% male rats fed and in female rats in the 0.25% groups and higher. There were not treatment-related changes in hematology, urinary and clinical chemistry parameters. The histological examination of the liver at necropsy revealed hepatocytic enlargement at 0.125% and higher, suggesting an increased liver metabolism on the basis of increased alkaline phosphatase activity at the higher dose levels. The NOAEL was established at 0.0625% (102 mg/kg/day).

Rats were fed C12-14AE7 in the diet at concentrations of 0%, 0.0313%, 0.0625%, 0.125%, 0.25%, 0.5% and 1.0% for 90 days. Body weight gain was significantly reduced in male and female rats in the 0.25% and higher dose groups, and was associated with marked decreases in food and water consumption. Relative liver weights were significantly increased in the 0.5% and 1% male rats fed and in female rats in the 0.25% groups and higher. There were not treatment-related changes in hematology, urinary and clinical chemistry parameters. The histological examination of the liver at necropsy revealed hepatocellular hypertrophy at 0.125% and higher, suggesting an increased liver metabolism on the basis of increased alkaline phosphatase activity at the higher dose levels. The NOAEL was established at 0.0625% (110 mg/kg/day).

Wistar rats were fed C14-15AE7 in the diet at concentrations of 0, 300, 1,000, 3,000, and 10,000 ppm for 90 days. All animals survived until their scheduled necropsy date. Significant treatment-related effects on body weight (*i.e.*, reduced mean body weights in males at 10,000 ppm and in females at 3,000 ppm), food intake (*i.e.*, reduced intake in both sexes at 10,000 ppm and at 3,000 ppm for females), organ weights (*i.e.*, increased relative liver weight in both sexes at 3,000 and 10,000 ppm and in females also at 1,000 ppm; increased spleen weight in males at 10,000 ppm; clinical chemistry (*i.e.*, confined to 10,000 ppm dose groups; significantly higher urea, chloride and potassium levels in males; significantly higher urea, chloride and cholesterol levels in females) and hematology (*i.e.*, in both sexes at 10,000 ppm and in males also at 3,000 ppm increased

total leukocytes and lymphocytes; females at 10,000 ppm showed depression in numbers of neutrophils, mean cell volume and mean cell hemoglobin) were identified in one or both sexes fed with dietary concentrations of 3,000 and 10,000 ppm. There were no compound-related histopathological effects at any dose level. Minor, but statistically significant changes in liver weight, kidney weights and plasma urea concentration were recorded in female rats in the 1,000 ppm group were not of toxicological significance. The NOAEL for this study is 1,000 ppm (50 mg/kg/day).

Rats were fed C14-15AE7 in the diet at concentrations of 0, 0.1%, 0.5% and 1% for 90 days. There were no treatment-related changes in body weight, food intake, and organ weights including those of the reproductive system, clinical chemistry and hematology at any treatment level. The NOAEL is 1% in the diet, which corresponded to 700 and 785 mg/kg/day for males and females, respectively.

Rats were fed C12-13AE6.5 in their diet at concentrations of 0, 0.1, 0.5 or 1% for two years. There was reduced food consumption in males (1%) and females (0.5 and 1%) which resulted in lower body weight gain compared to controls. At study termination, organ to body weight ratios were increased in the 0.5 and 1% females (liver, kidney and brain), 1% females (heart), and 1% males (liver). A dose-related focal myocarditis was observed in males. The NOAEL was established at 0.1% dietary level based on the relative organ weight increases. This corresponds to 50 mg/kg/day.

Rats were fed C14-15AE7 in their diet at concentrations of 0, 0.1, 0.5 or 1% for two years. There was reduced food consumption in males (1%) and females (0.5 and 1%) which resulted in lower body weight gain compared to controls. At study termination, organ to body weight ratios were increased in the 0.5 and 1% females (liver, kidney and brain), 1% females (heart), and 1% males (liver). A dose-related focal myocarditis was observed in males. The NOAEL was established at 0.1% dietary level based on the relative organ weight increases. This corresponds to 50 mg/kg/day.

Charles River rats were fed C14-15AE7 in the diet at concentrations of 0, 0.1, 0.5 and 1% for two years. There was a dose-related decrease in body weights in the 0.5 and 1% females and in the 1% males, the likely cause being poor palatability of the diet. At study termination, elevated organ-to-body weight ratios were noted for the liver, kidney, heart and thyroid/parathyroid glands in the 1% dietary group. The only significant histopathological finding prevalent in all dose groups was a dose-related increase in incidence of focal myocarditis at 12 months but not at study termination at 2 years. No other treatment-related histopathology was noted. The NOAEL was established at the 0.5% dietary level, which corresponds to about 162 and 190 mg/kg/day for males and females, respectively.

Genotoxicity

In all available *in vitro* and *in vivo* genotoxicity assays, there was no indication of genetic toxicity of broad range of structurally different alcohol ethoxylates.

Carcinogenicity

Alcohol ethoxylates as a class are not carcinogenic by the oral route based of available oral long term toxicity/carcinogenicity studies on AEs.

Charles River rats were given in their diet 0, 0.1, 0.5 or 1% C14-15AE7 for two years. There was no treatment-related changes in general behavior and appearance. The survival rate of the test animals was comparable if not better than the controls. Body weights of 0.5% females and 1% males and females had significantly lower weight gains than the control. There were no treatment-related effects on organ weights and tumor incidence.

Sprague-Dawley rats were fed C14-15AE7 at 0.1, 0.5 and 1% in the diet for two years. A treatment-related body weight depression was observed in females at the two highest treatment levels and in males at the 1% dose level, probably due to the poor palatability of the diet. There was no evidence for any carcinogenic activity.

Sprague-Dawley rats were fed C12-13AE6.5 in the diet at doses up to 1% (500 mg/kg/day). Reduced food consumption was noted at the higher dose levels (*i.e.*, 0.5 and 1% for females and 1% for males), resulting in a lower body weight gain compared to the control group. No treatment-related histopathology was found and no increase in tumor incidence was observed.

Reproductive Toxicity

In a two-generation reproductive toxicity study, Charles River rats were fed C12AE6 in the diet at dose levels of 0, 0.05, 0.1 and 0.5% (about 0, 25, 50 and 250 mg/kg/day). No treatment related effects in the parents or pups on general behaviour, appearance or survival were observed. Fertility of treated groups was comparable with the controls. The only observation was related to a reduced weight gain of parental rats and pups relative to the control at the 0.5% dose level. The NOAEL for reproduction was therefore set at the highest dose level which was 0.5% dietary level (250 mg/kg/day).

In a two-generation developmental and teratogenicity study, CD rats were fed C14-15AE7 in the diet at dose levels of 0, 0.05, 0.1 and 0.5% (about 0, 25, 50 and 250 mg/kg). The control group and the six treated groups comprised of 25 male and 25 female animals. Three of the groups received the compound continuously during the study. In the other three groups the females received the compound only during the 6th through the 15th day of gestation and the males were untreated. No treatment-related changes in behavior or appearance were observed in the parental rats or pups throughout the study. Female rats from the 0.5% continuous treatment group gained slightly less body weight compared to control females. No other consistent differences in body weight were observed. Food consumption was similar for control and treated rats. No compound related differences were seen between control and treated rats with respect to fertility, gestation or viability indices. The average 21-day body weights for pups at the 0.5% continuous treatment group were significantly lower as compared to the average pup

body weights in the controls. No other compound-related changes in body weight were observed. None of the deaths of parental rats during the study was considered to be compound-related. Examination of organ weight values revealed that compound-related effects were limited to increased group mean relative liver weights of male and female F1 from the 0.5% continuous feeding group at the 91-day sacrifice, and increases in group mean relative liver weights of males from the 0.5% continuous feeding group of the F2 generation at the 60-day and caesarean section sacrifices. No compound-related histopathological lesions were observed in any of the tissues examined from rats for the F0 and F1 generations. The NOAEL for reproductive toxicity is at least 0.5% in the diet (250 mg/kg/day).

Developmental Toxicity

In a two-generation reproductive toxicity study, Charles River rats were fed C12AE6 in the diet at dose levels of 0, 0.05, 0.1 and 0.5% (about 0, 25, 50 and 250 mg/kg/day). General behavior, appearance and survival were not affected by treatment. At the 0.5% dose level, adults and pups gained less weight than the control rats. In the 0.5% dose group, there was a statistical increase in embryo lethality and soft tissue anomalies and at the 0.1% there was a statistical decrease in mean fetal liver weight. Neither of these effects was considered to be treatment-related by the authors as they showed no dose response characteristics. The NOAEL for maternal toxicity is 50 mg/kg/day. The NOAEL for developmental and teratogenicity is 0.1% (50 mg/kg/day).

Pregnant rabbits were given by oral gavage 0, 50, 100 or 200 mg/kg C12AE6 from GD 2 to16. Nine control rabbits and 31 treated rabbits died during the study. Surviving rabbits at the 200 mg/kg dose level generally showed slight losses of body weight. At 100 and 200 mg/kg, ataxia and a slight decrease in body weight was observed in the pregnant animals. In seven treated and two control rabbits early deliveries were recorded. There were no treatment-related effects on corpora lutea, implantations, number of live fetuses and spontaneous abortions. The NOAEL for maternal toxicity is 50 mg/kg/day; the NOAEL for developmental toxicity is 200 mg/kg/day.

In two-generation developmental and teratogenicity study, CD rats were fed C14-15AE7 in the diet at dose levels of 0, 0.05, 0.1 and 0.5% (about 0, 25, 50 and 250 mg/kg). On the 13th day of the gestation period a representative number of female rats from each treatment group of the FC generation (*i.e.*, pups from the 3rd mating of the F0 and F1 parental generation) were sacrificed. Laparotomies were performed and the uterus was examined for uterine abnormalities, normal implantation and resorption sites. Remaining females were sacrificed on the 21st day of gestation. Various maternal and fetal parameters showed occasional values that were significantly different from the corresponding controls. However these were not considered related to the material tested as none occurred at the high feeding level and no dose response for these parameters was apparent. With respect to body weight gains, parental female rats and pups of the high dose group did not gain as much body weight as the control rats. Examination of organ weight values reveal compound related effects were limited to increased group mean liver weighs of male and female P1 generation from the 0.5% continuous feeding group at the

91 day sacrifice and increase in group mean relative liver weights of males of the 0.5% continuous feeding group of the P2 generation at the 60 day section sacrifices. T he NOAEL for maternal and developmental toxicity was established at the 0.1% in the diet (50 mg/kg/day).

Key Study/Critical Effect for Screening Criteria

AEs of different structures with regard to the length of the alkyl chain and the degree of ethoxylation have been evaluated in a number of 90-day and two-year oral toxicity studies. The lowest NOAEL of AEs for systemic toxicity was established at 50 mg/kg/day in two chronic (two-year) dietary studies on C12-13AE6.5 and C14-15AE7. Effects observed at the LOAEL were related to significantly elevated organ-to-body weight ratios for liver, kidney and heart, although there were no adverse histopathological changes.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD = 50/100 = 0.5 mg/kg/day

Drinking water guidance value = 1.8 ppm

References

Human and Environmental Risk Assessment (HERA) on Ingredients of Household Cleaning Products: Alcohol Ethoxylates (2009), http://www.heraproject.com

Talmage, S.S. (1994). Environmental and Human Safety of Major Surfactants – Alcohol Ethoxylates and Alkylphenol Ethoxylates, pp. 35, The Soap and Detergent Association, Lewis Publishers, Boca Raton, Florida.

Toxicity Profile

Calcium chloride
(CAS No. 10043-52-4)

Calcium chloride has been reviewed in the OECD-SIDS program (OECD, 2002a,b).

Calcium chloride is easily dissociated into calcium and chloride ions in water. The absorption, the distribution and the excretion of the ions in animals are regulated separately. Once calcium chloride is taken up, the effect of the substance on animals should be attributed to the effect of calcium, the effect of chloride, or both.

Calcium and chloride ions are essential constituents of all animals. Absorption, transport, distribution, excretion, and the homeostatic regulation of calcium and chloride ions in animals are well established, as are the mechanisms of action. Calcium is essential for the formation and maintenance of bones and teeth, and for the regulation of various physiological functions such as neural transmission and muscle contraction. Chloride is also essential for the regulation of acid-base balance of the body and intracellular osmotic pressure and acid-base buffering.

Acute Toxicity

The oral LD_{50} values were 2,045 (male) and 1,940 mg/kg (female) in mice, 3,798 (male) and 4,179 mg/kg (female) in rats, and 500-1,000 mg/kg in male rabbits. Acute oral toxicity of the substance is attributed to the severe irritating property of the original compound or its high-concentration solutions to the gastrointestinal tract, causing perforation and ulceration of the contact area of the tract. The dermal LD_{50} value in male/female rabbits was >5,000 mg/kg.

Irritation

Calcium chloride is non to slightly irritating to skin of rabbits; it is, however, severely irritating to eyes of rabbits. Irritating effect of calcium chloride has been observed in human skin injuries caused by the incidental contact with the substance or its high-concentration solutions.

Sensitization

There are no reliable data available for sensitization of calcium chloride.

Repeated Dose Toxicity

Rats (40-day old) were fed 20 mg/g calcium chloride in the diet for 12 months. There were no treatment-related effects on mortality, weight gain, or daily food consumption. In addition, no neoplastic lesions were observed in gastrointestinal tract, urinary tract, liver, heart, brain or spleen of the animals. From the food consumption (22 g diet/day), the daily intake of calcium chloride was estimated to be 440 mg. Considering that 1 mg/g diet is equivalent to 100 and 50 mg/kg/day for young and old rats, respectively, the dose used in this study (20 mg calcium chloride/g diet) corresponds to 1,000 to 2,000 mg/kg/day.

Calcium and chloride are both essential nutrients for humans as well as other animal species. As for healthy humans, the tolerable upper intake level for calcium is set at 2,500 mg per day (equivalent to 6.9 g $CaCl_2$ per day) and the reference nutrient intake for chloride at 2,500 mg/day (equivalent to 3.9 g $CaCl_2$ per day) (U.S Institute of Medicine Dietary Reference Intakes). The estimated intake of calcium chloride as food additives (160-345 mg/day) is considerably smaller than these values. Consistent with this, the establishment of the ADI for calcium chloride has not been deemed necessary by JECFA. The substance has also been considered a GRAS substance by the U.S. FDA. It is thus very unlikely that calcium chloride taken orally as food additives adversely affects human health.

Genotoxicity

In vitro studies for genetic toxicity with sufficient reliability have been reported. Genetic toxicity of calcium chloride was negative in the bacterial mutation tests and the mammalian chromosome aberration test.

Carcinogenicity

No carcinogenicity studies on calcium chloride were located.

Reproductive Toxicity

No reproductive toxicity studies on calcium chloride were located.

Developmental Toxicity

A developmental toxicity study showed no toxic effects on dams or fetuses at doses up to 189 mg/kg/day (mice), 176 mg/kg/day (rats) and 169 mg/kg/day (rabbits).

Key Study/Critical Effect for Screening Criteria

The drinking water guidelines for chloride and hardness (as calcium carbonate) may apply to calcium chloride.

References

OECD (2002). IUCLID Data Set for Calcium chloride (CASRN 10043-52-4), UNEP Publications.

OECD (2002). Screening Information Dataset (SIDS) Initial Assessment Report for Calcium chloride (CASRN 10043-52-4), UNEP Publications.

Toxicity Profile

Cocoamidopropyl betaine
(CAS No. 61789-40-0)

Cocoamidopropyl betaine has been reviewed in the OECD-SIDS program (OECD, 2006).

Acute Toxicity

The acute toxicity of cocoamidopropyl betaine (30-35.5% aqueous solution) in rats is low. The oral LD_{50} is $\geq$4,900 mg/kg, and the dermal LD_{50} is >2,000 mg/kg.

Irritation

A 30% aqueous solution of cocoamidopropyl betaine was only very slightly irritating to the skin of rabbits. In human studies, up to 3% solutions were weakly irritating. A 5-10% solution of cocamidopropyl betaine produced mild to moderate irritation to the eyes of rabbits; solutions containing 15% were irritating to highly irritating; and a 30% aqueous solution was irritating with irreversible damage.

Sensitization

The sensitizing potential of cocoamidopropyl betaine in humans is low. Commercial cocoamidopropyl betaine may, however, contain impurities identified as sensitizers (amidoamine and/or 3-dimethylaminopropylamine) which may explain positive results in human patch tests. There is no evidence for a photosensitizing potential.

Repeated Dose Toxicity

Rats were given a 30% aqueous solution of cocoamidopropyl betaine by oral gavage at doses of 0, 250, 500 or 1,000 mg/kg/day (corresponding to about 0, 75, 150, and 300 mg active substance/kg/day, respectively) 5 days/week for 28 days (Henkel KgA, 1991). The only treatment-related findings were forestomach lesions at the highest dose level, probably as a result of the irritant effect of the test substance. The NOAEL for this study is 500 mg/kg/day (150 mg cocoamidopropyl betaine/kg/day).

Rats were given a 30% aqueous solution of cocoamidopropyl betaine by oral gavage at doses of 0, 250, 500 or 1,000 mg/kg/day (corresponding to about 0, 75, 150, and 300 mg active substance/kg/day, respectively) five days/week for 90 days (Th. Goldschmidt AG, 1991). The only treatment-related findings were forestomach lesions at the 500 and 1,000 mg/kg dose levels , probably as a result of the irritant effect of the test substance. The NOAEL for this study is 250 mg/kg day (75 mg cocoamidopropyl betaine/kg/day).

Genotoxicity

There is no evidence for a genotoxic potential of cocoamidopropyl betaine. A 30% aqueous solution of cocoamidopropyl betaine was not genotoxic i*n vitro* in either a bacteria mutation test or in a mouse lymphoma test. A limited intraperitoneal mouse micronucleus test with 27 % active cocamidopropyl betaine was negative.

Carcinogenicity

No valid carcinogenicity studies have been conducted.

Reproductive Toxicity

No reproductive toxicity studies have been conducted on cocoamidopropyl betaine. However, there was no evidence of an adverse effect on the reproductive organs in rats given oral doses of up to 1,000 mg/kg/day of a 30% aqueous solution of cocoamidopropyl betaine (300 mg active substance/kg/day) for 90 days (Th. Goldschmidt AG, 1991).

Developmental Toxicity

A 28.9% aqueous solution of cocoamidopropyl betaine was tested in a rat developmental toxicity at doses of 330, 990, and 3,300 mg/kg/day (corresponding to 95, 286, and 950 mg/kg/day, respectively) (CESIO, 2004). There were dose-related maternal toxic effects (reduced body weights and stomach ulcers) at 990 mg/kg/day and above. Embryotoxic effects (increased numbers of resorptions, decreased number of viable fetuses, decreased fetal body weight) were found only at the maternal toxic dose level of 3,300 mg/kg/day. The NOAEL for maternal toxicity was 330 mg/kg/day (corresponding to 95 mg active substance/kg-day) and the NOAEL for developmental toxicity was 990 mg/kg/day (corresponding to 286 mg active substance/kg/day).

Key Study/Critical Effect for Screening Criteria

The key study is a 90-day rat oral gavage study in which forestomach lesions were seen at dose levels of 500 and 1,000 mg/kg of a 30% aqueous solution of cocoamidopropyl betaine. The NOAEL for this study is 250 mg/kg/day (75 mg active substance/kg/ay).

$NOAEL_{adjusted}$ = 75 * 5/7 = 53.6 mg/kg/day

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (subchronic to chronic)

Oral RfD = 0.05 mg/kg/day

Drinking water guideline: 0.19 ppm

References

CESIO (2004). Prenatal development toxicity study in rats with cocamidopropyl betaine by oral administration - according to OECD guideline 414 - DRAFT. Essen, LPT Study No. 17155/03 , 1-50.

Henkel KGaA (1991). Dehyton K; 28-Tage-Test mit wiederholter oraler Verabreichung an Ratten. TED 910119; Juli 1991, 1-139.

Human and Environmental Risk Assessment (HERA) on Ingredients of Household Cleaning Products: Cocoamidopropyl betaine (CAPB) (CAS No.: 61789-40-0, 70851-07-9, 4292-10-8), 2005; http://www.heraproject.com

OECD (2006). SIDS Initial Assessment Profile for Alkylamidopropyl betaines.

Th. Goldschmidt AG (1991). Tego-Betain. 90 day oral (gavage) subchronic toxicity study in the rat. Essen, Th. Goldschmidt AG, 954-348-155, 26.04.1991, 1-375.

Toxicity Profile

Crystalline Silica, Cristobalite
(CAS No 14464-46-1)

Crystalline Silica, Quartz
(CAS No. 14808-60-7)

Silica is an off-white granule that occurs naturally in various crystalline and amorphous or other non-crystalline forms. Crystalline silica is characterized by silicon dioxide (SiO_2) molecules oriented in fixed, periodic patterns to form stable crystals. The primary crystalline form of silica is quartz. Other crystalline forms of silica include cristobalite, tripoli and tridymite. Particle size is a key determinate of silica toxicity, since toxicity is restricted to particles that are small enough to be deposited into the target regions of the respiratory tract.

Oral Exposure

No oral studies were located; however, crystalline silica is not expected to exhibit toxicity by the oral route. Although absorption studies were not found for crystalline silica, kinetic studies on amorphous silica show no absorption from the gastrointestinal tract.

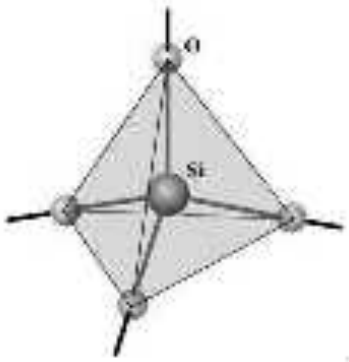
Dermal Exposure

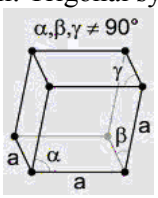
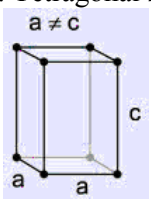
No dermal studies were located; however, crystalline silica is not expected to exhibit toxicity by the dermal route.

Inhalation Exposure

See attached OECD-SIDS Initial Targeted Assessment Profile on Quartz and Cristobalite, SIAM 32, 19-21 April 2011.

INITIAL TARGETED ASSESSMENT PROFILE (Human Health)

CAS No.	Quartz: CAS RN 14808-60-7 Cristobalite: CAS RN 14464-46-1
Chemical Name	Quartz and Cristobalite
Structural Formula	Molecular Formula: SiO_2 

Unit Cell: Trigonal symmetry	Unit Cell: Tetragonal symmetry
	
Quartz: CAS RN 14808-60-7	Cristobalite: CAS RN 14464-46-1

SUMMARY CONCLUSIONS OF THE TARGETED ASSESSMENT

NOTE: The present assessment is targeted to address the following human health endpoints: repeated dose toxicity and carcinogenicity via the inhalation route of exposure, and genotoxicity. It cannot be considered as a full SIDS Initial Assessment. Summary information on exposure is also reported here. Other endpoints for human health and the environment included in the Canadian screening assessment but have not been presented to OECD member countries, and thus are not included in this profile.

The final screening assessment will be published under the responsibility of the Government of Canada.

Rationale for Targeting the Assessment

The Government of Canada "categorized" or prioritized all 23,000 chemical substances on its Domestic Substances List (DSL) from 1999 to September 2006, as required by its *Canadian Environmental Protection Act, 1999* (CEPA 1999). Additional details may be found at http://www.chemicalsubstanceschimiques.gc.ca/about-apropos/categor/index-eng.php. Using information from Canadian industry, academic research and other countries, Government of Canada scientists applied a set of rigorous tools to the 23,000 chemical substances on the DSL. They were categorized to identify those that were: **inherently toxic** to humans or to the environment and that might be **persistent** and/or **bioaccumulative**; and substances to which people might have **greatest potential for exposure**. During this priority-setting exercise, distinct approaches were taken for identifying substances of likely concern for human health and the environment, and subsequent assessment activities may have focused on either human health or ecological endpoints. Through categorization, the Government of Canada has identified approximately 4,000 of the 23,000

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chemical substances on the DSL as priorities for further assessment, research and/or measures to control their use or release. Quartz and cristobalite were identified at that time, applying the categorization criteria, as high priorities for human health risk because they were considered to pose greatest potential for exposure and their respirable forms are classified by the International Agency for Research on Cancer as carcinogenic to humans (quartz and cristobalite) and by the National Toxicology Program as known human carcinogens (crystalline silica). These substances did not meet the ecological categorization criteria for bioaccumulation potential or inherent toxicity to aquatic organisms.

Under the Canadian legislation a determination of whether one or more of the criteria of the CANADIAN ENVIRONMENTAL PROTECTION ACT (CEPA) 1999, section 64 are met is based upon an assessment of potential risks to the environment and/or to human health associated with exposures in the general environment. For humans, this includes, but is not limited to, exposures from ambient and indoor air, drinking water, foodstuffs, and the use of consumer products. A conclusion under CEPA 1999 on the substances in the Chemicals Management Plan (CMP) Challenge is not relevant to, nor does it preclude, an assessment against the hazard criteria specified in the Controlled Products Regulations, which is part of the regulatory framework for the Workplace Hazardous Materials Information System [WHMIS] for products intended for workplace use.

Physical-chemical properties

The silicon dioxide group represents a polymorphic category containing a large number of forms identical in composition but with different atomic arrangements which afford different chemical properties. There are two sub-categories within this group: crystalline silica, to which the present substances quartz and cristobalite belong, and non-crystalline or amorphous silica. The key distinction between these sub-categories is that in crystalline substances, the building blocks are arranged in regular, repeating 3-dimensional pattern having long range order, whereas amorphous materials do not display long range order. In all forms of silica, (crystalline and non-crystalline), the silicon atom is tetrahedral and bound to four neighbouring oxygen atoms.

Quartz and cristobalite are solid at room temperature, existing normally as colourless or white crystals. The melting points for quartz and cristobalite are 1400-2000 ^{o}C and 1713-1728 ^{o}C, respectively and for both compounds, the boiling point is 2230^{o}C. Even though no experimental data were available, their vapour pressure and Henry's Law constant are likely negligible. Log K_{ow} (octanol-water partition coefficient) and log K_{oc} (organic carbon-water partition coefficient) are not applicable to these substances. The densities range from 2500-2700 kg/m^3 for quartz and 2300-2380 kg/m^3 for cristobalite.

The very similar physico-chemical properties of quartz and cristobalite reflect their closely related crystal forms. The solubility of crystalline silicates decreases as a function of silica tetrahedral packing density and long-range crystal order. For example, cristobalite has a more open framework structure than quartz and its density is lower, therefore, its solubility is higher. The water solubility of these minerals is also function of temperature, pH, particle size, and the presence of a disrupted surface layer. This may explain the variability of solubility values reported by many authors. The most probable solubility value for quartz is approximately 3.8 mg Si/L, or 6.4 mg/L expressed as the SiO_2 species, while the solubility of cristobalite is approximately 8.7 mg Si/L, or 18 mg SiO_2/L. The kinetics of dissolution of these substances is slow due to the high activation energy required to hydrolyse the Si-O-Si bond.

Human Health Targeted Endpoints

The majority of the studies described here have been reviewed by the International Agency for Research on Cancer (IARC 1997). However, additional data relevant to the screening assessment were identified up to August 2010.

Repeated dose toxicity/non-neoplastic effects (development of silicosis).

Studies on animals

Significant short-term and subchronic studies have demonstrated adverse effects in the lungs, while one of the 6 studies showed effects on the spleen in mice. Rats were exposed to 0, 10 or 100 mg/m^3 of cristobalite via inhalation for 6 hours/day during 3 days. Animals were observed 3 months after exposure. Elevated levels of granulocytes and elevated markers of cytotoxicity from the lung lavage fluid were noted in all exposed groups. Another study of similar duration (9 days) conducted in mice also identified a LOAEC of 10 mg/m^3. Effects observed included minimal interstitial thickening, accumulations of mononuclear cells and slight lymphoid tissue hypertrophy in the lungs.

In a 4-week inhalation study, female rats were exposed to 0, 0.1, 1 or 10 mg/m^3 of quartz 6 hours/day, 5 days/week. Bronchoalveolar lavage fluid was evaluated at 1, 8, and 24 weeks after exposure. Elevated levels of

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granulocytes and significant elevation of markers of cytotoxicity (Lactate dehydrogenase [LDH] and β-glucuronidase [β-glu]) were observed at 1 mg/m^3 and higher. The increased levels of LDH and β-glu were only significant at 24 weeks after exposure. A LOAEC of 1 mg/m^3 was identified at 24 weeks.

Male rats (4 animals per dose) were exposed to 0 or 3 mg/m^3 of cristobalite via inhalation for 6 hours/day, 5 days/week during 13 weeks. Pulmonary inflammation and fibrosis were observed in the exposed group at the end of treatment. When mice were similarly exposed to 5 mg/m^3 of quartz for 6 hours/day, 5 days/week for 15 or 27 weeks, the authors observed increased spleen weight and formation of plaque in the spleen.

In two separate studies, in which rats or hamsters were exposed to quartz via inhalation for at least 6 months, LOAECs of 2 and 3 mg/m^3 were identified, respectively. All the effects observed were related to inflammation and fibrosis of the lung tissue.

Several chronic studies investigated exposure of the respirable forms (i.e. accumulated via inhalation in the lung tissues) of quartz and cristobalite to rats, mice and hamsters. The following is a description of the study in which the lowest non-neoplastic LOAEC was determined. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz, containing 74% of respirable quartz, through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. The mean mass of particle at the end of the exposure period was 0.91 mg/lung. The LOAEC identified was 0.74 mg/m^3 (adjusted for 74% respirable quartz) based on lipoproteinosis, multifocal, inflammatory cell infiltrate and alveolar hyperplasia.

Human epidemiology data

In humans, the lowest observed adverse effect level was identified in a U.S. cohort study. The study was conducted on 3330 gold miners (all are males), who had an average of 9 years underground exposure during the period 1940 to 1965. The cohort was followed up through 1990. Silicosis[1] was identified through death certificates or chest X-rays. A job-exposure matrix together with work history was used to estimate individual exposure. The total silica content in the respirable dust in the mine was estimated at 13% and the median crystalline silica exposure was 0.05 mg/m^3. In this sub population of miners, 170 cases of silicosis were identified. The best predictor for risk of silicosis was cumulative exposure, which varied from less than 1% for a 0.5 mg/m^3-year exposure to 68-84% when exposed to more than 4 mg/m^3-year (based on the average daily dust exposure during the workday each year and summed over time for each miner). The main limitations identified by the authors include the limited number of radiographic surveys, the potential bias from death certificates

[1] Silicosis: Lung disease caused by inhalation of crystalline silica dust, and resulting in inflammation and scarring in forms of nodular lesions in the upper lobes of the lungs. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics). It does not follow that a history of exposure to silica necessarily results in silicosis (Nonsilicotics). The typical "Silicotic" lung nodule is shown in Figure 1.

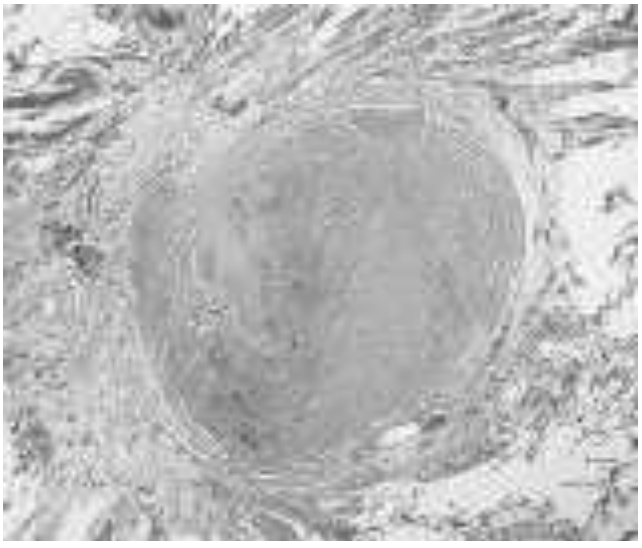


Figure 1. Silicotic nodule characterised by a central zone of hyalinised collagen with a whorled appearance and peripheral dust-containing macrophages (Rees and Murray, 2007).

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(relying on death certificates instead of relying on repeated x-rays, which were lacking for each miner, may have underestimated the number of cases) and the fact that the conversion of dust counts to

gravimetric measurements may not be accurate based on the estimation of 13% silica content in the respirable dust (although based on a relatively large number of samples (n = 82) collected in two different surveys, there was broad range of content in these samples (1% to 48%, SD = 9), and the percentage of respirable quartz may have differed in earlier years, but data were lacking for these years).

Two other human studies have identified similar LOAECs based on the critical endpoint of radiographic confirmed silicosis. A LOAEC of 0.053 mg/m^3 (mean exposure) was identified in a cross sectional study of South African gold miners and a LOAEC of 0.064 mg/m^3 (mean exposure) was derived in a mining community population-based random sample survey in Colorado.

Carcinogenicity studies

Studies on animals

Experimental studies conducted in rats have shown clear and consistent increases in lung tumours after chronic inhalation exposure. In the nine rat studies identified, five were inhalation studies and four were intratracheal instillation studies. All studies except one inhalation study showed increased incidence of lung tumours. For the inhalation studies with treatment related tumours, concentrations ranged from 1 to 50 mg/m^3 (1, 6, and 30 mg/m^3 of DQ-12 quartz; 12 and 50 mg/m^3 of Min-U-Sil 5 quartz) and duration of exposure ranged from 29 days to 2 years. In the inhalation study with no treatment-related tumours, exposure was 60 mg/m^3 of Sikron F300 quartz for 13 weeks. The following is a description of the neoplastic results in the study also identified as the critical study for non-neoplastic results. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. In the exposed group, 18 animals developed tumours (12 in females, 5 in males), as opposed to 3 and 2 for the control and positive control groups respectively. The majority (10/18) of the tumours observed were adenocarcinomas. The mean mass of particles in the lungs at the end of the exposure period was 0.91 mg/lung.

For the intratracheal instillation studies, doses ranged from 4 to 57 mg/kg-bw (based on 7, 12 or 20 mg/animal of Min-U-Sil (5) quartz or 20 mg/animal of novaculite quartz). Exposure regimes were diverse and included single instillation with observation for up to two years, to weekly instillation for 10 weeks. It is noteworthy that the single intratracheal administration of a 95% pure quartz particles (<5 μm) resulted in an increased incidence of silicotic granulomas after 3 weeks and lung tumours after 11 months. The most common tumours reported across the long term rat studies were adenocarcinomas, however other tumours such as squamous-cell carcinoma, alveolar carcinoma and bronchiole-alveolar adenoma were also reported, and all animals that developed tumours also showed some degree of fibrosis.

Of particular interest is the intratracheal instillation study, investigating the sequence of pathological events leading to lung tumors. An unspecified number of rats/sex/dose received a single intratracheal instillation of various crystalline silica dusts or ferric oxide, allowing direct administration into the bronchial tree. The doses were 12 or 20 mg of Min-U-Sil 5 quartz (MQZ), 12 mg of hydrofluoric-acid-etched Min-U-Sil 5 quartz (HFMQZ), 12 mg of cristobalite, 12 mg of tridymite and 12 mg of ferric oxide suspended in saline. All groups were observed until six months post exposure, except for both MQZ groups, the HFMQZ and the ferric oxide group which were observed up until 17 months post-exposure. Interim sacrifices were conducted at 6, 11 and 17 months. The rat lungs showed a clear progression of effects. The sequence of pathological events were, an initial inflammatory response leading to a marked hyperplasia and hypertrophy of alveolar cells after one month, and at six months hyperplasia was evident but no lung tumours were observed. In this study, lung tumours were observed starting at the 11 month sacrifice with a 17% and 42% incidence in males and females (based on 3/18 males and 8/19 females), respectively, and at 17 months incidences were 32% and 59% (based on 6/19 males and 10/17 females, respectively). No lung tumours were found in ferric oxide treated rats. Similar studies have also been conducted in hamsters and mice. Although treated mice and hamsters showed treatment related signs (inflammation or fibrosis), no tumours were observed in hamsters. No increase in the incidence of lung tumours was seen in mice treated with quartz; however silicotic granulomas and lymphoid cuffing around airways but no fibrosis were seen in the lungs of quartz-treated mice.

Human epidemiology data

There is an extensive dataset of human studies investigating the link between crystalline silica exposure and cancer. IARC (1997) identified over 50 epidemiological studies based on occupational exposure to dust containing respirable crystalline silica. Main industry sectors from which the human data is derived include gold mines, foundries, granite/stone industry, pottery workers and refractory brick workers. From the least confounded studies, it was noted that lung cancer tended to increase with the following parameters: cumulative

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exposure; duration of exposure; peak intensity of exposure; presence of radiographically defined silicosis; and length of follow-up time from date of silicosis diagnostic. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics).

Since the 1997 IARC report, a large number of epidemiological studies have been published, with the more recent studies being updates from supplementary follow-up of results from previously assessed case-control studies cohorts, new results based on refined exposure assessments or adjustment for confounders or meta-analyses of the pooled data from these epidemiology studies

In a meta-analysis of the data from 10 cohort studies of gold, tin and tungsten miners, granite workers, industrial sand, diatomaceous earth and pottery workers with quantitative exposure estimates for crystalline silica were pooled in order to analyse the risk related to lung cancer. The pooled cohort standardized mortality ratio (SMR, against national rates) [See Appendix 1 for definition] was 1.2 (Confidence Interval [CI] 1.1-1.3). The results from the case-control analyses show a statistically significant trend with duration of exposure (odds ratios (ORs) [See Appendix 1] by quintile of cumulative exposure increased from 1.0 to 1.6 [CIs of 0.85 to 2.1] and by quintile of average concentration increased from 1.0 to 1.7 [CIs of 1.1 to 2.3]), supporting the importance of the increasing lung burden of silica in the occurrence of cancer. Overall, the authors concluded that the results support the carcinogenicity conclusion presented by IARC (1997).

To investigate the link between crystalline silica, silicosis and lung cancer, epidemiological data published between 1966 and 2001 were gathered. Over 50 studies were selected and pooled according to type of study and the parameter being linked to lung cancer (i.e. silica exposure, presence of silicosis in subjects). The quality of study, adjustment for confounding factors, co-exposure to other carcinogens and availability of a more recent analysis of a same cohort were taken into consideration in the final selection of the studies. Analysis of the relationship between exposure to silica and lung cancer included 17 cohort and 13 case-control studies. For the analysis of lung cancer versus silicosis, 11 cohort and 5 case-control studies were selected. The third analysis included 6 cohort and 2 case-control studies to evaluate the risk of lung cancer in non-silicotics. A random effect model was used to conduct each meta-analysis. Pooled cancer risk ratios (RRs) were 1.32 (CI 1.23-1.41) for crystalline silica exposure, 2.37 (CI 1.98-2.84) for individuals exposed to silica with confirmed silicosis (Silicotics) and 0.96 (CI 0.81-1.15) for individuals with no evidence of silicosis (non-silicotics) with confirmed exposure to silica, supporting the general observation that silicosis has a stronger temporal relationship with crystalline silica exposure and furthermore support the view that a human silicotic response could be a preliminary stage in the development of cancer.

A more recent meta-analysis included 28 cohort, 15 case-control and two proportionate mortality ratio (PMR) [See Appendix 1] studies from a variety of occupational settings conducted between 1996 and 2005. Risk ratios (RRs) were calculated based on type of study and silicosis status using fixed and random effect models (results presented here are from the random model). RRs for all cohort studies was 1.34 (CI 1.25-1.45), and were 1.69 (CI 1.32-2.16) for silicotics, 1.25 (CI 1.18-1.33) for those with undefined silicosis status and 1.19 (CI 0.87-1.57) for non-silicotics. In the case-control studies, the general RR was 1.41 (CI1.18-1.67), and the same sub-groups as mentioned above resulted in RRs of 3.27 (CI 1.32-8.2), 1.41 (CI1.18-1.70) and 0.97 (CI 0.68-1.38), respectively. The proportionate mortality ratio for the last two studies was 1.24 (CI 1.05-1.47). The authors noted that the association between lung cancer and exposure to crystalline silica was more consistent for silicotics, i.e., those diagnosed with silicosis and RR values split into type of occupational settings in which participants worked.

Based upon the above three meta-analysis studies and the epidemiology studies discussed in IARC (1997), the following can be concluded. Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis. Cancer risk is often more significant in workers exposed to crystalline silica over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours. Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles.

There have been reports of tumours outside of the lungs in persons with high silica exposure; however, these reports are sparse and the data inconsistent and have not been unequivocally linked to exposure to either one of the crystalline forms (quartz or cristobalite). Some of the reported locations are: oesophagus, stomach, liver, skin and bone. Sufficient epidemiological or toxicological data do not currently exist for quantitative assessment of the exposure-response relationship on these other tissues or organs.

Genotoxicity

Potential genotoxicity has been assessed in multiple *in vitro* and *in vivo* assays. Table 1 below gives a brief summary of the positive results observed in each type of assay.

Table 1. Summary of positive results over total number of results for each assay and each category (all studies

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conducted with crystalline silica: quartz, except where indicated).

Assay	Animal data		Human data		Positives/Total	
	In vitro	In vivo	In vitro	In vivo[d]	In vitro	In vivo
Rec Assay	0/1				0/1	
DNA strand break	1/1	2/2	5/5[b]	1/1	6/6	3/3
Sister chromatid exchange	0/1		0/1[c]	1/1	0/2	1/1
Micronucleus	2/3	0/1	2/2[b]	1/1	4/5	1/2
Chromosome aberration	0/1			1/1	0/1	1/1
Aneuploidy/polyploidy	0/3				0/3	
Cell transformation	4/4				4/4	
Hprt mutation	1/2	2/2[a]	1/1[b]		2/3	2/2
Oxidative DNA damage		4/5	2/2		2/2	4/5
DNA binding		1/1				1/1
p53 activation		0/1				0/1

a. one assay conducted with crystalline silica: cristobalite
b. one assay conducted with "ultrafine crystalline silicon dioxide".
c. crystalline silica: tridymite
d. crystalline silica dust (subtypes not provided).

All the *in vivo* human genotoxicity studies are based on three independent studies that used blood samples from workers from diverse occupational settings with confirmed exposures to crystalline silica dust; however, quantification of exposure was not provided. After stratification by smoking status, sister chromatid exchange remained statistically significant in both smokers and non-smokers although the frequency was higher in smokers. For the chromosome aberration assay conducted as part of the same study (blood samples from workers in the stone crusher industry), the increased frequency was no longer significant after stratification. In the DNA damage study of foundry and pottery workers and the micronucleus assay of workers involved in sandblasting and related jobs, results were positive when compared to controls. However, in both studies, smoking status influenced the results, contributing to the increased DNA damage observed since results were greater in smokers versus non-smokers, and the frequency of micronuclei in nasal epithelial cells was higher in smokers (p=0.002) but when using peripheral blood lymphocytes did not differ statistically between smokers and non-smokers who were similarly exposed to silica dust,

The role of *in situ* generation of reactive oxygen species (ROS) and reactive nitrogen species (RNS) has been well established in the following types of DNA damage: small scale insertions, DNA base pair deletion, base modification, chromosomal change/loss, microsatellite instability, DNA strand break, 8-hydroxydeoxyguanosine (8-OHdG) mutation and point mutations. ROS and RNS generation is postulated to be (a part of) the DNA damage mechanism for crystalline silica. Studies are described below to support this hypothesis.

DNA was exposed *in vitro* to various crystalline silica dusts, to H_2O_2, or to both. Results show that DNA damage was limited when dust or H_2O_2 were administered alone but increased with the co-exposure. When the reactive oxygen scavenger, dimethylsulfoxide, was added to the test system, DNA strand break was inhibited, data supporting the viewpoint that it is the presence of radicals generated in response to quartz and cristobalite that causes the DNA damage and not quartz or cristobalite themselves.

Hprt mutation assays in rat alveolar epithelial cells, both *in vitro* and *in vivo,* were positive in response to quartz. The positive results *in vivo* were seen only in the presence of significant inflammatory responses in the treated animals. Also, in a parallel *in vitro* experiment, rat alveolar epithelial cells were incubated with the bronchoalveolar lavage fluid from the rats exposed to quartz. Both macrophage and neutrophil enriched lavage cells induced mutation in the exposed alveolar epithelial cells. Addition of catalase (an enzyme which inactivates H_2O_2) before incubation inhibited the increase in *hprt* mutation.

Rats were exposed to either crystalline or amorphous silica in a manner to induce the same level of

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inflammation in the lungs. The inflammatory response was assessed by measuring the proportion of neutrophils in the bronchiolar lavage fluid. The actual concentrations were 3 and 50 mg/m^3 for crystalline and amorphous silica respectively. The animals were exposed for 13 weeks. *Hprt* mutation frequency was measured in the alveolar epithelial cells at the end of the exposure period. Mutation frequency was greatly increased only in the crystalline silica treated rats; no treatment related increase was found in the rats treated with the amorphous form.

In an 8-OHdG assay conducted to monitor DNA damage by reactive oxygen species, female rats were exposed to 0, 0.3, 1.5 and 7.5 mg/animal of quartz via intratracheal instillation. Effects were observed 90 days post-exposure. A clear dose-response relationship was identified between quartz exposure and various inflammation markers (differential cell count, protein, lung surfactant lipids and tumour necrosis factor alpha). Inflammation was present starting at the lowest dose. However, 8-OHdG showed a statistically significant increase starting at 1.5 mg/animal only. Similarly, in another study, 8-OHdG and DNA strand breaks were observed at concentrations of or above 10 ug/m^3 in rat lung epithelial cells.

In the aim of investigating the role of ROS in lung carcinogenesis, rat lung epithelial cells were incubated with polymorphonuclear (PMN) leukocytes (involved in the inflammatory process and responsible for the release of certain ROS) or hydrogen peroxide. Statistically significant increases in 8-OHdG were observed in the presence of PMN or hydrogen peroxide in a dose-response manner.

In a series of experiments which used *in vitro* stimulation of macrophages with crystalline silica and *in vivo* intranasal instillation of crystalline silica in mice, it was demonstrated that that the chronic fibrosis seen in a murine model of silicosis *in vivo* is dependent on the presence of adaptor molecule ASC and Nalp3 inflammazome. These data support a potential mode of action whereby silica triggers cellular responses that in turn activate alveolar macrophages, resulting in an inflammatory response and silicosis. In mice deficient in Nalp3 inflammazome, the development of inflammation and collagen deposition was significantly reduced compared with normal mice 3 months after the initial intranasal instillation of silica.

Analysis of Lung Tumour Data

The weight of evidence for both rats and humans indicates that fibrotic and silicotic lesions in the lung result from inhalation exposure to crystalline silica and that lung cancer is secondary to those lesions in the lung. Although the mechanism of induction for the lung tumours has not been fully elucidated, there is sufficient supportive mode of action evidence from the data presented to demonstrate that a threshold approach to risk assessment is appropriate based on an understanding of the key events in the pathogenesis of crystalline silica induced lung tumours. The body of evidence include the following:

- In experimental studies, all rats that developed tumours also showed fibrosis.
- Adenocarcinomas, the most common type of tumour identified in rats, are commonly associated with fibrosis and deeply scarred lung tissue.
- Experimental rat studies showed a clear progression of the effects from initially mild inflammation, followed by fibrosis over-time, leading eventually to lung tumours.
- Tumours are not present in all treated species dosed in the same way.
- The tumours, both in rats and humans, are concentrated in the lungs only, although other organs are indirectly exposed.
- In human studies, cancer risk is often more significant in workers exposed over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours.
- Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles
- Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis.
- For genotoxicity, in vitro results were mostly mixed and in vivo results were mostly positive. However, the vast majority of the positive genotoxicity assay results can be explained by the generation of reactive oxygen species, as demonstrated experimentally, where ROS scavenging prevents the genotoxicity.
- *In vivo*, macrophage deficient mice (macrophages produce ROS in response to crystalline silica) do not develop silicosis nor do they develop tumours and the Nalp3 inflammazome, a key player in the macrophage initiated inflammatory response, is required for the development of pulmonary fibrosis after

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inhalation of silica.

- Though inhalation exposure to crystalline silica in multiple occupational settings is clear, the increase in risk, based on the several recent meta-analyses of the multiple human epidemiological studies, remains low.

It is worth noting that where aggressive engineering controls have been made to reduce silica dust levels in the workplace (Sweden), silicosis has been eliminated. By corollary, existing exposures outside of the workplace in such areas do not pose a risk for silicosis to the general population.

The respirable forms of quartz and cristobalite possess properties indicating a hazard for human health (repeated dose toxicity, carcinogenicity and genotoxicity). The mode of action in the lungs involves irritation, inflammation and reactive species formation, leading to silicosis, and eventually to tumour formation.

Exposure

Uses

Consistent with oxygen and silicon being the two most abundant elements in the Earth's crust, silicon-oxide minerals, including quartz are ubiquitous in the natural environment. In particular, as a component of sand, quartz may find use in a diverse array of applications. Several high volume uses include, but are not limited to, the use of sand as a filling material for the construction of roads and in general building activities, the use of sand and gravel aggregates as abrasives on roads in winter and the use of fly-ash, which may contain 4-14% quartz and 0.5-1% cristobalite, as a cement additive. These abrasives when used on winter roads are usually mixed with road salts and may be sand only, stone dust, sand and gravel aggregates, or pre-treated sand. They are used mainly by rural municipalities or in areas where cold temperatures diminish the efficiency of salts for de-icing. Quantities of abrasives used in Canada were 5.73×10^9 kg, 4.59×10^9 kg, and 4.93×10^9 kg for 2007, 2008 and 2009, respectively.

Industrial sand, high purity silica sand products with closely controlled sizing are expected to contain quartz and cristobalite, include lump silica (2-3mm up to 15 cm or more), silica sand (75µm to 2-3mm) and silica flour (less than 75µm). Lump silica may be used in the production of silicon alloys, silica bricks, and the linings of certain types of pulverizers (eg. ball mills and tube mills).

Silica sand may be used in the manufacture of glass and glass fibres, silicate chemicals and silicon carbide, the hydraulic fracturing of wells, foundry moulding, and for sandblasting. Silica flour may find use in the ceramics and cement industries, as a filler and extender in rubber and coatings, and as an abrasive in soaps.

Natural clays, such as bentonite and fuller's earth, are used in cat litters for their high water absorbance capacities. Quartz is a natural component of these clays, and consequently, it may be present in cat litter products. High purity α-quartz is a piezoelectric material, which means that application of a voltage induces a distortion in the crystal shape and vice versa. This ability to interconvert electrical and mechanical energy has led to the use of quartz crystals in electronic devices requiring precise timing control, for example telephones, radios, watches and computers.

According to a survey conducted in Canada, quartz and cristobalite are also used in abrasives, adsorbents, filter products (diatomaceous earth), grout and cement. These substances reportedly also find use as fillers, which add bulk and improve wear resistance, in paints and coatings, adhesives, sealants, polymer films, caulking, epoxy resins and silicones. Also, quartz is listed as an ingredient in 60 cosmetic products in Canada. The types of products include anti-wrinkle preparation, eye and face makeup, lipstick, hair dyes, shampoos and grooming products, as well as skin cleansers, moisturizers and tanning preparations.

Natural Sources

In Canada, quartz naturally occurs in many types of rock formations. Those with high silicon dioxide content (95% SiO_2 or more) include vein and massive intrusion bodies, quartz pebbles, silica sand, sandstone and quartzite. Sandstone is a sedimentary rock mostly composed of quartz grains cemented by a bonding material such as clay, calcite or iron oxide. Quartzite is a hard, compact, metamorphosed sandstone made of grains of quartz firmly bonded with a siliceous cement. Mineral aggregates (e.g., sand and gravel) have variable silicon dioxide content. Quartz is also found as crystals, aggregates or discrete particles in certain igneous rocks (e.g., granites and pegmatites), soils, sediments, air and surface water. This omnipresence is consistent with the fact that silicon is the second most abundant chemical element on Earth.

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Cristobalite is naturally produced in the ashes of volcanic eruptions, and by combustion metamorphism which is a local phenomenon of spontaneous combustion of naturally occurring substances such as bituminous rocks, coal or oil. It may be found in cavities in volcanic rocks and in thermally metamorphosed sandstones and may also be a transient stage in the diagenesis of diatomaceous shale with the result that soils made of these geologic formations may be rich in cristobalite. Unlike quartz, the natural occurrence of cristobalite is limited to specific geographic regions and mineral types.

Anthropogenic Sources

Natural quartz is isolated from ore via beneficiation, which involves milling or grinding the material into particles that are separated into desired mineral and waste. The materials obtained are either used directly or further purified. In Canada, in 2006, 2.146×10^{9} kg of pure quartz were mined, and 2.385×10^{11} kg of sand and gravel aggregates were produced. The proportion of quartz in silica sand deposits and gravel aggregates will vary from one site to another.

Cristobalite can form from silica melts during the preparation of silica glass; quartz is not obtained from melts but is manufactured at elevated temperature and pressure via a hydrothermal process. Cristobalite also forms during the calcination[2] of diatomaceous earth.

Human Exposure Estimate

Ambient air

The exposure assessment is focussed on respirable quartz and cristobalite, which in ambient air comprises a component of total particulate matter (PM). In Canada, data on the concentrations of silicon in PM was available and used as a surrogate for quartz and cristobalite. This approach is conservative because the measured silicon includes all silicon-containing substances and therefore represents the upper limit for quartz and cristobalite in ambient air.

The National Air Pollution Surveillance (NAPS) Program measured concentrations in $\mu g/m^3$ of silicon in PM with aerodynamic radii less than 2.5 µm ($PM_{2.5}$ (dichot)), and from 2.5 to 10 µm (PM_{10} (dichot)) (the total particulate matter with aerodynamic radii less than 10 µm (PM_{10}) is obtained by adding these values) in Canada. In 2009, as part of the NAPS Program, silicon concentrations were determined on over 1600 samples of $PM_{2.5}$(dichot) and over 1500 samples of PM_{10}(dichot) at 24 urban locations across Canada. An estimate of exposure to quartz and cristobalite can be obtained by assuming that all the silicon in the PM is represented stoichiometrically as SiO_2, and multiplying the reported concentration of silicon by 2.14 to obtain a value for silica.

The intake of respirable quartz and cristobalite by the general population of Canada is estimated using a range covering the lowest 50^{th} percentile SiO_2 concentration in PM_{10}, measured in Pt. Petre, ON, (0.12 $\mu g/m^3$) to the highest 50^{th} percentile concentration in PM_{10} measured in Calgary, AB (2.1 $\mu g/m^3$). The 50^{th} percentile SiO_2 concentrations ranged from 0.1 to 2.1 $\mu g/m^3$ across the survey sites; the top of this range is quite close to the average of the maximum values for the 24 sites (3.7 $\mu g/m^3$). The outdoor data were used to represent the indoor levels, because information on indoor silicon concentrations was not available, and the range of PM_{10} measured indoors is generally lower than the outdoor range. Thus, this approach conservatively overestimates indoor exposure in homes.

The highest exposure group based on these calculations is children ages 0.5 to 4 years with an estimated daily intake ranging from 0.07 to 5.26 µg/kg-bw per day; the estimated daily intake decreases with age due to changes in the ratio of inhalation rates to body weights; the daily intake of adults, 20-59 years old, is estimated to range from 0.03 to 2.00 µg/kg-bw per day.

Consumer Products

Exposure to respirable quartz from the use of cosmetic products, which contained quartz as an ingredient, was considered low because they are not formulated for spray application, the loose powders were reported to contain less than 0.1% quartz, and in these products the substance is not expected to be associated with other components of the formulation and not available in a free form.

For consumer Do It Yourself (DIY) activities around the home, the highest mean breathing zone concentration of particles from sanding dry wall (median cut-point of 10µm) of 6.31 mg/m^3, was used to derive an upper-

[2] Calcinations: Heat treating a substance, but without fusion, to bring about change in its physical or chemical constitution.

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bound exposure estimate ranging from 2 to10 µg/kg-bw per event.

Quartz is used to formulate a large number of paints and coatings. To estimate potential inhalation exposure to quartz from these products, the spray painting of wall paints with an airless spray gun was considered appropriate as a conservative scenario. Exposure to respirable paint particles was estimated using data from controlled a laboratory study in which walls of poorly ventilated test rooms were painted by professional painters using an airless sprayer to apply interior latex paint. The maximum concentration of 13% quartz in paint in Canada was used to estimate exposure. The upper-bound estimate of exposure to quartz, based on the maximum concentration of 13% quartz in paint in the Canadian market and the maximum concentration of respirable paint particles measured in these controlled studies when recommended personal protective equipment is used, is 0.954 µg/kg-bw per event.

Inhalation of ambient air containing quartz and cristobalite is the dominant pathway of chronic exposure (excluding that from DIY activities) for the general population. Because SiO_2 makes up only approximately 5% of PM_{10}, silicon concentrations (expressed as SiO_2) measured in the Canadian NAPS survey of 24 urban locations were considered most relevant to the estimation of exposure by the general population. Quartz and cristobalite comprise only a portion of the total SiO_2 in PM_{10}, therefore, the use of the total silicon concentration to represent the upper bound crystalline silica concentrations results in an overestimation of exposure.

Appendix 1: Definitions of Epidemiological Terms in the ITAP

SMR (Standardized Mortality Ratio): The ratio (x 100) of observed to expected deaths in a study population. Expected deaths are calculated by applying a set of standard age-specific mortality rates to the age distribution of the study population. Standardized ratios are only useful for comparisons. They have no intrinsic meaning.

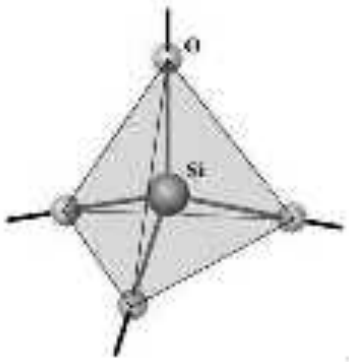
OR (Odds Ratio): In epidemiological case-control studies, a relative measure of disease occurrence. The odds in favour of a particular disease occurring in an exposed group are divided by the odds in favour of its occurring in an unexposed group. If the condition being studied is rare, the odds ratio is a close approximation to the relative risk.

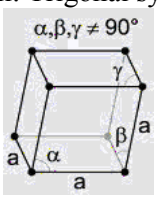
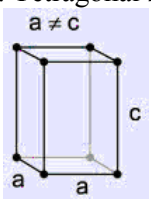
RR (Risk Ratio): The probability of the occurrence of a disease in a group that has been exposed to some environmental, medicinal, microbial, or toxic influence, relative to its probability in a randomly selected population.

PMR (Proportionate Mortality Ratio): Proportionate mortality is the proportion of deaths in a specified population over a period of time attributable to different causes. Each cause is expressed as a percentage of all deaths, and the sum of the causes must add to 100%. These proportions are not mortality rates, since the denominator is all deaths, not the population in which the deaths occurred. Thus, proportionate mortality ratio is a measure of the frequency of occurrence of the proportionate mortality in a defined population during a specified interval of time.

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INITIAL TARGETED ASSESSMENT PROFILE (Human Health)

CAS No.	Quartz: CAS RN 14808-60-7 Cristobalite: CAS RN 14464-46-1
Chemical Name	Quartz and Cristobalite
Structural Formula	Molecular Formula: SiO_2 

Unit Cell: Trigonal symmetry	Unit Cell: Tetragonal symmetry
	
Quartz: CAS RN 14808-60-7	Cristobalite: CAS RN 14464-46-1

SUMMARY CONCLUSIONS OF THE TARGETED ASSESSMENT

NOTE: The present assessment is targeted to address the following human health endpoints: repeated dose toxicity and carcinogenicity via the inhalation route of exposure, and genotoxicity. It cannot be considered as a full SIDS Initial Assessment. Summary information on exposure is also reported here. Other endpoints for human health and the environment included in the Canadian screening assessment but have not been presented to OECD member countries, and thus are not included in this profile.

The final screening assessment will be published under the responsibility of the Government of Canada.

Rationale for Targeting the Assessment

The Government of Canada "categorized" or prioritized all 23,000 chemical substances on its Domestic Substances List (DSL) from 1999 to September 2006, as required by its *Canadian Environmental Protection Act, 1999* (CEPA 1999). Additional details may be found at http://www.chemicalsubstanceschimiques.gc.ca/about-apropos/categor/index-eng.php. Using information from Canadian industry, academic research and other countries, Government of Canada scientists applied a set of rigorous tools to the 23,000 chemical substances on the DSL. They were categorized to identify those that were: **inherently toxic** to humans or to the environment and that might be **persistent** and/or **bioaccumulative**; and substances to which people might have **greatest potential for exposure**. During this priority-setting exercise, distinct approaches were taken for identifying substances of likely concern for human health and the environment, and subsequent assessment activities may have focused on either human health or ecological endpoints. Through categorization, the Government of Canada has identified approximately 4,000 of the 23,000

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chemical substances on the DSL as priorities for further assessment, research and/or measures to control their use or release. Quartz and cristobalite were identified at that time, applying the categorization criteria, as high priorities for human health risk because they were considered to pose greatest potential for exposure and their respirable forms are classified by the International Agency for Research on Cancer as carcinogenic to humans (quartz and cristobalite) and by the National Toxicology Program as known human carcinogens (crystalline silica). These substances did not meet the ecological categorization criteria for bioaccumulation potential or inherent toxicity to aquatic organisms.

Under the Canadian legislation a determination of whether one or more of the criteria of the CANADIAN ENVIRONMENTAL PROTECTION ACT (CEPA) 1999, section 64 are met is based upon an assessment of potential risks to the environment and/or to human health associated with exposures in the general environment. For humans, this includes, but is not limited to, exposures from ambient and indoor air, drinking water, foodstuffs, and the use of consumer products. A conclusion under CEPA 1999 on the substances in the Chemicals Management Plan (CMP) Challenge is not relevant to, nor does it preclude, an assessment against the hazard criteria specified in the Controlled Products Regulations, which is part of the regulatory framework for the Workplace Hazardous Materials Information System [WHMIS] for products intended for workplace use.

Physical-chemical properties

The silicon dioxide group represents a polymorphic category containing a large number of forms identical in composition but with different atomic arrangements which afford different chemical properties. There are two sub-categories within this group: crystalline silica, to which the present substances quartz and cristobalite belong, and non-crystalline or amorphous silica. The key distinction between these sub-categories is that in crystalline substances, the building blocks are arranged in regular, repeating 3-dimensional pattern having long range order, whereas amorphous materials do not display long range order. In all forms of silica, (crystalline and non-crystalline), the silicon atom is tetrahedral and bound to four neighbouring oxygen atoms.

Quartz and cristobalite are solid at room temperature, existing normally as colourless or white crystals. The melting points for quartz and cristobalite are 1400-2000 ^{o}C and 1713-1728 ^{o}C, respectively and for both compounds, the boiling point is 2230^{o}C. Even though no experimental data were available, their vapour pressure and Henry's Law constant are likely negligible. Log K_{ow} (octanol-water partition coefficient) and log K_{oc} (organic carbon-water partition coefficient) are not applicable to these substances. The densities range from 2500-2700 kg/m^3 for quartz and 2300-2380 kg/m^3 for cristobalite.

The very similar physico-chemical properties of quartz and cristobalite reflect their closely related crystal forms. The solubility of crystalline silicates decreases as a function of silica tetrahedral packing density and long-range crystal order. For example, cristobalite has a more open framework structure than quartz and its density is lower, therefore, its solubility is higher. The water solubility of these minerals is also function of temperature, pH, particle size, and the presence of a disrupted surface layer. This may explain the variability of solubility values reported by many authors. The most probable solubility value for quartz is approximately 3.8 mg Si/L, or 6.4 mg/L expressed as the SiO_2 species, while the solubility of cristobalite is approximately 8.7 mg Si/L, or 18 mg SiO_2/L. The kinetics of dissolution of these substances is slow due to the high activation energy required to hydrolyse the Si-O-Si bond.

Human Health Targeted Endpoints

The majority of the studies described here have been reviewed by the International Agency for Research on Cancer (IARC 1997). However, additional data relevant to the screening assessment were identified up to August 2010.

Repeated dose toxicity/non-neoplastic effects (development of silicosis).

Studies on animals

Significant short-term and subchronic studies have demonstrated adverse effects in the lungs, while one of the 6 studies showed effects on the spleen in mice. Rats were exposed to 0, 10 or 100 mg/m^3 of cristobalite via inhalation for 6 hours/day during 3 days. Animals were observed 3 months after exposure. Elevated levels of granulocytes and elevated markers of cytotoxicity from the lung lavage fluid were noted in all exposed groups. Another study of similar duration (9 days) conducted in mice also identified a LOAEC of 10 mg/m^3. Effects observed included minimal interstitial thickening, accumulations of mononuclear cells and slight lymphoid tissue hypertrophy in the lungs.

In a 4-week inhalation study, female rats were exposed to 0, 0.1, 1 or 10 mg/m^3 of quartz 6 hours/day, 5 days/week. Bronchoalveolar lavage fluid was evaluated at 1, 8, and 24 weeks after exposure. Elevated levels of

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granulocytes and significant elevation of markers of cytotoxicity (Lactate dehydrogenase [LDH] and β-glucuronidase [β-glu]) were observed at 1 mg/m^3 and higher. The increased levels of LDH and β-glu were only significant at 24 weeks after exposure. A LOAEC of 1 mg/m^3 was identified at 24 weeks.

Male rats (4 animals per dose) were exposed to 0 or 3 mg/m^3 of cristobalite via inhalation for 6 hours/day, 5 days/week during 13 weeks. Pulmonary inflammation and fibrosis were observed in the exposed group at the end of treatment. When mice were similarly exposed to 5 mg/m^3 of quartz for 6 hours/day, 5 days/week for 15 or 27 weeks, the authors observed increased spleen weight and formation of plaque in the spleen.

In two separate studies, in which rats or hamsters were exposed to quartz via inhalation for at least 6 months, LOAECs of 2 and 3 mg/m^3 were identified, respectively. All the effects observed were related to inflammation and fibrosis of the lung tissue.

Several chronic studies investigated exposure of the respirable forms (i.e. accumulated via inhalation in the lung tissues) of quartz and cristobalite to rats, mice and hamsters. The following is a description of the study in which the lowest non-neoplastic LOAEC was determined. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz, containing 74% of respirable quartz, through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. The mean mass of particle at the end of the exposure period was 0.91 mg/lung. The LOAEC identified was 0.74 mg/m^3 (adjusted for 74% respirable quartz) based on lipoproteinosis, multifocal, inflammatory cell infiltrate and alveolar hyperplasia.

Human epidemiology data

In humans, the lowest observed adverse effect level was identified in a U.S. cohort study. The study was conducted on 3330 gold miners (all are males), who had an average of 9 years underground exposure during the period 1940 to 1965. The cohort was followed up through 1990. Silicosis[1] was identified through death certificates or chest X-rays. A job-exposure matrix together with work history was used to estimate individual exposure. The total silica content in the respirable dust in the mine was estimated at 13% and the median crystalline silica exposure was 0.05 mg/m^3. In this sub population of miners, 170 cases of silicosis were identified. The best predictor for risk of silicosis was cumulative exposure, which varied from less than 1% for a 0.5 mg/m^3-year exposure to 68-84% when exposed to more than 4 mg/m^3-year (based on the average daily dust exposure during the workday each year and summed over time for each miner). The main limitations identified by the authors include the limited number of radiographic surveys, the potential bias from death certificates

[1] Silicosis: Lung disease caused by inhalation of crystalline silica dust, and resulting in inflammation and scarring in forms of nodular lesions in the upper lobes of the lungs. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics). It does not follow that a history of exposure to silica necessarily results in silicosis (Nonsilicotics). The typical "Silicotic" lung nodule is shown in Figure 1.

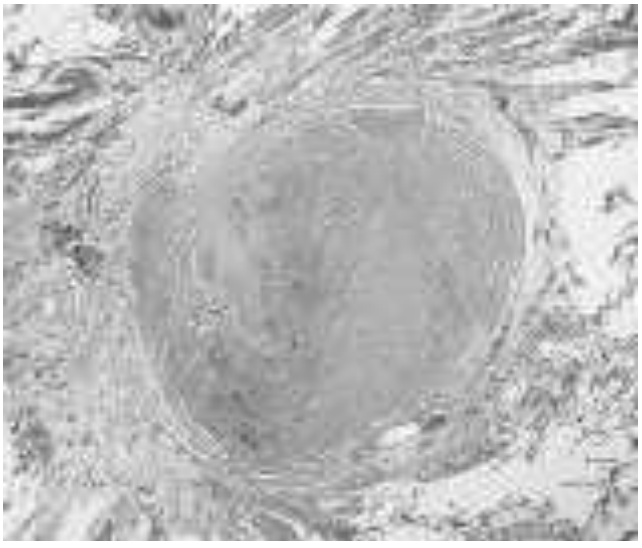


Figure 1. Silicotic nodule characterised by a central zone of hyalinised collagen with a whorled appearance and peripheral dust-containing macrophages (Rees and Murray, 2007).

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(relying on death certificates instead of relying on repeated x-rays, which were lacking for each miner, may have underestimated the number of cases) and the fact that the conversion of dust counts to

gravimetric measurements may not be accurate based on the estimation of 13% silica content in the respirable dust (although based on a relatively large number of samples (n = 82) collected in two different surveys, there was broad range of content in these samples (1% to 48%, SD = 9), and the percentage of respirable quartz may have differed in earlier years, but data were lacking for these years).

Two other human studies have identified similar LOAECs based on the critical endpoint of radiographic confirmed silicosis. A LOAEC of 0.053 mg/m^3 (mean exposure) was identified in a cross sectional study of South African gold miners and a LOAEC of 0.064 mg/m^3 (mean exposure) was derived in a mining community population-based random sample survey in Colorado.

Carcinogenicity studies

Studies on animals

Experimental studies conducted in rats have shown clear and consistent increases in lung tumours after chronic inhalation exposure. In the nine rat studies identified, five were inhalation studies and four were intratracheal instillation studies. All studies except one inhalation study showed increased incidence of lung tumours. For the inhalation studies with treatment related tumours, concentrations ranged from 1 to 50 mg/m^3 (1, 6, and 30 mg/m^3 of DQ-12 quartz; 12 and 50 mg/m^3 of Min-U-Sil 5 quartz) and duration of exposure ranged from 29 days to 2 years. In the inhalation study with no treatment-related tumours, exposure was 60 mg/m^3 of Sikron F300 quartz for 13 weeks. The following is a description of the neoplastic results in the study also identified as the critical study for non-neoplastic results. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. In the exposed group, 18 animals developed tumours (12 in females, 5 in males), as opposed to 3 and 2 for the control and positive control groups respectively. The majority (10/18) of the tumours observed were adenocarcinomas. The mean mass of particles in the lungs at the end of the exposure period was 0.91 mg/lung.

For the intratracheal instillation studies, doses ranged from 4 to 57 mg/kg-bw (based on 7, 12 or 20 mg/animal of Min-U-Sil (5) quartz or 20 mg/animal of novaculite quartz). Exposure regimes were diverse and included single instillation with observation for up to two years, to weekly instillation for 10 weeks. It is noteworthy that the single intratracheal administration of a 95% pure quartz particles (<5 μm) resulted in an increased incidence of silicotic granulomas after 3 weeks and lung tumours after 11 months. The most common tumours reported across the long term rat studies were adenocarcinomas, however other tumours such as squamous-cell carcinoma, alveolar carcinoma and bronchiole-alveolar adenoma were also reported, and all animals that developed tumours also showed some degree of fibrosis.

Of particular interest is the intratracheal instillation study, investigating the sequence of pathological events leading to lung tumors. An unspecified number of rats/sex/dose received a single intratracheal instillation of various crystalline silica dusts or ferric oxide, allowing direct administration into the bronchial tree. The doses were 12 or 20 mg of Min-U-Sil 5 quartz (MQZ), 12 mg of hydrofluoric-acid-etched Min-U-Sil 5 quartz (HFMQZ), 12 mg of cristobalite, 12 mg of tridymite and 12 mg of ferric oxide suspended in saline. All groups were observed until six months post exposure, except for both MQZ groups, the HFMQZ and the ferric oxide group which were observed up until 17 months post-exposure. Interim sacrifices were conducted at 6, 11 and 17 months. The rat lungs showed a clear progression of effects. The sequence of pathological events were, an initial inflammatory response leading to a marked hyperplasia and hypertrophy of alveolar cells after one month, and at six months hyperplasia was evident but no lung tumours were observed. In this study, lung tumours were observed starting at the 11 month sacrifice with a 17% and 42% incidence in males and females (based on 3/18 males and 8/19 females), respectively, and at 17 months incidences were 32% and 59% (based on 6/19 males and 10/17 females, respectively). No lung tumours were found in ferric oxide treated rats. Similar studies have also been conducted in hamsters and mice. Although treated mice and hamsters showed treatment related signs (inflammation or fibrosis), no tumours were observed in hamsters. No increase in the incidence of lung tumours was seen in mice treated with quartz; however silicotic granulomas and lymphoid cuffing around airways but no fibrosis were seen in the lungs of quartz-treated mice.

Human epidemiology data

There is an extensive dataset of human studies investigating the link between crystalline silica exposure and cancer. IARC (1997) identified over 50 epidemiological studies based on occupational exposure to dust containing respirable crystalline silica. Main industry sectors from which the human data is derived include gold mines, foundries, granite/stone industry, pottery workers and refractory brick workers. From the least confounded studies, it was noted that lung cancer tended to increase with the following parameters: cumulative

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exposure; duration of exposure; peak intensity of exposure; presence of radiographically defined silicosis; and length of follow-up time from date of silicosis diagnostic. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics).

Since the 1997 IARC report, a large number of epidemiological studies have been published, with the more recent studies being updates from supplementary follow-up of results from previously assessed case-control studies cohorts, new results based on refined exposure assessments or adjustment for confounders or meta-analyses of the pooled data from these epidemiology studies

In a meta-analysis of the data from 10 cohort studies of gold, tin and tungsten miners, granite workers, industrial sand, diatomaceous earth and pottery workers with quantitative exposure estimates for crystalline silica were pooled in order to analyse the risk related to lung cancer. The pooled cohort standardized mortality ratio (SMR, against national rates) [See Appendix 1 for definition] was 1.2 (Confidence Interval [CI] 1.1-1.3). The results from the case-control analyses show a statistically significant trend with duration of exposure (odds ratios (ORs) [See Appendix 1] by quintile of cumulative exposure increased from 1.0 to 1.6 [CIs of 0.85 to 2.1] and by quintile of average concentration increased from 1.0 to 1.7 [CIs of 1.1 to 2.3]), supporting the importance of the increasing lung burden of silica in the occurrence of cancer. Overall, the authors concluded that the results support the carcinogenicity conclusion presented by IARC (1997).

To investigate the link between crystalline silica, silicosis and lung cancer, epidemiological data published between 1966 and 2001 were gathered. Over 50 studies were selected and pooled according to type of study and the parameter being linked to lung cancer (i.e. silica exposure, presence of silicosis in subjects). The quality of study, adjustment for confounding factors, co-exposure to other carcinogens and availability of a more recent analysis of a same cohort were taken into consideration in the final selection of the studies. Analysis of the relationship between exposure to silica and lung cancer included 17 cohort and 13 case-control studies. For the analysis of lung cancer versus silicosis, 11 cohort and 5 case-control studies were selected. The third analysis included 6 cohort and 2 case-control studies to evaluate the risk of lung cancer in non-silicotics. A random effect model was used to conduct each meta-analysis. Pooled cancer risk ratios (RRs) were 1.32 (CI 1.23-1.41) for crystalline silica exposure, 2.37 (CI 1.98-2.84) for individuals exposed to silica with confirmed silicosis (Silicotics) and 0.96 (CI 0.81-1.15) for individuals with no evidence of silicosis (non-silicotics) with confirmed exposure to silica, supporting the general observation that silicosis has a stronger temporal relationship with crystalline silica exposure and furthermore support the view that a human silicotic response could be a preliminary stage in the development of cancer.

A more recent meta-analysis included 28 cohort, 15 case-control and two proportionate mortality ratio (PMR) [See Appendix 1] studies from a variety of occupational settings conducted between 1996 and 2005. Risk ratios (RRs) were calculated based on type of study and silicosis status using fixed and random effect models (results presented here are from the random model). RRs for all cohort studies was 1.34 (CI 1.25-1.45), and were 1.69 (CI 1.32-2.16) for silicotics, 1.25 (CI 1.18-1.33) for those with undefined silicosis status and 1.19 (CI 0.87-1.57) for non-silicotics. In the case-control studies, the general RR was 1.41 (CI1.18-1.67), and the same sub-groups as mentioned above resulted in RRs of 3.27 (CI 1.32-8.2), 1.41 (CI1.18-1.70) and 0.97 (CI 0.68-1.38), respectively. The proportionate mortality ratio for the last two studies was 1.24 (CI 1.05-1.47). The authors noted that the association between lung cancer and exposure to crystalline silica was more consistent for silicotics, i.e., those diagnosed with silicosis and RR values split into type of occupational settings in which participants worked.

Based upon the above three meta-analysis studies and the epidemiology studies discussed in IARC (1997), the following can be concluded. Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis. Cancer risk is often more significant in workers exposed to crystalline silica over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours. Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles.

There have been reports of tumours outside of the lungs in persons with high silica exposure; however, these reports are sparse and the data inconsistent and have not been unequivocally linked to exposure to either one of the crystalline forms (quartz or cristobalite). Some of the reported locations are: oesophagus, stomach, liver, skin and bone. Sufficient epidemiological or toxicological data do not currently exist for quantitative assessment of the exposure-response relationship on these other tissues or organs.

Genotoxicity

Potential genotoxicity has been assessed in multiple *in vitro* and *in vivo* assays. Table 1 below gives a brief summary of the positive results observed in each type of assay.

Table 1. Summary of positive results over total number of results for each assay and each category (all studies

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conducted with crystalline silica: quartz, except where indicated).

Assay	Animal data		Human data		Positives/Total	
	In vitro	In vivo	In vitro	In vivo[d]	In vitro	In vivo
Rec Assay	0/1				0/1	
DNA strand break	1/1	2/2	5/5[b]	1/1	6/6	3/3
Sister chromatid exchange	0/1		0/1[c]	1/1	0/2	1/1
Micronucleus	2/3	0/1	2/2[b]	1/1	4/5	1/2
Chromosome aberration	0/1			1/1	0/1	1/1
Aneuploidy/polyploidy	0/3				0/3	
Cell transformation	4/4				4/4	
Hprt mutation	1/2	2/2[a]	1/1[b]		2/3	2/2
Oxidative DNA damage		4/5	2/2		2/2	4/5
DNA binding		1/1				1/1
p53 activation		0/1				0/1

a. one assay conducted with crystalline silica: cristobalite
b. one assay conducted with "ultrafine crystalline silicon dioxide".
c. crystalline silica: tridymite
d. crystalline silica dust (subtypes not provided).

All the *in vivo* human genotoxicity studies are based on three independent studies that used blood samples from workers from diverse occupational settings with confirmed exposures to crystalline silica dust; however, quantification of exposure was not provided. After stratification by smoking status, sister chromatid exchange remained statistically significant in both smokers and non-smokers although the frequency was higher in smokers. For the chromosome aberration assay conducted as part of the same study (blood samples from workers in the stone crusher industry), the increased frequency was no longer significant after stratification. In the DNA damage study of foundry and pottery workers and the micronucleus assay of workers involved in sandblasting and related jobs, results were positive when compared to controls. However, in both studies, smoking status influenced the results, contributing to the increased DNA damage observed since results were greater in smokers versus non-smokers, and the frequency of micronuclei in nasal epithelial cells was higher in smokers (p=0.002) but when using peripheral blood lymphocytes did not differ statistically between smokers and non-smokers who were similarly exposed to silica dust,

The role of *in situ* generation of reactive oxygen species (ROS) and reactive nitrogen species (RNS) has been well established in the following types of DNA damage: small scale insertions, DNA base pair deletion, base modification, chromosomal change/loss, microsatellite instability, DNA strand break, 8-hydroxydeoxyguanosine (8-OHdG) mutation and point mutations. ROS and RNS generation is postulated to be (a part of) the DNA damage mechanism for crystalline silica. Studies are described below to support this hypothesis.

DNA was exposed *in vitro* to various crystalline silica dusts, to H_2O_2, or to both. Results show that DNA damage was limited when dust or H_2O_2 were administered alone but increased with the co-exposure. When the reactive oxygen scavenger, dimethylsulfoxide, was added to the test system, DNA strand break was inhibited, data supporting the viewpoint that it is the presence of radicals generated in response to quartz and cristobalite that causes the DNA damage and not quartz or cristobalite themselves.

Hprt mutation assays in rat alveolar epithelial cells, both *in vitro* and *in vivo,* were positive in response to quartz. The positive results *in vivo* were seen only in the presence of significant inflammatory responses in the treated animals. Also, in a parallel *in vitro* experiment, rat alveolar epithelial cells were incubated with the bronchoalveolar lavage fluid from the rats exposed to quartz. Both macrophage and neutrophil enriched lavage cells induced mutation in the exposed alveolar epithelial cells. Addition of catalase (an enzyme which inactivates H_2O_2) before incubation inhibited the increase in *hprt* mutation.

Rats were exposed to either crystalline or amorphous silica in a manner to induce the same level of

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inflammation in the lungs. The inflammatory response was assessed by measuring the proportion of neutrophils in the bronchiolar lavage fluid. The actual concentrations were 3 and 50 mg/m^3 for crystalline and amorphous silica respectively. The animals were exposed for 13 weeks. *Hprt* mutation frequency was measured in the alveolar epithelial cells at the end of the exposure period. Mutation frequency was greatly increased only in the crystalline silica treated rats; no treatment related increase was found in the rats treated with the amorphous form.

In an 8-OHdG assay conducted to monitor DNA damage by reactive oxygen species, female rats were exposed to 0, 0.3, 1.5 and 7.5 mg/animal of quartz via intratracheal instillation. Effects were observed 90 days post-exposure. A clear dose-response relationship was identified between quartz exposure and various inflammation markers (differential cell count, protein, lung surfactant lipids and tumour necrosis factor alpha). Inflammation was present starting at the lowest dose. However, 8-OHdG showed a statistically significant increase starting at 1.5 mg/animal only. Similarly, in another study, 8-OHdG and DNA strand breaks were observed at concentrations of or above 10 ug/m^3 in rat lung epithelial cells.

In the aim of investigating the role of ROS in lung carcinogenesis, rat lung epithelial cells were incubated with polymorphonuclear (PMN) leukocytes (involved in the inflammatory process and responsible for the release of certain ROS) or hydrogen peroxide. Statistically significant increases in 8-OHdG were observed in the presence of PMN or hydrogen peroxide in a dose-response manner.

In a series of experiments which used *in vitro* stimulation of macrophages with crystalline silica and *in vivo* intranasal instillation of crystalline silica in mice, it was demonstrated that that the chronic fibrosis seen in a murine model of silicosis *in vivo* is dependent on the presence of adaptor molecule ASC and Nalp3 inflammazome. These data support a potential mode of action whereby silica triggers cellular responses that in turn activate alveolar macrophages, resulting in an inflammatory response and silicosis. In mice deficient in Nalp3 inflammazome, the development of inflammation and collagen deposition was significantly reduced compared with normal mice 3 months after the initial intranasal instillation of silica.

Analysis of Lung Tumour Data

The weight of evidence for both rats and humans indicates that fibrotic and silicotic lesions in the lung result from inhalation exposure to crystalline silica and that lung cancer is secondary to those lesions in the lung. Although the mechanism of induction for the lung tumours has not been fully elucidated, there is sufficient supportive mode of action evidence from the data presented to demonstrate that a threshold approach to risk assessment is appropriate based on an understanding of the key events in the pathogenesis of crystalline silica induced lung tumours. The body of evidence include the following:

- In experimental studies, all rats that developed tumours also showed fibrosis.
- Adenocarcinomas, the most common type of tumour identified in rats, are commonly associated with fibrosis and deeply scarred lung tissue.
- Experimental rat studies showed a clear progression of the effects from initially mild inflammation, followed by fibrosis over-time, leading eventually to lung tumours.
- Tumours are not present in all treated species dosed in the same way.
- The tumours, both in rats and humans, are concentrated in the lungs only, although other organs are indirectly exposed.
- In human studies, cancer risk is often more significant in workers exposed over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours.
- Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles
- Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis.
- For genotoxicity, in vitro results were mostly mixed and in vivo results were mostly positive. However, the vast majority of the positive genotoxicity assay results can be explained by the generation of reactive oxygen species, as demonstrated experimentally, where ROS scavenging prevents the genotoxicity.
- *In vivo*, macrophage deficient mice (macrophages produce ROS in response to crystalline silica) do not develop silicosis nor do they develop tumours and the Nalp3 inflammazome, a key player in the macrophage initiated inflammatory response, is required for the development of pulmonary fibrosis after

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inhalation of silica.

- Though inhalation exposure to crystalline silica in multiple occupational settings is clear, the increase in risk, based on the several recent meta-analyses of the multiple human epidemiological studies, remains low.

It is worth noting that where aggressive engineering controls have been made to reduce silica dust levels in the workplace (Sweden), silicosis has been eliminated. By corollary, existing exposures outside of the workplace in such areas do not pose a risk for silicosis to the general population.

The respirable forms of quartz and cristobalite possess properties indicating a hazard for human health (repeated dose toxicity, carcinogenicity and genotoxicity). The mode of action in the lungs involves irritation, inflammation and reactive species formation, leading to silicosis, and eventually to tumour formation.

Exposure

Uses

Consistent with oxygen and silicon being the two most abundant elements in the Earth's crust, silicon-oxide minerals, including quartz are ubiquitous in the natural environment. In particular, as a component of sand, quartz may find use in a diverse array of applications. Several high volume uses include, but are not limited to, the use of sand as a filling material for the construction of roads and in general building activities, the use of sand and gravel aggregates as abrasives on roads in winter and the use of fly-ash, which may contain 4-14% quartz and 0.5-1% cristobalite, as a cement additive. These abrasives when used on winter roads are usually mixed with road salts and may be sand only, stone dust, sand and gravel aggregates, or pre-treated sand. They are used mainly by rural municipalities or in areas where cold temperatures diminish the efficiency of salts for de-icing. Quantities of abrasives used in Canada were 5.73×10^9 kg, 4.59×10^9 kg, and 4.93×10^9 kg for 2007, 2008 and 2009, respectively.

Industrial sand, high purity silica sand products with closely controlled sizing are expected to contain quartz and cristobalite, include lump silica (2-3mm up to 15 cm or more), silica sand (75µm to 2-3mm) and silica flour (less than 75µm). Lump silica may be used in the production of silicon alloys, silica bricks, and the linings of certain types of pulverizers (eg. ball mills and tube mills).

Silica sand may be used in the manufacture of glass and glass fibres, silicate chemicals and silicon carbide, the hydraulic fracturing of wells, foundry moulding, and for sandblasting. Silica flour may find use in the ceramics and cement industries, as a filler and extender in rubber and coatings, and as an abrasive in soaps.

Natural clays, such as bentonite and fuller's earth, are used in cat litters for their high water absorbance capacities. Quartz is a natural component of these clays, and consequently, it may be present in cat litter products. High purity α-quartz is a piezoelectric material, which means that application of a voltage induces a distortion in the crystal shape and vice versa. This ability to interconvert electrical and mechanical energy has led to the use of quartz crystals in electronic devices requiring precise timing control, for example telephones, radios, watches and computers.

According to a survey conducted in Canada, quartz and cristobalite are also used in abrasives, adsorbents, filter products (diatomaceous earth), grout and cement. These substances reportedly also find use as fillers, which add bulk and improve wear resistance, in paints and coatings, adhesives, sealants, polymer films, caulking, epoxy resins and silicones. Also, quartz is listed as an ingredient in 60 cosmetic products in Canada. The types of products include anti-wrinkle preparation, eye and face makeup, lipstick, hair dyes, shampoos and grooming products, as well as skin cleansers, moisturizers and tanning preparations.

Natural Sources

In Canada, quartz naturally occurs in many types of rock formations. Those with high silicon dioxide content (95% SiO_2 or more) include vein and massive intrusion bodies, quartz pebbles, silica sand, sandstone and quartzite. Sandstone is a sedimentary rock mostly composed of quartz grains cemented by a bonding material such as clay, calcite or iron oxide. Quartzite is a hard, compact, metamorphosed sandstone made of grains of quartz firmly bonded with a siliceous cement. Mineral aggregates (e.g., sand and gravel) have variable silicon dioxide content. Quartz is also found as crystals, aggregates or discrete particles in certain igneous rocks (e.g., granites and pegmatites), soils, sediments, air and surface water. This omnipresence is consistent with the fact that silicon is the second most abundant chemical element on Earth.

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Cristobalite is naturally produced in the ashes of volcanic eruptions, and by combustion metamorphism which is a local phenomenon of spontaneous combustion of naturally occurring substances such as bituminous rocks, coal or oil. It may be found in cavities in volcanic rocks and in thermally metamorphosed sandstones and may also be a transient stage in the diagenesis of diatomaceous shale with the result that soils made of these geologic formations may be rich in cristobalite. Unlike quartz, the natural occurrence of cristobalite is limited to specific geographic regions and mineral types.

Anthropogenic Sources

Natural quartz is isolated from ore via beneficiation, which involves milling or grinding the material into particles that are separated into desired mineral and waste. The materials obtained are either used directly or further purified. In Canada, in 2006, 2.146×10^{9} kg of pure quartz were mined, and 2.385×10^{11} kg of sand and gravel aggregates were produced. The proportion of quartz in silica sand deposits and gravel aggregates will vary from one site to another.

Cristobalite can form from silica melts during the preparation of silica glass; quartz is not obtained from melts but is manufactured at elevated temperature and pressure via a hydrothermal process. Cristobalite also forms during the calcination[2] of diatomaceous earth.

Human Exposure Estimate

Ambient air

The exposure assessment is focussed on respirable quartz and cristobalite, which in ambient air comprises a component of total particulate matter (PM). In Canada, data on the concentrations of silicon in PM was available and used as a surrogate for quartz and cristobalite. This approach is conservative because the measured silicon includes all silicon-containing substances and therefore represents the upper limit for quartz and cristobalite in ambient air.

The National Air Pollution Surveillance (NAPS) Program measured concentrations in $\mu g/m^3$ of silicon in PM with aerodynamic radii less than 2.5 µm ($PM_{2.5}$ (dichot)), and from 2.5 to 10 µm (PM_{10} (dichot)) (the total particulate matter with aerodynamic radii less than 10 µm (PM_{10}) is obtained by adding these values) in Canada. In 2009, as part of the NAPS Program, silicon concentrations were determined on over 1600 samples of $PM_{2.5}$(dichot) and over 1500 samples of PM_{10}(dichot) at 24 urban locations across Canada. An estimate of exposure to quartz and cristobalite can be obtained by assuming that all the silicon in the PM is represented stoichiometrically as SiO_2, and multiplying the reported concentration of silicon by 2.14 to obtain a value for silica.

The intake of respirable quartz and cristobalite by the general population of Canada is estimated using a range covering the lowest 50^{th} percentile SiO_2 concentration in PM_{10}, measured in Pt. Petre, ON, (0.12 $\mu g/m^3$) to the highest 50^{th} percentile concentration in PM_{10} measured in Calgary, AB (2.1 $\mu g/m^3$). The 50^{th} percentile SiO_2 concentrations ranged from 0.1 to 2.1 $\mu g/m^3$ across the survey sites; the top of this range is quite close to the average of the maximum values for the 24 sites (3.7 $\mu g/m^3$). The outdoor data were used to represent the indoor levels, because information on indoor silicon concentrations was not available, and the range of PM_{10} measured indoors is generally lower than the outdoor range. Thus, this approach conservatively overestimates indoor exposure in homes.

The highest exposure group based on these calculations is children ages 0.5 to 4 years with an estimated daily intake ranging from 0.07 to 5.26 µg/kg-bw per day; the estimated daily intake decreases with age due to changes in the ratio of inhalation rates to body weights; the daily intake of adults, 20-59 years old, is estimated to range from 0.03 to 2.00 µg/kg-bw per day.

Consumer Products

Exposure to respirable quartz from the use of cosmetic products, which contained quartz as an ingredient, was considered low because they are not formulated for spray application, the loose powders were reported to contain less than 0.1% quartz, and in these products the substance is not expected to be associated with other components of the formulation and not available in a free form.

For consumer Do It Yourself (DIY) activities around the home, the highest mean breathing zone concentration of particles from sanding dry wall (median cut-point of 10µm) of 6.31 mg/m^3, was used to derive an upper-

[2] Calcinations: Heat treating a substance, but without fusion, to bring about change in its physical or chemical constitution.

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bound exposure estimate ranging from 2 to10 µg/kg-bw per event.

Quartz is used to formulate a large number of paints and coatings. To estimate potential inhalation exposure to quartz from these products, the spray painting of wall paints with an airless spray gun was considered appropriate as a conservative scenario. Exposure to respirable paint particles was estimated using data from controlled a laboratory study in which walls of poorly ventilated test rooms were painted by professional painters using an airless sprayer to apply interior latex paint. The maximum concentration of 13% quartz in paint in Canada was used to estimate exposure. The upper-bound estimate of exposure to quartz, based on the maximum concentration of 13% quartz in paint in the Canadian market and the maximum concentration of respirable paint particles measured in these controlled studies when recommended personal protective equipment is used, is 0.954 µg/kg-bw per event.

Inhalation of ambient air containing quartz and cristobalite is the dominant pathway of chronic exposure (excluding that from DIY activities) for the general population. Because SiO_2 makes up only approximately 5% of PM_{10}, silicon concentrations (expressed as SiO_2) measured in the Canadian NAPS survey of 24 urban locations were considered most relevant to the estimation of exposure by the general population. Quartz and cristobalite comprise only a portion of the total SiO_2 in PM_{10}, therefore, the use of the total silicon concentration to represent the upper bound crystalline silica concentrations results in an overestimation of exposure.

Appendix 1: Definitions of Epidemiological Terms in the ITAP

SMR (Standardized Mortality Ratio): The ratio (x 100) of observed to expected deaths in a study population. Expected deaths are calculated by applying a set of standard age-specific mortality rates to the age distribution of the study population. Standardized ratios are only useful for comparisons. They have no intrinsic meaning.

OR (Odds Ratio): In epidemiological case-control studies, a relative measure of disease occurrence. The odds in favour of a particular disease occurring in an exposed group are divided by the odds in favour of its occurring in an unexposed group. If the condition being studied is rare, the odds ratio is a close approximation to the relative risk.

RR (Risk Ratio): The probability of the occurrence of a disease in a group that has been exposed to some environmental, medicinal, microbial, or toxic influence, relative to its probability in a randomly selected population.

PMR (Proportionate Mortality Ratio): Proportionate mortality is the proportion of deaths in a specified population over a period of time attributable to different causes. Each cause is expressed as a percentage of all deaths, and the sum of the causes must add to 100%. These proportions are not mortality rates, since the denominator is all deaths, not the population in which the deaths occurred. Thus, proportionate mortality ratio is a measure of the frequency of occurrence of the proportionate mortality in a defined population during a specified interval of time.

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Toxicity Profile

Endo-1,4-beta-Mannanase
(CAS No. 37288-54-3)

No data could be located on endo-1,4-beta-mannanase. There is information, however, on α-amylases. α-Amylase catalyzes the endo-hydrolysis of 1,4-α-D-glycosidic linkages in polysaccharides like starches, glycogen, and oligosaccharides containing three or more 1,4-α-linked glucose units. Given the similarity of the substrates, amylases and endo-1,4-beta-mannanase would be expected to have similar physico-chemical properties relevant to evaluating their mammalian toxicity potential.

The data on α-amylases have come from detergent amylases, the typical ones being *Bacillus*, which has an neutral isoelectric point and a broad pH optimum between pH 5 and 9. The enzyme is characterized by a molecular weight of 58 kD (HERA, 2005).

Acute Toxicity

No deaths were observed when male and female rats were given an aqueous suspension of 0, 4,000 or 10,000 mg/kg of α-amylase ("salt free" batch PPY 1316, enzyme derived from *B. subtilis*) by oral gavage. The actual enzyme content of this batch was 239 mg aep/g. In another study, male and female rats were given an aqueous suspension of 0 or 5,000 mg/kg α-amylase preparation derived from *B. licheniformis*, the actual enzyme content of the preparation was 60.13 mg aep/g. There were no deaths.

Rats were exposed by inhalation to either 1.6 mg/L of a production α-amylase (from *B. subtilis*) batch ADTA 202-204, a mixture of two batches prepared by the standard production process (45.9% of particles <4.7 μm) or 1.08 mg/L of a "salt-free" α-amylase (from *B. subtilis*) batch PPY 1316, prepared from production batch ADTA 202-204 by removal of NaCl (33.3% of particles <4.7 μm), for 4 hours. An air-exposed control group was also included. The actual amount of enzyme protein in the test aerosols was 0.114 mg aep/L (production batch) and 0.258 mg aep/L (salt-free batch). There were no deaths occurred. In another study, rats were exposed to 1.6 mg/L α-amylase (from *B. subtilis*) preparation (highest concentration attainable) derived from a genetically modified strain of *B. subtilis* for 4 hours. Total organic solids comprised 83.3% of the test substance (active and inactive enzyme as well as other organic material). There were no deaths (HERA, 2005).

Irritation

α-Amylase (from *B. subtilis*) has a low potential for irritation to the skin and eyes of rabbits (HERA, 2005). In a human repeat insult patch test (HRIPT), although skin irritation did not appear after a single application, irritation was reported in human

volunteers receiving nine topical applications of 1, 2.5, 5 or 10% α-amylase (from *B. subtilis*) in distilled water. The magnitude of responses increased with increasing concentration such that the use of the 10% concentration was discontinued and was replaced for the rest of the study by a 0.5 % α-amylase. The irritation was thought to be due to residual protease activity present in the amylase preparation (HERA, 2005).

Sensitization

α-Amylase (from *B. subtilis*) was not a skin sensitizer to guinea pigs in two different studies (HERA, 2005). In a human repeat insult patch test (HRIPT) reported above, there were no significant reactions indicative of skin sensitization in the challenge phase (HERA, 2005).

Repeated Dose Toxicity

Rats and dogs have been given amylase enzymes orally for up to 90 days. These studies were not reported in any detail and the actual amount of enzyme in the formulations tested in these studies is unclear. No findings of toxicological significance were observed in either species exposed to any of the α-amylase formulations tested other than "slight" reductions in food consumption at high dietary doses ($\geq$5% of the diet) or irritation of the stomach of rats dosed by oral gavage with $\geq$3,000 mg/kg/day (HERA, 2005).

Genotoxicity

α-Amylase (from *B. licheniformis* and from *B. subtilis*) was not mutagenic to *S. typhimurium* strains TA 1535, TA 1537, TA 98, TA 100 in bacterial reverse mutation assays in the presence or absence of metabolic activation (HERA, 2005). α-Amylase (from *B. licheniformis*) did not induce chromosome aberrations in human lymphocytes, which were obtained from one donor only (HERA, 2005). It was also inactive when tested in an *in vivo* bone marrow chromosomal aberrations study, in which rats were dosed orally up to 5,000 mg/kg (HERA, 2005).

Carcinogenicity

No data were found.

Reproductive/Developmental Toxicity

Two α-amylases, one derived from *B. stearothermophilus* and one derived from a genetically modified strain of *B. subtilis* have been evaluated for effects on fertility in one-generation studies in rats. The diets containing 0, 36 or 72 units of α-amylase/g

food. No treatment-related effects on fertility or other findings of toxicological significance were observed for either enzyme.

Key Study/Critical Effect for Screening Criteria

Oral studies (dietary and/or oral gavage) up to 90 days on α-amylase have been conducted in rats and dogs. These studies have been poorly reported. Slight reductions in food consumption was reported at ≥5% in the diet (2,500 mg/kg/day in rats) and irritation of the stomach of rats dosed with ≥3,000 mg/kg/day. These studies are considered unreliable because of the lack of reported key information needed for risk assessment purposes.

There is, however, a 13-week rat dietary study conducted on a cellulase enzyme (HERA, 2005). The cellulase enzymes cleave the ß-1,4-glycosidic bonds in cellulose. For the purposes of risk assessment, the structure of amylases would be expected to be relatively similar to that of celluloses, given that amylases and cellulases are both enzyme families that hydrolyze polysaccharides, although differing in their substrates. Thus, the toxicity data on cellulases will be used as read-across to amylases for the repeat dose toxicity endpoint.

In the 13-week dietary study on a cellulase enzyme, there was reduced body weight gain in rats given 3,000 mg/kg/day. No other adverse effects were observed. The NOAEL for this study is 600 mg/kg/day.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (subchronic to chronic)

Oral RfD = 600/1000 = 0.6 mg/kg/day

Drinking water guidance value = 2.1 ppm

Reference

Human and Environmental Risk Assessment (HERA) on Ingredients of Household Cleaning Products: α-amylase, CAS No. 9000-90-2; Cellulase (β-(1,4)-glucanase), CAS No. 9012-54-8; Lipase, 9001-62-1, 2005. http://www.heraproject.com

Toxicity Profile

Ethanol
(CAS No. 64-17-5)

Ethanol has been reviewed in the OECD-SIDS program (OECD, 2004a,b).

Acute Toxicity

Ethanol has a low order of acute toxicity by all routes of exposure. The lowest well-conducted acute oral LD_{50} value is 8,300 mg/kg in mice, and an inhalation 1-hour LC_{50} value of >60,000 ppm (114,000 mg/m^3) in mice.

Irritation

Ethanol is a moderate eye irritant but it is not a skin irritant.

Sensitization

Ethanol is not a sensitizer.

Repeated Dose Toxicity

There are numerous repeat dose toxicity studies on ethanol by the oral route. Many of these studies were designed to increase our understanding of the risks associated with alcoholic beverages. Thus, these studies were carried out by the oral route and at high doses. The selected studies were considered appropriate for risk assessment purposes.

In a 90-day study, male and female Sprague-Dawley rats were fed a diet containing 0, 1, 2, 3, 4, 5 or 10% ethanol. The 2% dose was calculated to be equivalent to 2,400 mg/kg/day. There were no deaths and no clinical signs of noted. Weight gain throughout the study was unaffected by treatment, but the final weights decreased with dose. Food and water consumption in the 10% group was reduced relative to controls. There was no treatment-related effect on serum liver enzymes and kidney clinical chemistry findings were minimal. In the liver, centrilobular steatosis increased in severity with dose as did the frequency and severity of Mallory bodies (hyaline) and acidophilic degeneration and necrosis. Most liver findings were absent or mild at 2% ethanol but became more significant at $\geq$3%. The NOAEL for this study has been established to at 2% (2,400 mg/kg/day).

In an NTP 90-day study, F344/N rats and $B6C3F_1$ mice were given in their drinking water 0 or 5% ethanol in drinking water. Based on the water consumption data in the

study and averaged body weights over the exposure period, this equated to doses of at least 4,000 mg/kg in rats and 7.500 mg/kg in mice. Male rats showed minor changes to organ weights and hematology and clinical chemistry parameters (these were not considered to be adverse changes); female rats showed minor clinical chemistry changes and increased length of estrus cycle, as well as liver nodules. The male mice showed increased organ weights, fatty changes to the liver, and a decrease in sperm concentration.

In the NTP two-year bioassay, B6C3F$_1$ mice were given in their drinking 0, 2.5% and 5% ethanol Concentrations of 2.5% and 5% ethanol resulted in average daily consumption of approximately 100 and 180 mg ethanol for males and 80 and 155 mg for females. There was a marginal exposure-related increase in survival of the males, but no effect on the survival of the females. Water consumption was reduced with increasing concentrations of ethanol which was more marked in males than females. No further information was given on non-neoplastic effects.

Genotoxicity

The balance of evidence is that ethanol is not genotoxic. Negative results from a number of bacterial mutation assays appear to be reliable. Of the mammalian cell mutation assays a weak mutagenic effect in mouse lymphoma cells occurred only at very high ethanol concentrations. *In vivo* tests for chromosome aberrations in both rats and Chinese hamsters have given negative results. There is very little evidence to suggest that ethanol is genotoxic in somatic cells and it may have a very limited capacity to induce genetic changes *in vivo* but under very specific circumstances and at very high doses achievable in humans only by deliberate oral ingestion.

Carcinogenicity

Evidence of the carcinogenicity of ethanol is confined to epidemiological studies assessing the impact of alcoholic beverage consumption. These do not indicate any such hazard exists from potential exposure to ethanol in the work place or from the use of ethanol in consumer products.

Reproductive/Developmental Toxicity

The lowest reported NOAEL for fertility by the oral route was 2,000 mg/kg in rats, equivalent to a blood alcohol concentration of 1,320 mg/L, although this was based on a significant increase in the number of small pups rather than a direct effect on fertility; such direct effects are not seen until much higher doses. Many studies exist examining the developmental end point for ethanol. However, most use very high doses and few are individually robust enough to allow a NOAEL to be established. However, the collective weight of evidence is that the NOAEL for developmental effects in animals is high,

typically >6,400mg/kg, compared to maternally toxic effects at 3,600 mg/kg. The potential for reproductive and developmental toxicity exists in humans from deliberate over-consumption of ethanol. Blood ethanol concentrations resulting from ethanol exposure by any other route are unlikely to produce reproductive or developmental effects.

Key Study/Critical Effect for Screening Criteria

The lowest reported NOAEL is approximately 2,400 mg/kg/day from a 90-day dietary study with rats.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (subchronic to chronic)

Oral RfD = 2,400/1,000 = 2.4 mg/kg/day

Drinking water guidance value = 8.4 ppm

References

OECD (2004a). IUCLID Data Set for Ethanol (CAS No. 64-17-5), UNEP Publications.

OECD (2004b). Screening Information Dataset (SIDS) Initial Assessment Report for Ethanol (CAS No. 64-17-5), UNEP Publications.

Toxicity Profile

Ethoxylated Fatty Acid Ester II

This substance is a hydrophilic, non-ionic surfactant used in pharmaceutical preparations, and cosmetics as an emulsifier, dispersant, or stabilizer, and as a food additive. It is considered a mixture and thus a UVCB substance (substance of unknown or variable composition, complex reaction products or biological materials).

Acute Toxicity

Reported oral LD_{50} values for rats range from approximately 33,800 mg/kg to approximately 54,500 mg/kg, while the oral LD_{50} for mice is greater than 25,000 mg/kg. Clinical experience with humans who have ingested large quantities of this substance indicates that it is essentially nontoxic by the oral route, with the estimated lethal dose being 15,000 mg/kg.

Irritation

In 24-hour rabbit skin-patch tests, this substance was found to produce minimal or no irritation. Daily application of 100% solutions of this substance to the backs of rabbits for 30 days produced histologic changes in the skin, including mild to moderate inflammation, acanthosis, and necrosis. Application of 1% or 2.5% aqueous solutions of this substance to the backs of mice for up to 9 days produced no gross or microscopic lesions. Studies conducted in humans did not result in skin irritation.

Sensitization

Repeated intradermal injections of this substance into guinea pigs did not produce skin sensitization, and studies conducted in humans did not result in sensitization.

Repeated Dose Toxicity

In a multi-generation study, doses of 5%, l0%, and 20% of test material were administered in the feed to male and female rats. Composition of the diet was altered for different dose levels to compensate for the decrease in caloric value caused by addition of the test material. Diarrhea was seen in animals fed 10% or 20% test substance, and was presumably due to the osmotic effect of the large amounts of polyoxyethylene moiety in the intestinal tract. There was some reduction in growth rate, postnatal survival of pups, lactation and breeding efficiency, and longevity in rats fed the diet containing 20% test material. Hematologic examination showed no abnormalities and no treatment-related histologic lesions were seen upon examination of kidneys, livers, and gross lesions. No

significant findings were reported in a three-generation study using groups of 30 rats fed 2% test substance. Degeneration of the heart, liver, and kidney were reported in groups of 12 Charles Foster rats administered a daily dose of 1.5 mL of a solution of 1%, 2%, or 3% test substance for 3 months. Similar effects were not reported in other studies using higher doses for longer periods, so the significance of the findings of this single study is debatable. Daily administration of 1g of this substance to each of two monkeys for 17 months produced no compound-related gross or microscopic lesions.

Evidence indicates that the long-term ingestion of this substance by humans does not result in toxicity. Long-term consumption (one or more years) of 4.5 to 6 g of this substance per day by human patients for the treatment of lipid malabsorption syndromes has been reported to cause no adverse effects. The consumption of doses as high as 15 g/day for several months caused no clinical indications of toxicity.

Groups of 10 F344/N rats and 10 B6C3F_1 mice of each sex received diets containing 0, 3,100, 6,200, 12,500, 25,000 or 50,000 ppm test material. All animals survived to the end of the studies. The final mean body weights of dosed rats and mice were similar to those of the controls. No clinical findings, changes in absolute or relative organ weights, or gross or microscopic lesions in rats or mice were related to test material administration. The NOAEL is 50,000 ppm.

Genotoxicity Studies

This substance is not genotoxic is a variety of in vitro and in vivo assays.

Carcinogenicity studies

In one study, 28 mice were fed diets containing 10 mg of this substance daily for 51 week, no neoplasms occurred as the result of treatment.

Groups of 60 F344/N rats and 60 B6C3F_1 mice of each sex received diets containing 0, 25,000, or 50,000 ppm test material for up to 103 weeks. Interim evaluations were performed on 7 to 10 rats and mice from each dose group at 15 months. There were no significant changes in absolute or relative organ weights. Incidences of hyperplasia and inflammation of the forestomach were increased in female mice that received 50,000 ppm. No other chemical-related lesions occurred in rats or male mice evaluated at 15 months.

The mean body weights in male and female rats and male mice administered test material were similar to those of the controls throughout the studies. The final mean body weight of female mice receiving 50,000 ppm was 11% lower than that of the controls. No clinical findings were associated with administration of test material. The survival of dosed male rats was lower than that of the controls (0 ppm, 29/50; 25,000 ppm, 18/50; 50,000 ppm, 18/50); the survival of dosed female rats and male and female mice was

similar to that of the respective controls (female rats: 23/50, 25/50, 25/50; male mice: 33/49, 34/50, 32/50; female mice: 30/50, 28/50, 26/50).

The incidence of adrenal medulla pheochromocytoma was marginally increased in high-dose male rats (21/50, 19/50, 29/50). The slight increase in incidence of pheochromocytoma in the high-dose male rat group was judged to be of questionable significance based on historical control data. The incidence of hyperplasia of the adrenal medulla was increased in low-dose male rats but not in high-dose male rats (11/50, 22/50, 12/50). The marginal increased incidence of pheochromocytoma in combination with the increased incidence of hyperplasia were considered to be an equivocal finding.

No chemical-related increases in the incidences of neoplasms occurred in male or female mice. The incidences of squamous hyperplasia and inflammation of the forestomach were significantly increased in high-dose male and female mice; forestomach ulcers were significantly increased in high-dose females.

Developmental Toxicity

Timed-mated Sprague-Dawley rats were exposed to 0, 500 or 5,000 mg/kg/day of test material on gestational days (GD) 6 through 15. All treated females survived to scheduled necropsy and 19-23 pregnancies per group were confirmed. No dose-related signs of toxicity were observed for individual animals during the in-life phase of the study or at scheduled necropsy. Average maternal body weight (GD 0, 3, 6, 9, 12, 15, 18, or 20) did not differ among treatment groups, nor was there a treatment-related change in maternal weight gain during treatment or gestation (absolute or corrected). There were no treatment-related effects upon the following maternal organ weights: gravid weight (absolute), kidney weight (absolute or relative), and heart weight (absolute or relative). Relative maternal liver weight (% body weight on GD 20 or % corrected body weight) was elevated in both treated groups and absolute liver weight was elevated at 500 mg/kg/day. Maternal food intake was comparable across groups during the pre- and post-treatment periods, but was decreased by 14% during the first 3 days of treatment at 5,000 mg/kg/day relative to the vehicle control group. Maternal relative water intake was comparable among treatment groups throughout gestation. No differences among groups were noted for the number of corpora lutea per dam, the number of implantation sites per dam or the percent preimplantation loss per litter. No adverse effects were noted on the growth, viability or morphological development of the conceptuses. In conclusion, the maternal LOAEL was 500 mg/kg/day (based upon an increase in maternal relative liver weight). No definitive adverse effects of test material upon prenatal development were noted in this study. Thus, the developmental NOAEL was greater than 5,000 mg/kg/day.

Key Study/Critical Effect for Screening Criteria

Compound-related lesions of the forestomach occurred in all dosed mouse groups in a two-year feeding study. These included squamous hyperplasia of the epithelium,

inflammation, and, in high-dose females, ulcers. It was suggested that this substance ,as a surfactant, produced forestomach injury by localized irritation to the epithelial cells.

LOAEL = 25,000 ppm in mice (forestomach lesions)

LOAEL (mg/kg/day) = 25,000 ppm * 0.13 = 3,250 mg/kg/day

Where 0.13 is the fraction of body weight that is consumed per day as food for the mouse (U.S. EPA).

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (LOAEL to NOAEL)

Oral RfD = 3,250/1,000 = 3.25 mg/kg/day

Drinking water guidance value = 11.4 ppm

Toxicity Profile

Ethoxylated Sorbitan Monooelate
Polysorbate 80
(CAS No. 9005-65-6)

Ethoxylated sorbitan monooleate or polysorbate 80 is a hydrophilic, non-ionic surfactant used in pharmaceutical preparations, and cosmetics as an emulsifier, dispersant, or stabilizer, and as a food additive. It is a mixture of oleic esters of sorbitan and its anhydrides copolymerized with approximately 20 mol of ethylene oxide (Sweetman, 2002). Thus, polysorbate 80 is considered a UVCB substance (substance of unknown or variable composition, complex reaction products or biological materials).

The information below and the references can be found in NTP (1992a).

Metabolism

The metabolism of radiolabeled polysorbates in rats has been studied. After oral administration, the ester linkage of the polysorbate molecule is hydrolyzed by pancreatic lipase and the released fatty acid is absorbed and metabolized; essentially all of the fatty acid in polysorbate 80 fed as 10% of the diet is hydrolyzed and absorbed. The sorbitol-polyoxyethylene moiety is poorly absorbed and most is excreted in the feces. In metabolism studies conducted with rats fed polysorbate 80 containing radiolabeled sorbitol, 91% of the radioactivity was found in the feces, 2.1% was found in the urine, and 1.6% was found in the carcass. None was found in the liver, kidney, adrenal glands, spleen, brain, or fat. Following intravenous administration of polysorbates to rats, the ester linkage of the polysorbates is hydrolyzed by blood lipases. Intravenous studies using radiolabeled polysorbate 20 in rats demonstrated that the fatty acid portion was metabolized and excreted mostly as expired carbon dioxide, with lesser amounts appearing in the urine and feces; the sorbitol-polyoxyethylene moiety was not catabolized and was excreted mainly in the urine, although a small amount was found in the feces, indicating some biliary excretion; trace amounts were detected in the carcass and liver.

Metabolism of polysorbates in humans appears to be similar to that in rats. Analysis of urine and feces from human volunteers who consumed 4.5 g of polysorbate 80 daily showed that 95% of the polyoxyethylene portion was excreted in the feces and 5% in urine; apparently, none was retained in the body.

Acute Toxicity

Reported oral LD_{50} values for rats range from approximately 33,800 mg/kg to approximately 54,500 mg/kg, while the oral LD_{50} for mice is greater than 25,000 mg/kg. Clinical experience with humans who have ingested large quantities of polysorbate 80 indicates that the compound is essentially nontoxic by the oral route, with the estimated lethal dose being 15,000 mg/kg.

Irritation

In 24-hour rabbit skin-patch tests, polysorbate 80 was found to produce minimal or no irritation. Daily application of 100% solutions of polysorbate 80 to the backs of rabbits for 30 days produced histologic changes in the skin, including mild to moderate inflammation, acanthosis, and necrosis. Application of 1% or 2.5% aqueous solutions of polysorbate 80 to the backs of mice for up to 9 days produced no gross or microscopic lesions. Studies conducted in humans did not result in skin irritation.

Sensitization

Repeated intradermal injections of polysorbate 80 into guinea pigs did not produce skin sensitization, and studies conducted in humans did not result in sensitization.

Repeated Dose Toxicity

In a multi-generation study, doses of 5%, l0%, and 20% polysorbate 80 were administered in the feed to male and female rats. Composition of the diet was altered for different dose levels to compensate for the decrease in caloric value caused by addition of polysorbate 80. Diarrhea was seen in animals fed 10% or 20% polysorbate 80, and was presumably due to the osmotic effect of the large amounts of unabsorbed sorbitol-polyoxyethylene moiety in the intestinal tract. There was some reduction in growth rate, postnatal survival of pups, lactation and breeding efficiency, and longevity in rats fed the diet containing 20% polysorbate 80. Hematologic examination showed no abnormalities and no treatment-related histologic lesions were seen upon examination of kidneys, livers, and gross lesions. No significant findings were reported in a three-generation study using groups of 30 rats fed 2% polysorbate 80. Degeneration of the heart, liver, and kidney were reported in groups of 12 Charles Foster rats administered a daily dose of 1.5 mL of a solution of 1%, 2%, or 3% polysorbate 80 for 3 months. Similar effects were not reported in other studies using higher doses for longer periods, so the significance of the findings of this single study is debatable. Daily administration of 1g polysorbate 80 to each of two monkeys for 17 months produced no compound-related gross or microscopic lesions.

Evidence indicates that the long-term ingestion of polysorbate 80 by humans does not result in toxicity. Long-term consumption (one or more years) of 4.5 to 6 g polysorbate 80 per day by human patients for the treatment of lipid malabsorption syndromes has been reported to cause no adverse effects. The consumption of doses as high as 15 g/day for several months caused no clinical indications of toxicity.

Groups of 10 F344/N rats and 10 $B6C3F_1$ mice of each sex received diets containing 0, 3,100, 6,200, 12,500, 25,000 or 50,000 ppm polysorbate 80. All animals survived to the

end of the studies. The final mean body weights of dosed rats and mice were similar to those of the controls. No clinical findings, changes in absolute or relative organ weights, or gross or microscopic lesions in rats or mice were related to polysorbate 80 administration. The NOAEL is 50,000 ppm (NTP, 1992a).

Genotoxicity Studies

Polysorbate 80 is not genotoxic is a variety of in vitro and in vivo assays.

Carcinogenicity studies

In one study, 28 mice were fed diets containing 10 mg polysorbate 80 daily for 51 week, no neoplasms occurred as the result of treatment.

Groups of 60 F344/N rats and 60 B6C3F mice of each sex received diets containing 0, 25,000, or 50,000 ppm polysorbate 80 for up to 103 weeks. Interim evaluations were performed on 7 to 10 rats and mice from each dose group at 15 months. There were no significant changes in absolute or relative organ weights. Incidences of hyperplasia and inflammation of the forestomach were increased in female mice that received 50,000 ppm. No other chemical-related lesions occurred in rats or male mice evaluated at 15 months.

The mean body weights in male and female rats and male mice administered polysorbate 80 were similar to those of the controls throughout the studies. The final mean body weight of female mice receiving 50,000 ppm was 11% lower than that of the controls. No clinical findings were associated with administration of polysorbate 80. The survival of dosed male rats was lower than that of the controls (0 ppm, 29/50; 25,000 ppm, 18/50; 50,000 ppm, 18/50); the survival of dosed female rats and male and female mice was similar to that of the respective controls (female rats: 23/50, 25/50, 25/50; male mice: 33/49, 34/50, 32/50; female mice: 30/50, 28/50, 26/50).

The incidence of adrenal medulla pheochromocytoma was marginally increased in high-dose male rats (21/50, 19/50, 29/50). The slight increase in incidence of pheochromocytoma in the high-dose male rat group was judged to be of questionable significance based on historical control data. The incidence of hyperplasia of the adrenal medulla was increased in low-dose male rats but not in high-dose male rats (11/50, 22/50, 12/50). The marginal increased incidence of pheochromocytoma in combination with the increased incidence of hyperplasia were considered to be an equivocal finding.

No chemical-related increases in the incidences of neoplasms occurred in male or female mice. The incidences of squamous hyperplasia and inflammation of the forestomach were significantly increased in high-dose male and female mice; forestomach ulcers were significantly increased in high-dose females (NTP, 1992a).

Developmental Toxicity

Timed-mated Sprague-Dawley-derived (CD® rats were exposed to 0, 500 or 5,000 mg/kg/day of polysorbate 80 on gestational days (GD) 6 through 15. All treated females survived to scheduled necropsy and 19-23 pregnancies per group were confirmed. No dose-related signs of toxicity were observed for individual animals during the in-life phase of the study or at scheduled necropsy. Average maternal body weight (GD 0, 3, 6, 9, 12, 15, 18, or 20) did not differ among treatment groups, nor was there a treatment related change in maternal weight gain during treatment or gestation (absolute or corrected). There were no treatment-related effects upon the following maternal organ weights: gravid weight (absolute), kidney weight (absolute or relative), and heart weight (absolute or relative). Relative maternal liver weight (% body weight on gd 20 or % corrected body weight) was elevated in both treated groups and absolute liver weight was elevated at 500 mg/kg/day. Maternal food intake was comparable across groups during the pre- and post-treatment periods, but was decreased by 14% during the first 3 days of treatment at 5000 mg/kg/day relative to the vehicle control group. Maternal relative water intake was comparable among treatment groups throughout gestation. No differences among groups were noted for the number of corpora lutea per dam, the number of implantation sites per dam or the percent preimplantation loss per litter. No adverse effects were noted on the growth, viability or morphological development of the conceptuses. In conclusion, the maternal LOAEL was 500 mg/kg/day (based upon an increase in maternal relative liver weight). No definitive adverse effects of polysorbate 80 upon prenatal development were noted in this study. Thus, the developmental NOAEL was greater than 5,000 mg/kg/day (NTP 1992b).

Key Study/Critical Effect for Screening Criteria

Compound-related lesions of the forestomach occurred in all dosed mouse groups in a two-year feeding study. These included squamous hyperplasia of the epithelium, inflammation, and, in high-dose females, ulcers. It was suggested that polysorbate 80 as a surfactant produced forestomach injury by localized irritation to the epithelial cells.

LOAEL = 25,000 ppm in mice (forestomach lesions)

LOAEL (mg/kg/day) = 25,000 ppm * 0.13 = 3,250 mg/kg/day

Where 0.13 is the fraction of body weight that is consumed per day as food for the mouse (U.S. EPA).

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (LOAEL to NOAEL)

Oral RfD = 3,250/1,000 = 3.25 mg/kg/day

Drinking water guidance value = 11.4 ppm

References

NTP (1992a). Toxicology and Carcinogenesis Studies of Polysorbate 80 (CAS No. 9005-65-6) in F344/N rats and B6C3F$_1$ Mice (Feed Studies), NTP TR 415, NIH Publication No. 92-3146, National Toxicology Program, U.S. Department of Health and Human Services, Public Health Service, National Institutes of Health.

NTP (1992b). Developmental Toxicology of Polyoxyethylene Sorbitan Monooleate (CAS #9005-65-6) in Sprague-Dawley CD® Rats, NTP Study: TER91009, National Toxicology Program, U.S. Department of Health and Human Services, Public Health Service, National Institutes of Health.

Sweetman, S.C. (2002). Martindale: the Complete Drug Reference, London, Pharmaceutical Press; cited in Carlsson *et al.* (2006).

Toxicity Profile

Fatty Acid Ester

This fatty acid ester is a non-ionic surfactant-active agent that typically finds use as an emulsifier, stabilizer and thickener in foods, cosmetics, medical products, and lubricants, and other applications. It is approved by FDA as an indirect food additive.

Acute Toxicity

The acute oral LD_{50} of this substance in rats was reported to be > 39,800 mg/kg.

Irritation

No data were located.

Sensitization

No data were located.

Repeated Dose Toxicity/Carcinogenicity

Oral feeding toxicity studies have been carried out in rats for 16 weeks with this substance at dietary concentrations of 0, 2.5, 5 and 10%. The LOAEL was 2.5% dietary concentration (~1800 mg/kg/day) based on increased kidney weight findings that were considered significant in both male and female rats.

This substance fed to rats at 5% concentrations in the diet for 2 years showed no adverse effects on growth, hematology, clinical chemistry, survival, organ size or histopathology. The NOAEL was reported to be 5% in the diet.

Genotoxicity

No genotoxicity studies could be located for this substance; however, there are two studies conducted on a structurally similar substance.

The surrogate was not mutagenic to *Salmonella typhimurium* TA98 and TA100 in a Ames mutation assay in the presence or absence of metabolic activation. It did not cause any chromosomal aberrations in the Syrian golden hamster embryo cell assay and did not show clastogenic activity.

Reproductive/Developmental Toxicity

No studies could be located for this substance; however, there is one study conducted in a structurally similar substance.

The surrogate was administered in the diet at dose levels of 0, 5, 10, and 20% over a period of two years and over four generations of rats. No effects were observed on growth, food efficiency, reproduction, lactation, metabolism, behavior, mortality, or in the gross and histopathological examination. At the 20% dose level in the diet, newborn mortality was not increased but there were slight effects on growth and impairment of lactation.

Key Study/Critical Effect for Screening Criteria

No treatment-related effects were noted in a two-year carcinogenicity study in which rat were fed this fatty acid ester in the diet at concentrations up to 5% (50,000 ppm).

NOAEL (mg/kg/day) = 50,000 ppm * 0.05 = 2,500 mg/kg/day

Where 0.05 is the fraction of body weight that is consumed per day as food for the rat (U.S. EPA).

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD = 2,500/100 = 25 mg/kg/day

Drinking water guidance value = 87.5 ppm

Toxicity Profile

Guar Gum
(CAS No. 9000-30-0)

Guar gum (CAS No. 9000-30-0) is the milled endosperm of the leguminous plant *Cyanopsis tetragonolobus*. Structurally, it is a galactomannan consisting of a main chain of D-mannose with a side chain of D-galactose at approximately every second mannose unit. The mannose units are β-(l-4) linked, and the single D-galactose units are joined to the main chain by α-(1-6) linkages. The estimated molecular weight of guar gum cranges from 200,000 to 300,000 daltons (Glickman, 1969).

Guar gum is approved for use as a food additive by the U.S. Food and Drug Administration and is on the list of substances "generally recognized as safe" (CFR 1974).

Acute Toxicity

The oral LD_{50} is 8,100 mg/kg for mice and 9,400 mg/kg for rats (Bailey and Morgareidge, 1948).

Irritation

No data were found.

Sensitization

There are reports of respiratory sensitization in workers exposed occupationally to guar gum dusts (Maio, 1986).

Repeat Dose Toxicity Studies

F344 rats and B6C3F_1 mice were given diets containing 0, 6,300, 12,500, 25,000, 50,000 or 100,000 ppm guar gum for 13 weeks (NTP, 1982). Mean body weights were decreased in male rats (100,000 ppm group) and in female mice (50,000 and 100,000 ppm). A dose-related decrease in feed consumption was observed for male and female rats; male and female mice were comparable or higher than that of controls. There were no compound-related clinical signs or histopathological effects.

F344 rats and B6C3F_1 mice were given diets containing 0, 25,000 ppm or 50,000 ppm guar gum for 103 weeks (NTP, 1982). Mean body weights of the high-dose females were

lower than those of the controls after week 20 for mice and week 40 for rats. No compound-related clinical signs or adverse effects on survival were observed. Feed consumption by dosed rats and mice of either sex was lower than that of controls. There were no non-neoplastic histopathological effects in either rats or mice that were treatment-related.

Genotoxicity

Guar gum was not mutagenic to *Salmonella typhimurium* TA 1530 or G-46 when tested without metabolic activation; however, it was mutagenic to *Saccharomyces cerevisiae* D-3 (Green, 1977). Guar gum also was reported to cause chromosomal aberrations in human embryonic lung cells WI-38 (Green, 1977). No *in vivo* genotoxicity studies have been conducted on guar gum.

Carcinogenicity

F344 rats and B6C3F_1 mice were given diets containing 0, 25,000 ppm or 50,000 ppm guar gum for 103 weeks (NTP, 1982). There were increased incidences of adenomas of the pituitary in male rats and pheochromocytomas of the adrenal in female rats that were statistically significant, but these differences were considered to be unrelated to guar gum administration. When pituitary adenomas or carcinomas and when pheochromocytomas or malignant pheochromocytomas are combined, the statistical differences disappear. Hepatocellular carcinomas occurred in treated male mice at incidences that were significantly lower than that in controls. The combined incidence of male mice with either hepatocellular adenomas or carcinomas was also significantly lower in the high-dose group. It was concluded that under conditions of this bioassay, guar gum was not carcinogenic for F344 rats or B6C3F_1 mice.

Reproductive Toxicity

No data were found.

Developmental Toxicity

Female rabbits were given daily (6 hours/day) dermal administration of 0, 2, 10 and 50 mg/kg guar gum during gestational days 6 through 18 (IRDC, 1988). Mortalities included 2 deaths at 50 mg/kg and 1 death at 10 mg/kg. A single animal was killed in extremis. A dose-related increase in dermal irritation (including erythema, edema, and desquamation) was observed in animals receiving 10 and 50 mg/kg. The number of early resorptions was significantly increased and the number of viable fetuses was correspondingly decreased at 50 mg/kg/day ($p<0.05$). The frequency of fetal malformations and variations in the treated groups was comparable to that of the control

group at all dose levels. The NOEL for this study is 2 mg/kg/day.

Key Study/Critical Effect for Screening Criteria

The key studies for the determination of a drinking water guidance value is the NTP two-year chronic bioassays. The LOAELs are based on decreased mean body weights in female mice and rats fed 50,000 ppm guar gum in diet for 103 weeks. The NOAELs for these studies are 25,000 ppm guar gum.

Rat: NOAEL (mg/kg/day) = 25,000 ppm * 0.05 = 1,250 mg/kg/day

Mouse: NOAEL (mg/kg/day) = 25,000 ppm * 0.13 = 3,250 mg/kg/day

Where 0.05 and 0.13 are the fraction of body weight that rats and mice, respectively, consume per day as food (U.S. EPA).

The lowest NOAEL of 1,250 mg/kg/day for the rat will be used to derive a drinking water guidance value.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD = 1,250/100 = 12.5 mg/kg/day

Drinking water guideline = 44 ppm

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Toxicity Profile

Hydrocarbons, Terpene Processing By-products
(CAS No. 68956-56-9)

Terpenes and Terpenoids, Sweet Orange Oil
(CAS No. 68647-72-3)

CAS No. 68956-56-9 is a by-product of the manufacturing process in which high-quality gum turpentine oil or alpha pinene is synthesized into terpineol. It is largely composed of alpha terpinene, dl-limonene, cineol, gamma terpinene, terpinolene and other terpene hydrocarbons. The composition of CAS No. 68956-56-9 in the HPV Test Plan for Monoterpene Hydrocarbon Category is: 22-34% limonene, 22-33% terpinolene, 5-10% mycene, 18% limonene isomers, 10% other terpene hydrocarbons.

CAS No. 68647-72-3 is composed of 91-95% d-limonene, 1-3% beta-myrcene, and 1-2% alpha-pinene.

Acute Toxicity

The oral and dermal LD_{50} values for limonene, myrcene, terpinolene, dihydromyrcene and sweet orange peel oil indicate a low order of both oral and dermal toxicity. All rabbit and rat dermal, and mouse and rat oral LD50 values are >4,000 mg/kg with the majority of values being >5,000 mg/kg.

Irritation

No data were located.

Sensitization

No data were located.

Repeated Dose Toxicity/Carcinogenicity

Selected repeat dose toxicity studies were included in this toxicity profile. For summaries on all conducted studies, see the U.S. HPVIS.

Groups of ten Sprague Dawley rats of each sex were administered 0, 240, 600 or 1,500 mg/kg sweet orange oil in 1% methyl cellulose by gavage daily for 30 days. Observations included survival, clinical observations, body weights, food consumption, clinical

pathology, gross pathology, organ weights and histopathology. No treatment related effects were reported for survival, clinical observations, body weights or food consumption. Decreases in glucose levels related to treatment were reported in the mid-dose females and high-dose males and females. Increases in serum albumin and total serum protein were observed in all treated females and the high-dose males. Histopathology revealed treatment related lesions in the nonglandular stomach of the high-dose males and females and in the kidney of all treated male groups. Kidney weights were also increased in all of the treated male groups and in the high-dose female group. Liver weight increases related to treatment were reported for the high-dose females and all treated male groups. The authors concluded that the no-observed-effect-level (NOEL) under conditions of this study was less than 240 mg/kg/day for both male and female rats. The authors noted that the kidney changes observed in the male rat at all dose levels were expected given the known interaction between limonene and *alpha*-2-microglobulin. Limonene is the principal constituent of orange oil.

In a NTP 13-week study, male and female F344/N rats were dosed by oral gavage 0, 150, 300, 600, 1,200 or 2,400 mg/kg *d*-limonene in corn oil for 5 days/week. At 2,400 mg/kg, 9/10 female rats and 5/10 male rats (5/10) died within the first week of the study. The final mean body weights of male rats receiving the three highest doses (600, 1,200 or 2,400 mg/kg) were reported to be 6%, 12%, or 23% lower than that of the controls, respectively. Rough hair coats, lethargy, and excessive lacrimation were observed for all animals in the 1,200 and 2,400 mg/kg dose groups. Kidney effects were seen in all treated male rats, with a dose-related increase in severity. The kidney effects were characterized by degeneration of epithelium in the convoluted tubules, granular casts with tubular lumens, primarily in the outer stripe of the outer medulla, and regeneration of the tubular epithelium. Hyaline droplets were observed in the epithelium of the proximal convoluted tubules in all groups of male rats including vehicle controls.

In a NTP 13-week study, male and female $B6C3F_1$ mice were dosed by oral gavage with 0, 125, 250, 500, 1,000 or 2,000 mg/kg *d*-limonene for five days/week. At 2,000 mg/kg, 1/10 males and 2/10 females died before the end of the study; 1/10 females in the 500 mg/kg group also died before study termination. Several other animals also died as a result of gavage error. Mean body weights were 10% lower than control for male mice and 2% lower than control for female mice for the 1,000 and 2,000 mg/kg groups. Clinical signs of rough hair coats and decreased activity were reported for the two highest dose levels.

Male rats were dosed by oral gavage with 0, 2, 5, 10, 30 or 75 mg/kg *d*-limonene 5 days/week for 13 weeks. Linear regression analyses indicated increased relative kidney and liver weights at 30 and 75 mg/kg. Histological examination showed changes in the kidney characterized by hyaline droplet formation, granular casts and multiple cortical changes. Exacerbation of hyaline droplet formation was reported at the earliest necropsy eight days after administration at the 10 mg/kg dose level.

In a two-year NTP bioassay, male and female F344/N rats were dosed with 0, 75 or 150 mg/kg or 0, 300 or 600 mg/kg *d*-limonene for five days/week. Mean body weights for

the 150 mg/kg male rats were generally 4-7% lower than vehicle controls from week 2 to study termination. Mean body weights of the 600 mg/kg females were generally 4-7% lower than vehicle controls from week 28 to study termination. No treatment-related clinical signs were reported for the duration of the study. Survival of the 150 mg/kg male group was significantly greater than that of the vehicle alone after week 81. Survival of the 600 mg/kg female group was significantly lower than that of the vehicle controls after week 39. In the male rat kidneys, a dose-related increase was observed in the incidence of mineralization and epithelial hyperplasia. A dose-related increase in the severity of spontaneous nephropathy was reported in the treated male rats. Increased incidences in tubular cell hyperplasia and neoplasia were also reported in dosed male rats. Tubular cell adenoma incidence in 150 mg/kg male rats and tubular cell adenoma or tubular cell carcinomas (combined) in dosed male rats were significantly greater than vehicle controls. There was no evidence of carcinogenic activity of *d*-limonene for female rats receiving 300 or 600 mg/kg. The NOAEL for male rats (excluding the kidney effects) is 150 mg/kg/day (see below on the relevance of the male rat kidney effects for human risk assessment). The NOAEL for female rats is 300 mg/kg/day based on low survival in the 600 mg/kg dose group.

In a NTP two-year bioassay, male and female $B6C3F_1$ mice were dosed by oral gavage with 0, 250, or 500 mg/kg or 0, 500 or 1,000 mg/kg *d*-limonene, respectively, five days a week. Mean body weights for the 1,000 mg/kg female mice administered 1,000 mg/kg were generally 5-15% lower than vehicle controls from week 28 to study termination. No treatment related clinical signs were reported for the duration of the study. Survival of the 250 mg/kg male group was significantly lower than that of the vehicle controls by study termination. In the 500 mg/kg males, livers exhibited presence of cells with abnormal numbers of nuclei and cytomegaly. There was no evidence of carcinogenic activity of *d*-limonene for male or female $B6C3F_1$ mice at the dose levels tested. The NOAEL for male mice is 250 mg/kg/day based on liver effects at 500 mg/kg/day. Although there was reduced survival in the 250 mg/kg male mice, NTP did not considered this to be dose-related. The NOAEL for female mice is considered to be 500 mg/kg/day based on decreased survival and lower body weights (5 - 15%) in the 1,000 mg/kg dose group.

The kidney changes seen in male rats administered limonene have been well characterized, and are known to be specific to the male rat and of no significance in human risk assessment.

Genotoxicity

Given the structural similarity between the members of this chemical category, the substances in this category exhibit low genotoxic potential *in vitro.*

Mutagenicity/genotoxicity testing has been performed on three members of this chemical category, including a complete battery of *in vitro* genotoxicity tests using limonene. No evidence of mutagenicity was observed when limonene was incubated with *Salmonella*

typhimurium strains TA98, TA100, TA102, TA1535, TA1537, and TA1538 with and without S-9 metabolic activation at concentrations up to and including 150,000 μg/plate. Limonene did not induce chromosomal aberrations when incubated with Chinese hamster ovary cells at a concentration of 50-500 μg/ml, nor did it induce sister chromatid exchanges in Chinese hamster ovary cells at concentrations of 16.2-162 μg/ml. In a mouse lymphoma forward mutation assay, limonene was negative in L5178Y cells with and without S-9 metabolic activation up to a maximum concentration of 100 μg/ml. When incubated with Syrian hamster embryo cells up to 100 μg/ml or 3 mM, limonene did not induce statistically significant cell transformation. The effects of limonene on gap junction intercellular communications were also tested at concentrations up to 1 mM in Syrian hamster embryo cells, and showed no effects.

In an *in vitro* chromosome aberration test with human lymphocytes, myrcene did not induce chromosomal aberrations at concentrations up to 1,000 μg/ml with and without metabolic activation. When incubated with Chinese hamster ovary cells in a V79- HPRT Gene Mutation Assay, myrcene was not mutagenic with or without metabolic activation. In sister chromatid exchange (SCE) tests with human lymphocytes, myrcene did not induce sister chromatid exchanges at concentrations up to 1,000 μg/ml with or without metabolic activation. Additionally, there was no evidence of genotoxicity when myrcene was incubated with V79 and hepatic tumor (HPT) Chinese hamster cells at concentrations up to 500 μg/ml in SCE assays. In fact, myrcene reduced the SCE inducing effect of S-9 mix activated cyclophosphamide in human lymphocytes and Chinese hamster ovary (CHO) cells, and aflatoxin B1 in V79 and HTC Chinese hamster cells in a dose dependent manner.

No evidence of mutagenicity was observed when sweet orange peel oil was incubated with *Salmonella typhimurium* strains TA98, TA100, TA1535, TA1537, and TA1538 with and without S-9 metabolic activation at concentrations up to 5000 μg/plate. In a mouse lymphoma forward mutation assay, sweet orange peel oil was positive in L5178Y cells with and without S-9 metabolic activation up to a maximum concentration of 75 μg/ml but only at highly toxic concentrations. The authors noted that that positive results in this assay may be associated with changes in physiologic culture conditions (pH and osmolality). Negative results were obtained with sweet orange peel oil in the Rec DNA repair assay using *Bacillus subtilis* strains H17 and M45.

In eighteen separate *in vitro* tests on the mutagenicity and genotoxicity of limonene, myrcene, and sweet orange peel oil; the majority was negative, with the exception of the mouse lymphoma assay using sweet orange peel oil. This result is questionable given the culture conditions present and the negative results of the mouse lymphoma assay using limonene since limonene is the majority (greater than 90%) constituent of sweet orange peel oil.

Two *in vivo* genotoxicity assays are available for two substances in this chemical category. In an *in vivo* mammalian spot test, no evidence of mutagenicity was reported when mouse embryos were treated *in utero* with 215 mg/kg/day limonene on days 10 -11 of gestation.

In an *in vivo* cytogenetic bone marrow assay, *beta*-myrcene (100, 500 or 1,000 mg/kg) was orally administered *via* gavage to up to male and female Wistar rats. A dose- related increase in the mitotic index in bone marrow cells was reported for rats administered the test substance. The authors commented that this might be an interaction between *beta*-myrcene, which is known to induce CYP-450 enzymes, and colchicine, which arrests cell division at metaphase. *beta*-Myrcene may have increased the bioavailability of colchicine leading to the increase in mitotic index observed in the experiment. No significant increases in chromosomal aberrations were reported in the treated animals at either 24 or 48 hours. The authors concluded that given the results, *beta*-myrcene was not clastogenic to the rat when orally administered at dose levels up to 1,000 mg/kg. Based on the results of this *in vivo* genotoxicity assay and the numerous *in vitro* genotoxicity assays, it is unlikely that any of these materials would exhibit a significant genotoxic potential *in vivo*.

Reproductive Toxicity

Selected repeat dose toxicity studies were included in this toxicity profile. For summaries on all conducted studies, see the U.S. HPVIS.

beta-Myrcene was administered *via* gavage to female Wistar rats at dose levels of 250, 500, 1,000 and 1,500 mg/kg of *beta*-myrcene from the 15th day of gestation until weaning of the offspring which was day 21 postnatal. Fertility was impaired in female offspring exposed to 1,000 or 1,500 mg/kg *beta*-myrcene.

In a one-generation reproductive toxicity study, male and female Wistar rats were dosed by oral gavage with 0, 100, 300 or 500 mg/kg *beta*-myrcene. The exposure period was 91 days prior to and during the mating period for the males and 21 days prior to and during the mating period for females, pregnancy, and lactation until 21 days post parturition. Neither deaths nor signs of toxicity were reported in male rats at any dose level. No statistically significant differences in body weight gain were reported between control and test animals. A slight increase in liver and kidney weights was reported for treated male (highest dose only) and female rats. No morphological alterations of the liver or testis tissue were revealed upon microscopic examination. No effects were reported on the number of spermatids in the testis or on the number of spermatozoa in the cauda epididymis. No adverse effects on body weight gain and no other signs of toxicity were observed in treated female rats during the pre-mating or mating periods. No treatment related effects were reported on fertility as measured by the mating index and pregnancy index upon comparison to controls. At the highest dose level, a slight increase in the resorption rate and a parallel decrease in the ratio of live fetuses per implantation site were reported. Increases in the occurrence of fetal skeleton abnormalities between control and treated groups were reported at the 500 mg/kg level. No adverse effects were reported on duration of pregnancy, labor, pup mortality, and maternal or offspring weight changes. Slight delays in incisor eruption (300 mg/kg) and eye opening (100, 300 mg/kg) were reported but were not dose-related. The authors attributed the increase in skeletal

abnormalities at the highest dose level tested to known strain-specific anomalies including increases of dislocated sternums, and lumbar extra ribs. The authors concluded that the NOAEL for toxic effects on fertility and general reproductive performance *via* the oral route was 300 mg /kg for *beta*-myrcene.

Female rats were dosed by oral gavage with 0, 375, 750 or 1,500 mg/kg sweet orange peel for seven days prior to and through cohabitation, gestation, delivery and a four day lactation period. No deaths occurred at any dose level. Statistically significant numbers of rats from all three dose groups experienced excess salvation during the pre-mating and gestation periods, and during the lactation period for high-dose animals. The dosed rats had decreased weight gains compared to the control rats during the seven day premating period. Absolute and relative maternal food consumption was significantly decreased for the 750 and 1,500 mg/kg dose groups during the seven day premating period. No treatment related effect on mating performance or fertility was reported at any dose level. A significant increase in stillbirths and pup deaths was reported for the highest dose group compared to the control group (see next section for developmental effects).

Given the results of three reproductive toxicity assays using sweet orange peel oil predominantly composed of *d*-limonene and *beta*-myrcene, it may be concluded that the substances within this chemical category exhibit low reproductive toxicity potential.

Developmental Toxicity

Pregnant female Wistar rats were dosed by oral gavage with 0, 591 or 2,869 mg/kg *d*-limonene on days 9-15 of gestation. At the highest dose level, increases in maternal mortality and decreases in maternal and fetal body weights were reported. Additionally at the highest dose level, delayed ossification of fetal metacarpal bones and proximal phalanx and decreased weights of the thymus, spleen, and ovaries were reported. The NOAEL for both maternal and offspring toxicity was reported to be 591 mg/kg.

Pregnant Japanese white rabbits were administered 0, 250, 500 or 1,000 mg/kg *d*-limonene on days 6 to 18 of gestation. Increased maternal mortality was reported at the highest dose level. Significant decreases in maternal body weight gain and food consumption were temporarily observed at the 500 and 1,000 mg/kg dose levels. No treatment related effects were reported for the offspring. The NOAEL for maternal toxicity was reported to be 250 mg/kg/day. The NOAEL for offspring toxicity was reported to be greater than 1,000 mg/kg/day.

Pregnant ICR mice were administered 0, 591 or 2,363 mg/kg *d*-limonene on days 7 to 12 of gestation. Significant decreases in body weight gain were reported for pregnant ICR mice administered the highest dose level of *d*-limonene. In the offspring, increased incidence of fused ribs compared to that of the controls, delayed ossification of some bones and decreased body weight gain were reported at the highest dose level tested. The NOAEL for both maternal and offspring toxicity was reported to be 591 mg/kg/day.

Pregnant Wistar rats were administered 0, 250, 500 or 1,200 mg/kg *beta*-myrcene on gestational days 6-15. The vehicle was corn oil. Decreased maternal weight gain was reported at the 1,200 mg/kg dose. Increased fetal skeletal malformations were reported at the 1,200 mg/kg dose level. The NOAEL for both maternal and offspring toxicity was reported to be 500 mg/kg/day.

beta-Myrcene was administered *via* gavage to female Wistar rats at dose levels of 250, 500, 1,000 or 1,500 mg/kg from pregnancy day 15 until weaning of the offspring, which was day 21 postnatal. Mortality, weight gain and post-natal development were evaluated. Reproductive capacity was assessed in the exposed offspring upon reaching maturity (120 days). No adverse effects were noted in the offspring at the lowest dose level tested. Decreased body weight, increased perinatal mortality, and delayed developmental landmarks were noted at the 500, 1000 and 1500 mg/kg dose levels. Fertility was impaired in female offspring exposed to the two highest doses of *beta*-myrcene. The NOAEL for peri- and post-natal development was set at 250 mg/kg/day.

Female rats were dosed by oral gavage with 0, 375, 750 or 1,500 mg/kg sweet orange peel for seven days prior to and through cohabitation, gestation, delivery and a four day lactation period. No deaths occurred at any dose level. Statistically significant numbers of rats from all three dose groups experienced excess salvation during the premating and gestation periods, and during the lactation period for high-dose animals. The dosed rats had decreased weight gains compared to the control rats during the seven-day premating period. Absolute and relative maternal food consumption was significantly decreased for the 750 and 1500 mg/kg/day dose groups during the seven day premating period. No treatment related effects were reported on maternal body weight, changes in body weight, and absolute and relative feed consumption during the lactation period. No treatment related effect on mating performance or fertility was reported at any dose level. A significant increase in stillbirths and pup deaths was reported for the highest dose group compared to the control group. The treatment with sweet orange oil had no effect on the incidence of malformations or gross lesions in the pups. The NOAEL for this study was reported to be less than 375 mg/kg/day for maternal toxicity and 750 mg/kg/day for offspring development.

Given the results of six developmental toxicity assays using limonene, sweet orange oil and *beta*-myrcene, it may be concluded that the substances within this chemical category exhibit low developmental toxicity potential.

Key Study/Critical Effect for Screening Criteria

The toxicity data on d-limonene will be used as read-across to CAS No. 68956-56-9 and 68647-72-3. The kidney changes seen in male rats administered limonene have been well characterized, and are known to be specific to the male rat and of no significance in human risk assessment. Thus, the male rat kidney effects will not be considered in the determining the critical effect for a drinking water guideline value.

In the NTP two-year rat bioassay, the NOAELs for male and female rats were 150 and 300 mg/kg/day, respectively. In the NTP two-year mouse bioassay, the NOAELs for male and female mice were 250 and 500 mg/kg/day, respectively.

The lowest NOAEL is 150 mg/kg/day for male rats in the NTP 2-year bioassay based on liver effects. Adjusting for 5 days/week to 7 days/week, results in a NOAEL for continuous exposure of 107 mg/kg/day.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD = 107/100 = 1.1 mg/kg/day

Drinking water guidance value = 3.8 ppm

Reference

U.S. EPA HPVIS database: http://www.epa.gov/chemrtk/hpvis/index.html

Toxicity Profile

Hydrochloric acid
(CAS No. 7647-01-0)

Hydrochloric acid has been reviewed in the OECD-SIDS program (OECD, 2002a,b).

Hydrochloric acid (HCl) or hydrogen chloride is readily dissociated in water into hydrated protons and chloride ion.

Acute Toxicity

The oral LD_{50} value of hydrogen chloride is reported to be 238 to 277 mg/kg for female rats (Hoechst AG, 1966), and 900 mg/kg for rabbits (Loewy and Munzer, 1923). The lethal dose by dermal exposure is >5,010 mg/kg for rabbits (Monsanto, 1976). The LC_{50} values for HCl are reported to be 23.7 - 60.9 mg/L/5min, 5.7- 7.0 mg/L/30min and 4.2 4.7 mg/L/60min for rats; and 20.9 mg/L/5min, 3.9 mg/L/30min and 1.7 mg/L/60min for mice (Darmer *et al.*, 1974; Hartzell *et al.*, 1990; MacEwean *et al.*, 1974).

Irritation

Concentrations >3.3% cause skin irritation, and concentrations >17% cause corrosion in animal studies (OECD, 2002a,b). An aqueous solution (4%) of hydrogen chloride was slightly irritating (Agner and Serup, 1988), and a 10% solution was determined to be 'Irritating to skin' for the EU Dangerous Preparations Directive, in human volunteer experiments (York *et al.*, 1996).

0.1 mL of 10% aqueous solution of HCl was highly irritating to the eyes of rabbits (Jacobs, 1992); 0.03 mL or more of 5% HCl was corrosive to the eyes of rabbits (Griffith *et al.*, 1980); 0.1 mL of a 3.3% aqueous solution of HCL was slightly irritating the eyes of rabbits (Hoechst AG, 1966); and 0.1 mL of a 0.33% aqueous solution of HCl was not irritating to the eyes of rabbits. (Hoechst AG, 1966).

Sensitization

Hydrogen chloride is not a skin sensitizer to guinea pigs and humans (Gad *et al.*, 1986).

Repeated Dose Toxicity

Rats were fed diets containing 280 to 1,250 mmol/kg hydrochloric acid (10.2 to 45.6 mg/kg) for 7-12 weeks. There was increased water intake in all treated groups. All

animals fed diet containing 937 mmol/kg and above for 9 weeks, and half of the animals fed diet containing 900 mmol/kg for 12 weeks died. Also at doses ≥937 mmol/kg, there was decreased body weight, food consumption, blood pH, femur length, rate of ash in bone (Upotn and L'Estrange, 1977). In another study with rats, hydrochloric acid was administered via drinking water at pH 2-3 (study duration not provided). Decreased protein levels in urine and decreased urine volumes were observed in the treatment groups (Clausing and Gottschalk, 1989).

Genotoxicity

While consistent negative results have been obtained in the bacterial systems, positive results have been obtained in the non-bacterial systems (OECD, 2002a,b). The positive results were observed at high concentrations, but they were considered to be artifacts due to the low pH. Positive results were obtained in a sex-linked recessive lethal study with *D. melanogaster*; only one dose level was tested (Stumm-Tegethoff, 1966) There are no mammalian studies on *in vivo* mutagenicity with hydrogen chloride

Carcinogenicity (Oral Studies only)

A ten-month study has been conducted using mice (Dyer *et al.*, 1946). Because the methods such as strain used, duration and dose of administration, presence of co-administration substance, were not appropriate, it cannot be used for the assessment of carcinogenicity of hydrochloric acid.

Reproductive Toxicity

No reliable studies were identified by the oral route.

Developmental Toxicity

No reliable studies were identified by the oral route.

Key Study/Critical Effect for Screening Criteria

The Australian drinking water guideline value for pH may apply to hydrochloric acid.

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Toxicity Profile

Monoethanolamine borate
(CAS No. 26038-87-9)

The toxicity profile includes toxicity data on boric acid, reaction products with ethanolamine and triethanolamine (CAS No. 68512-53-8), which is structurally similar to monoethanolamine borate.

Acute Toxicity

The acute oral LD_{50} in rats is >2,000 mg/kg, and the acute dermal LD_{50} of CAS 68512-53-8 in rats is >2,000 mg/kg.

Irritation

Monoethanolamine borate was slightly irritating and was not considered to be a skin irritant when tested on the skin of rabbits. Monoethanolamine (MEA) Polyborate 1:1 and MEA Polyborate 1:3 were tested for eye irritancy using the Bovine Corneal Opacity and Permeability test (BCOP test). Minimal to no ocular irritation was observed in both studies.

Sensitization

CAS No. 68512-53-8 was not a skin sensitizer to guinea pigs using the Buehler method.

Repeated Dose Toxicity

Groups of male and female rats received CAS No. 68512-53-8 by oral gavage at dose levels of 0, 62.5, 250 or 1,000 mg/kg body weight per day for a period of 28 days. No deaths occurred throughout the study. Behavior, state of health, body weight development and food consumption, were not affected by administration of the test substance. No treatment-related clinical signs were observed in all animals. No changes of the oral mucosa or impairment of dental growth was observed in all study groups. There were no substance related adverse findings either in hematological examinations, clinical chemistry or urine analyses throughout the study period. As a non-adverse finding, the test substance induced slightly lower total bilirubin, cholesterol and triglycerides in high dose group rats (1,000 mg/kg body weight) and possibly marginally lower hemoglobin and hematocrit content when compared to the controls at the end of the study period. These changes were at the lower range of the historical control data for this rat strain and age and hence, not considered to be of toxicological significance. The test

substance did not influence any of the neurotoxicological parameters. No test article related changes in organ weights were observed. Necropsy at terminal sacrifice revealed no gross pathology findings in the animals of all experimental groups. All microscopic findings sporadically observed in different organs of single animals were interpreted as not compound related. The NOAEL for this study is 1,000 mg/kg/day.

Genotoxicity

In an *in vitro* chromosomal aberration test using cultured peripheral human lymphocytes, MEA Polyborate 1:1 showed a clastogenic response in experiments where the pH of the treated cultures was above the pH of the solvent control. The clastogenicity was only observed in the first cytogenetic assay. Due to fact that the adjustment of the pH of the cultures treated with MEA Polyborate 1:1 did not show a clastogenic response in the third cytogenetic assay, it has to be assumed that the high pH is responsible for the detected clastogenic activity.

In an *in vitro* chromosomal aberration test using cultured peripheral human lymphocytes, MEA Polyborate 1:3 did not induce a statistically significant or biologically relevant increase in the number of cells with chromosome aberrations in the absence and presence of S9-mix, in either of the two independently repeated experiments. CAS No. 68512-53-8 did not induce gene mutations in an *in vitro* HPRT-test with V79 Chinese hamster lung fibroblast cells, either in the presence or in the absence of metabolic activation.

Carcinogenicity

No data are available.

Reproductive Toxicity

No data are available.

Developmental Toxicity

No data are available.

Key Study/Critical Effect for Screening Criteria

A 28-day oral toxicity study conducted was conducted in rats with CAS No. 68512-53-8 (Boric acid, reaction products with ethanolamine and triethanolamine). The NOAEL for this study is 1,000 mg/kg/day. Data from CAS No. 68512-53-8 is being used as read-across to monoethanolamine borate.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (subacute to chronic)

Oral RfD = 1000/1000 = 1 mg/kg/day

Drinking water guideline: 3.5 ppm

Reference

ECHA REACH database: http://apps.echa.europa.eu/registered/registered-sub.aspx

Toxicity Profile

PEG Oleate Ester
[Poly(oxy-1,2-ethanediyl), .alpha.-hydro-.omega.-hydroxy-, (9Z)-9-octadecenoate]
(CAS No. 56449-46-8)

Ethoxylated fatty acids are also called PEG fatty acid esters because the substance is a PEG chain linked to a fatty acid via an ester linkage. Data were located on the PEG stearate, PEG laurate, and PEG castor oil; these substances will be used as a surrogates for this substance.

Acute Toxicity

The acute oral LD_{50} of PEG stearates (50% preparations) were >10,000 mg/kg in rats, and the acute dermal LD_{50} of PEG stearate (15% preparation) was >10,000 ml/kg in rabbits.

Irritation

PEG stearates (100%) were mildly irritating the skin of rabbits, and non-irritating to human skin. PEG stearates (100%) was minimally irritating to the eyes of rabbits. PEG castor oils (100%) was considered non-irritating to the eyes of rabbits.

Sensitization

Clinical studies on the PEG stearates indicate that these ingredients are neither irritants nor sensitizers at concentrations of ≤25%.

Repeated Dose Toxicity

PEG-8 stearate at 5% in the diet did not produce any treatment-related effects in rabbits after 19 weeks, or any treatment-related effects at 4% after 4 months.

In a two-year dietary study, PEG-8 stearate at 4% produced no treatment-related effects over three generations. Likewise, PEG-100 at 2% did not produce any treatment-related effects over three generations in a two-year dietary study.

In a two-year dietary study, male and female rats (12/sex/dose) were given 0, 2, 5, 10, and 25% PEG-20 laurate in feed, At 25%, growth reduction occurred in the male rats, three rats had gastric mucosa hyperplasia, hepatic cysts in five rats, and cecal enlargement in 17 animals. At 10%, there were hepatic cysts in four rats and cecal

enlargement in four animals. At 5%, there was one hepatic cyst and cecal enlargement in three animals. At 2%, there was one hepatic cyst, and cecal enlargement in two animals (Fitzhugh et al., 1960).

Genotoxicity

There is no indication of a genotoxic effect of PEG fatty acids.

Carcinogenicity

No carcinogenicity studies could be located for PEG fatty acids.

Reproductive/Developmental Toxicity

Multi-generation studies with PEG- 40 stearates showed no adverse effects on reproduction and development. There was no evidence of developmental toxicity seen in mice and rat feeding studies with PEG-35 castor oil.

Key Study/Critical Effect for Screening Criteria

Liver cysts and cecal enlargement were seen in all tested rats given PEG-20 laurate in feed for two years. It cannot determined whether the lowest concentration tested (2%) is a LOAEL or a NOAEL. Thus, for the purposes of this risk assessment, the 2% concentration in this study will be considered a LOAEL.

NOAEL (mg/kg/day) = 20,000 ppm * 0.05 = 1,000 mg/kg/day

Where 0.05 is the fraction of body weight that is consumed per day as food for the rat (U.S. EPA).

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (LOAEL to NOAEL)

Oral RfD = 1,000/1,000 = 1 mg/kg/day

Drinking water guidance value = 3.5 ppm

References

Fitzhugh, O.G., Schouboe, P.J., and Nelson, A.A. (1960). Oral toxicities of lauric acid and certain lauric acid derivatives. Toxicol. Appl. Pharmacol. 2: 59-67.

Fruijtier-Pölloth, C. (2005). Safety assessment on polyethylene glycols (PEGs) and their derivatives as used in cosmetics. Toxicol. 214: 1-38.

Toxicity Profile

Sodium hydroxide
(CAS No. 1310-73-2)

Sodium hydroxide (NaOH) has been reviewed in the OECD-SIDS program (OECD, 2002a,b).

Sodium hydroxide (NaOH) is present in the environment as sodium (Na^+) and hydroxyl ions (OH^-). Sodium is a normal constituent of the blood and an excess is excreted in the urine. A significant amount of sodium is taken up via the food because the normal uptake of sodium via food is 3.1-6.0 g per day according to Fodor *et al.* (1999). Exposure to NaOH could potentially increase the pH of the blood. However, the pH of the blood is regulated between narrow ranges to maintain homeostasis (pH of 7.4 to 7.5) by urinary excretion of bicarbonate and via exhalation of carbon dioxide.

Acute Toxicity

An oral LD_{50} of a 1-10% solution of NaOH in rabbits was reported to be 325 mg/kg (expressed as 100% NaOH). Mortality was also observed when 1% NaOH was dosed, but in this case, the applied volume was relatively high (24 mL per kg body weight).

Irritation

A NaOH solution of 8% can be considered corrosive based on animal data. Human data indicate that concentrations of 0.5 to 4% were irritating. In two different studies a concentration of 0.5% was irritating for only 55 and 61% of the volunteers, respectively. Thus, it is assumed that a concentration, which is slightly lower than 0.5%, is the non-irritating concentration.

The available animal data on eye irritation showed that the non-irritant level was 0.2-1.0 %, while the corrosive concentration was 1.2 % or >2%.

Sensitization

Male volunteers were exposed on the back to sodium hydroxide concentrations of 0.063 – 1.0% (induction). After 7 days the volunteers were challenged to a concentration of 0.125%. The irritant response correlated well with the concentration of NaOH, but an increased response was not observed when the previously patch tested sites were re-challenged. Based on this study sodium hydroxide has no skin sensitization potential.

Repeated Dose Toxicity

No animal data are available on repeated dose toxicity studies by oral, dermal, inhalation or by other routes for NaOH. It is not useful to study the repeated dose toxicity of hydroxide via an oral study because at high concentrations the substance is corrosive or irritating, while at low concentrations the hydroxide will be neutralized in the stomach by gastric juice, which has a very low pH.

Genotoxicity

Both the *in vitro* and the *in vivo* genotoxicity tests are negative.

Carcinogenicity

No carcinogenicity studies on sodium hydroxide were identified.

Reproductive Toxicity

No valid studies were identified regarding toxicity to reproduction in animals after oral, dermal or inhalation exposure to NaOH. It is not useful to study the reproduction/developmental toxicity of hydroxide via an oral study because at high concentrations the substance is corrosive or irritating, while at low concentrations the hydroxide will be neutralized in the stomach by gastric juice, which has a very low pH.

Developmental Toxicity

No valid studies were identified regarding developmental toxicity in animals after oral, dermal or inhalation exposure to NaOH. It is not useful to study the reproduction/developmental toxicity of hydroxide via an oral study because at high concentrations the substance is corrosive or irritating, while at low concentrations the hydroxide will be neutralized in the stomach by gastric juice, which has a very low pH.

Key Study/Critical Effect for Screening Criteria

The Australian drinking water guideline value for pH may apply to sodium hydroxide.

Reference

OECD (2002). IUCLID Data Set for Sodium hydroxide (CAS No. 1310-73-2), UNEP Publications.

OECD (2002). Screening Information Dataset (SIDS) Initial Assessment Report for Sodium hydroxide (CAS No. 1310-73-2), UNEP Publications.

Toxicity Profile

Sodium sulfate
(CAS No. 7757-82-6)

Sodium sulfate has been reviewed in the OECD-SIDS program (OECD, 2005a,b).

Acute Toxicity

The acute toxicity (LD_{50}) of sodium sulfate has not been reliably established. Human data indicate a very low acute toxicity of sodium sulfate. High oral doses of sodium sulfate, from 300 mg/kg up to 20 grams for an adult, are well tolerated, except from (intentionally) causing severe diarrhea. There are no data on acute dermal toxicity.

Irritation

Sodium sulfate is not irritating to the skin and slightly irritating to the eyes. Respiratory irritation has never been reported.

Sensitization

Sodium sulfate is unlikely to be a skin or respiratory sensitizer based on wide practical experience with sodium sulfate, in combination with the natural occurrence of sulfate in the body.

Repeated Dose Toxicity

Valid oral repeated dose toxicity studies with 21, 28 and 35 day studies in hens and pigs are available. Toxicity was confined to changes in bodyweight, water and feed intake and diarrhea These changes occurred only at very high doses of sodium sulfate. The available data do not allow for the derivation of a NOAEL. Based on available consumer data, a daily dose of around 25 mg/kg/day is well tolerated by humans.

Genotoxicity

Sodium sulfate was not mutagenic in an Ames test.

Carcinogenicity

There is no valid oral carcinogenicity study. Limited data from experimental studies

support the notion that a substance that is abundantly present in and essential to the body is unlikely to be carcinogenic.

Reproductive/Developmental Toxicity

Limited data of poor validity did not provide an indication of toxicity to reproduction.

Key Study/Critical Effect for Screening Criteria

Exposure to sodium sulfate occurs via drinking water and through naturally occurring amounts in foodstuffs. In drinking water (wells) concentrations up to 2 g/L were measured in the U.S. The taste threshold for sodium sulfate is 250 – 900 mg/L. The maximum acceptable concentration for drinking water is 200 – 500 mg/L sulfate and is based on taste.

No data on the sulfate content of foodstuffs were found; however, according to WHO, sulfates are used as additives in the food industry and the estimated average daily intake of sulfate in food in the U.S. is 453 mg/person, based on data on food consumption and reported usage of sulfates as additives. An Acceptable Daily Intake for sodium sulfate has not been established.

The Australian drinking water guideline values for sodium and sulfate may apply to sodium sulfate.

References

OECD (2005). IUCLID Data Set for Sodium sulfate (CAS No. 7757-82-6), UNEP Publications.

OECD (2005). Screening Information Dataset (SIDS) Initial Assessment Report for Sodium sulfate (CAS No. 7757-82-6), UNEP Publications.

Toxicity Profile

Sodium sulfite
CAS No. 7757-83-7)

Sodium sulfite has been reviewed in the OECD-SIDS program (OECD, 2008a,b).

Sodium sulfite is completely dissociated in aqueous media into 2 Na^+ and sulfite anion (SO_3^{2-}). Sodium sulfite is a salt of sulfurous acid (H_2SO_3). In aqueous solutions, sulfurous acid dissociates, the dissociation constants are pK_{a1} of 1.8 and pK_{a2} of 7.0 at 25°C. At neutral pH, a mixture of 50% sulfite (SO_3^{2-}) and 50% bisulfite (HSO_3^{2-}) is present. At concentrations above 1M, bisulfite anions will dimerize with the elimination of water to form metabisulfite ($S_2O_5^{2-}$). At low concentrations, metabisulfite will hydrolyze to form bisulfite.

In surface waters, sulfite is oxidized to sulfate either catalytically by air oxygen or by microbial action. The presence of cations like iron, copper or manganese in the environment accelerates the oxidation rate significantly.

Sodium sulfite is rapidly absorbed from the gastro-intestinal tract. Sulfate is the main metabolite formed by the action of sulfite oxidase in many tissues. Tissue accumulation of sulfite-derived S is highest in stomach, skin and hair, intestine and kidney. Excretion is rapid, mainly in the urine.

Acute Toxicity

The oral LD_{50} values are $\geq$ 3,560 mg/kg in rats and 820 – 920 mg/kg in mice. No dermal LD_{50} values or acute LC_{50} values are available.

Irritation

Sodium sulfite was not irritating to the skin or eyes of rabbits.

Sensitization

No dermal sensitization studies in animals are available. In humans, some cases of sensitization from topical contact with sodium sulfite have been described. Only 1.4% of a population of 1762 eczema patients showed a positive reaction to sodium sulfite in patch tests.

Repeated Dose Toxicity

In a 90-day feeding study, a NOAEL for male rats of 2% in diet corresponding to 1,670 mg/kg/day was found. The LOAEL was 4% in diet based on decreased body weight gain and increased relative weights of testis and brain. In female rats, the highest tested dose of 4% in diet was the NOAEL corresponding to 3,070 mg/kg/day.

A two-year rat feeding of sodium metabisulfite ($Na_2S_2O_5$). The NOAEL was 0.5%, which is equivalent to a dose of 144 mg/kg/day calculated as sodium sulfite. The LOAEL for local effects (forestomach and glandular stomach hyperplasia or inflammation) corresponded to 1.0% in diet, which is equivalent to 300 mg/kg/day calculated as sodium sulfite. The NOAEL for systemic effects corresponded to the highest dose of 2% in diet (equivalent to 625 mg/kg/day calculated as sodium sulfite).

Genotoxicity

Sodium sulfite is not genotoxic based on the available studies that have been conducted *in vitro* and *in vivo*.

In vitro, sodium sulfite gave no indication of mutagenic or clastogenic activity up to cytotoxic concentrations both in the absence and presence of metabolic activation systems when tested in Ames tests/*Salmonella typhimurium* reversion assays, in gene mutation tests with *Saccharomyces cerevisiae* and in mammalian V79 cells (without metabolic activation), in a DNA damage and repair assay with *Escherichia coli*, as well as in a chromosomal aberration test with CHL cells (without metabolic activation).

There are no *in vivo* tests with application of pure sodium sulfite. Several genotoxicity studies *in vivo* with sulfites other than sodium sulfite were negative. The negative findings in whole animals are regarded as consistent with the high reactivity of sulfite e.g. with proteins and its rapid inactivation in mammals due to metabolism. However, in contrast to the consistent negative findings in earlier studies, recent investigations of a single working group demonstrated dose-dependent increases of micronuclei in bone marrow and DNA damage in tissues of mice after intraperitoneal injection of a mixture of sodium sulfite and sodium bisulfite. No parallel investigations were performed with the pure compounds as controls.

Carcinogenicity

There are no carcinogenicity studies available with administration of sodium sulfite.

Male and female Wistar rats exposed to sodium metabisulfite ($Na_2S_2O_5$) given in the diet with 0.125, 0.25, 0.5, 1.0 and 2.0% and supplemented with thiamine due to its breakdown by sulfite in the diet) for 104 weeks. The number of lymphoreticular pulmonary tumors in males decreased with increasing levels of sulfite. The incidence of thyroid and

pituitary tumors in control males was exceptionally low, whereas those noted in the various test groups represented numbers normally found in the strain of Wistar rats used. All other neoplasms occurred in a sporadic manner with no apparent relationship between number, location or type of tumors and the treatment.

Male and female mice were given 0, 1 or 2% potassium metabisulfite in drinking water for 104 weeks. There was no increased incidence of tumors in the treated mice compared to controls.

Reproductive Toxicity

There are no reproductive toxicity studies with sodium sulfite investigating effects on male or female fertility.

In a three-generation study with sodium metabisulfite (Na2S2, there was no suggestive evidence of reproductive toxicity or impairment of fertility in rats that received up to 2% in the diet. No effects on gonads were seen histologically. This NOAEL for reproductive toxicity would be equivalent to a dose of 625 mg/kg bw/day calculated as sodium sulfite, which is higher than the NOAEL for chronic toxicity of 0.5% in the diet (based on local irritation of the stomach), being equivalent to a dose of 144 mg/kg bw/day calculated as sodium sulfite.

In a long-term (see repeat dose toxicity section for results) and three-generation study, rats were treated with 0, 0.125, 0.25, 0.5, 1.0 and 2.0% of sodium metabisulfite (corresponding to 0, 32, 70, 144, 300 and 625 mg/kg/day as Na_2SO_3 equivalents) in a supplemented diet with thiamine, since sulfites are known to break down thiamine in the diet. F_0- and F_1-generation were exposed for 104 weeks, and the F_2-generation for 30 weeks. The F_0-generation was mated at week 21 of treatment. Half of the animals were mated again at week 34. Animals from the first litter were selected at weaning to become the F_{1a}-generation being mated at weeks 12 and 30 to produce F_{2a}- and F_{2b}-generations. Animals from the F_{2a} litters were mated to produce the F_{3a}- and F_{3b}-generations by pairing on weeks 14 and 22.

Body weight was not reduced in any treatment group in the F_0-generation. There was a marginal reduction in body weight in both sexes of the 2% group in the F_1- and F_2-generations. Results in successive generations showed no substantial treatment-related effects in terms of fertility, the number of animals/litter or the birth weight or mortality of the young. During lactation the body weight of the young in the 2% group was generally lower than the controls and the lower-dosed groups. This reduced body weight was probably not a true substance-related effect because it was transient and could be due to a higher initial body weight in the control groups. A reduction in the number of F_{2a}-generation offspring (F_{3a} pups) was observed in the 0.5, 1.0 and 2.0% dose groups, but it was not dose-dependent and did not occur in the F_{2b}-generation offspring (F_{3b} pups).

No pronounced effects were observed on reproductive performance in any generation and no effects on gonads were seen histologically. The NOAEL for reproduction toxicity was

the highest dose of 2% in the diet (625 mg/kg/day calculated as sodium sulfite). The NOAEL for chronic toxicity of the F_0-generation corresponding to 0.5% in the diet (144 mg/kg/day calculated as sodium sulfite). The LOAEL for local effects (irritation of the stomach) corresponded to 1.0% in diet (300 mg/kg/day calculated as sodium sulfite). The NOAEL for systemic effects corresponded to the highest dose of 2% (625 mg/kg/day calculated as sodium sulfite).

Developmental Toxicity

Pregnant female Wistar rats were given in their diet 0, 0.32, 0.63, 1.25, 2.5 or 5% sodium sulfite heptahydrate (ca. 0, 150, 300, 550, 1,050 or 1,650 mg/kg as sodium sulfite) on gestational days 8-20. Satellite groups of 4 rats received 0, 0.32 or 5% in the diet on the same days and were allowed to deliver and rear their litters to weaning. In dams, statistically significant decreased food consumption was seen at 150, 300 or 1650 mg sodium sulfite/kg and body weight gains were also significantly decreased at 1,650 mg/kg during the exposure period. In fetuses of all dosed animals, there was a decrease in fetal body weights without clear dose-response relationship. In the satellite groups there was no evidence of toxicity or growth retardation in dams or offspring during a 21-day lactation period. The observed fetal growth retardation was without clear dose-response relationship and there were also no adverse findings concerning this endpoint in the satellite groups allowed to deliver and rear their litters to weaning. Therefore, the relevance of this isolated effect is questionable and is not considered as adverse finding. There was no indication for teratogenic effects at all tested doses. The NOAEL for maternal toxicity is 1,050 mg/kg/day and the NOAEL for developmental effects is 1,650 mg/kg/day.

Key Study/Critical Effect for Screening Criteria

The Australian drinking water guideline values for sodium and sulfate may apply to sodium sulfate.

Reference

OECD (2008). IUCLID Data Set for Sodium sulfite (CAS No. 7757-83-7).

OECD (2008). Screening Information Dataset (SIDS) Initial Assessment Report for Sodium sulfite (CAS No. 7757-83-7).

Toxicity Profile

Sodium thiosulfate (CASRN 7772-98-7)

Thiosulfate is a metastable, moderately reducing oxyanion of sulfur. Chemical reactions (redox reactions) of thiosulfate generate chemical species of sulfur that differ in their oxidation state. The thiosulfate anion ($S_2O_3^{2-}$) is only stable in neutral or alkaline media. It is unstable in acid media. In aqueous media, thiosulfate irreversibly disproportionates to sulfide and sulfate. The chemistry of sulfur in soils (and in water) is complex because of its many oxidation states. The terminal, thermodynamically-favored reaction product of thiosulfate is sulfate, except in highly reduced soils.

Acute Toxicity

The acute oral LD_{50} of an aqueous solution of calcium thiosulfate is >2,000 mg/kg in female rats. For ammonium thiosulfate, the acute oral rat LD_{50} is 4,054 mg/kg in males, 3,500 mg/kg, and 3,824 mg/kg in combined sexes. The acute oral LD_{50} of potassium thiosulfate solution was estimated to be >5,000 mg/kg (for pure test item > 2,500 mg/kg) in the rat.

Irritation

No data were located.

Sensitization

Ammonium thiosulfate at concentrations of 10%, 25% and 50% (w/w) in aqua ad iniectabilia did not reveal any sensitising properties in the local lymph node assay.

Repeated Dose Toxicity

No data on sodium thiosulfate were located.

Genotoxicity

Ammonium thiosulfate was not mutagenic in the bacterial reverse mutation assay using *S. typhimurium* tester strains TA 98, TA 100, TA 1535 and TA 1537 and *Escherichia coli* strain WP2 *uvr*A in the presence and absence of metabolic activation system. Ammonium thiosulfate was negative in an *in vitro* chromosomal aberration assay using CHO cells. Ammonium thiosulfate was also negative in a mouse lymphoma cells.

Carcinogenicity

No data on sodium thiosulfate were located.

Reproductive Toxicity

No data on sodium thiosulfate were located.

Developmental Toxicity

The administration of up to 550 mg/kg sodium thiosulfate to pregnant mice for 10 consecutive days had no clearly discernible effect on nidation or on maternal or fetal survival. The number of abnormalities seen in either soft or skeletal tissues of the test groups did not differ from the number occurring spontaneously in the sham-treated controls. Thus, the NOAEL for maternal and developmental toxicity can be expected above the highest dose of 550 mg/kg.

Key Study/Critical Effect for Screening Criteria

The Australian drinking water guideline values for sodium and sulfate may apply to sodium thiosulfate.

References

ECHA REACH database: http://apps.echa.europa.eu/registered/registered-sub.aspx

U.S. EPA (2007). Reregistration Elibility Decision (RED) for Ammonium Thiosulfate, Office of Prevention, Pesticides an Toxic Substances, EPA 738-R-07-001, December 20, 2007.

Toxicity Profile

Sorbitan Monooelate
(CAS No. 1338-43-8)

Sorbitan fatty acid esters are non-ionic surfactant-active agents that typically find use as emulsifiers, stabilizers and thickeners in foods, cosmetics, medical products, lubricants and other applications (Andersen, 2002; Eisenhard, 1999). Sorbitan monooleate is approved by FDA as an indirect food additive.

The information in this toxicity profile was obtained from the U.S. EPA HPV Test Plan for Sorbitan Esters Category of the Aliphatic Esters Chemicals, November 26, 2003.

Metabolism

Metabolism of the sorbitan esters in animals has been reported to occur initially via enzymatic hydrolysis, leading to sorbitan and the corresponding natural fatty acids. Oral gavage studies in rats with radiolabelled sorbitan monostearate, which is structurally similar to sorbitan monooleate, have demonstrated that about 90% of the sorbitan monostearate dose was absorbed and hydrolyzed to stearic acid and sorbitan (Elder, 1985; Wick, 1953). The resulting sorbitan and fatty acid metabolites, in turn would be expected to be metabolized further (via fatty acid beta-oxidation or carbohydrate metabolic pathways) to either smaller and more polar water-soluble metabolites, which can be excreted in the urine or as carbon dioxide exhaled in the lungs.

Acute Toxicity

The acute oral LD_{50} for sorbitan monooleate in rats was reported to be > 39,800 mg/kg (Elder, 1985).

Irritation

No data were located.

Sensitization

No data were located.

Repeated Dose Toxicity/Carcinogenicity

Oral feeding toxicity studies have been carried out in rats for 16 weeks with sorbitan

monooleate at dietary concentrations of 0, 2.5, 5 and 10% (Ingram *et al.*, 1978). The LOAEL was 2.5% dietary concentration (~1800 mg/kg/day) based on increased kidney weight findings that were considered significant in both male and female rats.

Sorbitan monooleate fed to rats at 5% concentrations in the diet for 2 years showed no adverse effects on growth, hematology, clinical chemistry, survival, organ size or histopathology (ACI, 1970). The NOAEL was reported to be 5% in the diet for sorbitan monooleate in this study.

Genotoxicity

No genotoxicity studies could be located for sorbitan monooleate; however, there are two studies conducted on the structurally similar substance sorbitan monostearate.

Sorbitan monostearate was not mutagenic to *Salmonella typhimurium* TA98 and TA100 in a Ames mutation assay in the presence or absence of metabolic activation (Inoue *et al.*, 1980). Sorbitan monostearate did not cause any chromosomal aberrations in the Syrian golden hamster embryo cell assay and did not show clastogenic activity Inoue *et al.*, 1980).

Reproductive/Developmental Toxicity

No studies could be located for sorbitan monooleate; however, there is one study conducted in the structurally similar substance sorbitan monostearate.

Sorbitan monostearate was administered in the diet at dose levels of 0, 5, 10, and 20% over a period of two years and over four generations of rats (Oser *et al.*, 1956a,b; Oser et al., 1957a,b). No effects were observed on growth, food efficiency, reproduction, lactation, metabolism, behavior, mortality, or in the gross and histopathological examination. At the 20% dose level in the diet, newborn mortality was not increased but there were slight effects on growth and impairment of lactation.

Key Study/Critical Effect for Screening Criteria

No treatment-related effects were noted in a two-year carcinogenicity study in which rat were fed sorbitan monooleate in the diet at concentrations up to 5% (50,000 ppm).

NOAEL (mg/kg/day) = 50,000 ppm * 0.05 = 2,500 mg/kg/day

Where 0.05 is the fraction of body weight that is consumed per day as food for the rat (U.S. EPA).

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD = 2,500/100 = 25 mg/kg/day

Drinking water guidance value = 87.5 ppm

References

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Toxicity Profile

Terpenes and Terpenoids
Terpenes and Terpenoids, Sweet Orange Oil
(CAS No. 68647-72-3)

The chemical category designated terpenes and terpenoids are hydrocarbons that can include C_{10} isomeric monocyclic terpene hydrocarbons (*d*-limonene, *dl*-limonene, and terpinolene) and two C_{10} acyclic terpene hydrocarbons (*beta*-myrcene and dihydromyrcene).

Terpenes and terpenoids, sweet orange oil (CAS 68647-72-3) is composed of 91-95% d-limonene, 1-3% beta-myrcene, and 1-2% alpha-pinene.

Acute Toxicity

The oral and dermal LD_{50} values for limonene, myrcene, terpinolene, dihydromyrcene and sweet orange peel oil indicate a low order of both oral and dermal toxicity. All rabbit and rat dermal, and mouse and rat oral LD_{50} values are >4,000 mg/kg with the majority of values being >5,000 mg/kg.

Irritation

No data were located.

Sensitization

No data were located.

Repeated Dose Toxicity/Carcinogenicity

Selected repeat dose toxicity studies were included in this toxicity profile. For summaries on all conducted studies, see the U.S. HPVIS.

Groups of ten Sprague Dawley rats of each sex were administered 0, 240, 600 or 1,500 mg/kg sweet orange oil in 1% methyl cellulose by gavage daily for 30 days. Observations included survival, clinical observations, body weights, food consumption, clinical pathology, gross pathology, organ weights and histopathology. No treatment related effects were reported for survival, clinical observations, body weights or food consumption. Decreases in glucose levels related to treatment were reported in the mid-dose females and high-dose males and females. Increases in serum albumin and total

serum protein were observed in all treated females and the high-dose males. Histopathology revealed treatment related lesions in the nonglandular stomach of the high-dose males and females and in the kidney of all treated male groups. Kidney weights were also increased in all of the treated male groups and in the high-dose female group. Liver weight increases related to treatment were reported for the high-dose females and all treated male groups. The authors concluded that the no-observed-effect-level (NOEL) under conditions of this study was less than 240 mg/kg/day for both male and female rats. The authors noted that the kidney changes observed in the male rat at all dose levels were expected given the known interaction between limonene and *alpha*-2-microglobulin. Limonene is the principal constituent of orange oil.

In a NTP 13-week study, male and female F344/N rats were dosed by oral gavage 0, 150, 300, 600, 1,200 or 2,400 mg/kg *d*-limonene in corn oil for 5 days/week. At 2,400 mg/kg, 9/10 female rats and 5/10 male rats (5/10) died within the first week of the study. The final mean body weights of male rats receiving the three highest doses (600, 1,200 or 2,400 mg/kg) were reported to be 6%, 12%, or 23% lower than that of the controls, respectively. Rough hair coats, lethargy, and excessive lacrimation were observed for all animals in the 1,200 and 2,400 mg/kg dose groups. Kidney effects were seen in all treated male rats, with a dose-related increase in severity. The kidney effects were characterized by degeneration of epithelium in the convoluted tubules, granular casts with tubular lumens, primarily in the outer stripe of the outer medulla, and regeneration of the tubular epithelium. Hyaline droplets were observed in the epithelium of the proximal convoluted tubules in all groups of male rats including vehicle controls.

In a NTP 13-week study, male and female B6C3F_1 mice were dosed by oral gavage with 0, 125, 250, 500, 1,000 or 2,000 mg/kg *d*-limonene for five days/week. At 2,000 mg/kg, 1/10 males and 2/10 females died before the end of the study; 1/10 females in the 500 mg/kg group also died before study termination. Several other animals also died as a result of gavage error. Mean body weights were 10% lower than control for male mice and 2% lower than control for female mice for the 1,000 and 2,000 mg/kg groups. Clinical signs of rough hair coats and decreased activity were reported for the two highest dose levels.

Male rats were dosed by oral gavage with 0, 2, 5, 10, 30 or 75 mg/kg *d*-limonene 5 days/week for 13 weeks. Linear regression analyses indicated increased relative kidney and liver weights at 30 and 75 mg/kg. Histological examination showed changes in the kidney characterized by hyaline droplet formation, granular casts and multiple cortical changes. Exacerbation of hyaline droplet formation was reported at the earliest necropsy eight days after administration at the 10 mg/kg dose level.

In a two-year NTP bioassay, male and female F344/N rats were dosed with 0, 75 or 150 mg/kg or 0, 300 or 600 mg/kg *d*-limonene for five days/week. Mean body weights for the 150 mg/kg male rats were generally 4-7% lower than vehicle controls from week 2 to study termination. Mean body weights of the 600 mg/kg females were generally 4-7% lower than vehicle controls from week 28 to study termination. No treatment-related clinical signs were reported for the duration of the study. Survival of the 150 mg/kg male

group was significantly greater than that of the vehicle alone after week 81. Survival of the 600 mg/kg female group was significantly lower than that of the vehicle controls after week 39. In the male rat kidneys, a dose-related increase was observed in the incidence of mineralization and epithelial hyperplasia. A dose-related increase in the severity of spontaneous nephropathy was reported in the treated male rats. Increased incidences in tubular cell hyperplasia and neoplasia were also reported in dosed male rats. Tubular cell adenoma incidence in 150 mg/kg male rats and tubular cell adenoma or tubular cell carcinomas (combined) in dosed male rats were significantly greater than vehicle controls. There was no evidence of carcinogenic activity of *d*-limonene for female rats receiving 300 or 600 mg/kg. The NOAEL for male rats (excluding the kidney effects) is 150 mg/kg/day (see below on the relevance of the male rat kidney effects for human risk assessment). The NOAEL for female rats is 300 mg/kg/day based on low survival in the 600 mg/kg dose group.

In a NTP two-year bioassay, male and female B6C3F_1 mice were dosed by oral gavage with 0, 250, or 500 mg/kg or 0, 500 or 1,000 mg/kg *d*-limonene, respectively, five days a week. Mean body weights for the 1,000 mg/kg female mice administered 1,000 mg/kg were generally 5-15% lower than vehicle controls from week 28 to study termination. No treatment related clinical signs were reported for the duration of the study. Survival of the 250 mg/kg male group was significantly lower than that of the vehicle controls by study termination. In the 500 mg/kg males, livers exhibited presence of cells with abnormal numbers of nuclei and cytomegaly. There was no evidence of carcinogenic activity of *d*-limonene for male or female B6C3F_1 mice at the dose levels tested. The NOAEL for male mice is 250 mg/kg/day based on liver effects at 500 mg/kg/day. Although there was reduced survival in the 250 mg/kg male mice, NTP did not considered this to be dose-related. The NOAEL for female mice is considered to be 500 mg/kg/day based on decreased survival and lower body weights (5 - 15%) in the 1,000 mg/kg dose group.

The kidney changes seen in male rats administered limonene have been well characterized, and are known to be specific to the male rat and of no significance in human risk assessment.

Genotoxicity

Given the structural similarity between the members of this chemical category, the substances in this category exhibit low genotoxic potential *in vitro.*

Mutagenicity/genotoxicity testing has been performed on three members of this chemical category, including a complete battery of *in vitro* genotoxicity tests using limonene. No evidence of mutagenicity was observed when limonene was incubated with *Salmonella typhimurium* strains TA98, TA100, TA102, TA1535, TA1537, and TA1538 with and without S-9 metabolic activation at concentrations up to and including 150,000 µg/plate. Limonene did not induce chromosomal aberrations when incubated with Chinese hamster ovary cells at a concentration of 50-500 µg/ml, nor did it induce sister chromatid

exchanges in Chinese hamster ovary cells at concentrations of 16.2-162 μg/ml. In a mouse lymphoma forward mutation assay, limonene was negative in L5178Y cells with and without S-9 metabolic activation up to a maximum concentration of 100 μg/ml. When incubated with Syrian hamster embryo cells up to 100 μg/ml or 3 mM, limonene did not induce statistically significant cell transformation. The effects of limonene on gap junction intercellular communications were also tested at concentrations up to 1 mM in Syrian hamster embryo cells, and showed no effects.

In an *in vitro* chromosome aberration test with human lymphocytes, myrcene did not induce chromosomal aberrations at concentrations up to 1,000 μg/ml with and without metabolic activation. When incubated with Chinese hamster ovary cells in a V79- HPRT Gene Mutation Assay, myrcene was not mutagenic with or without metabolic activation. In sister chromatid exchange (SCE) tests with human lymphocytes, myrcene did not induce sister chromatid exchanges at concentrations up to 1,000 μg/ml with or without metabolic activation. Additionally, there was no evidence of genotoxicity when myrcene was incubated with V79 and hepatic tumor (HPT) Chinese hamster cells at concentrations up to 500 μg/ml in SCE assays. In fact, myrcene reduced the SCE inducing effect of S-9 mix activated cyclophosphamide in human lymphocytes and Chinese hamster ovary (CHO) cells, and aflatoxin B1 in V79 and HTC Chinese hamster cells in a dose dependent manner.

No evidence of mutagenicity was observed when sweet orange peel oil was incubated with *Salmonella typhimurium* strains TA98, TA100, TA1535, TA1537, and TA1538 with and without S-9 metabolic activation at concentrations up to 5000 μg/plate. In a mouse lymphoma forward mutation assay, sweet orange peel oil was positive in L5178Y cells with and without S-9 metabolic activation up to a maximum concentration of 75 μg/ml but only at highly toxic concentrations. The authors noted that that positive results in this assay may be associated with changes in physiologic culture conditions (pH and osmolality). Negative results were obtained with sweet orange peel oil in the Rec DNA repair assay using *Bacillus subtilis* strains H17 and M45.

In eighteen separate *in vitro* tests on the mutagenicity and genotoxicity of limonene, myrcene, and sweet orange peel oil; the majority was negative, with the exception of the mouse lymphoma assay using sweet orange peel oil. This result is questionable given the culture conditions present and the negative results of the mouse lymphoma assay using limonene since limonene is the majority (greater than 90%) constituent of sweet orange peel oil.

Two *in vivo* genotoxicity assays are available for two substances in this chemical category. In an *in vivo* mammalian spot test, no evidence of mutagenicity was reported when mouse embryos were treated *in utero* with 215 mg/kg/day limonene on days 10 -11 of gestation.

In an *in vivo* cytogenetic bone marrow assay, *beta*-myrcene (100, 500 or 1,000 mg/kg) was orally administered *via* gavage to up to male and female Wistar rats. A dose- related increase in the mitotic index in bone marrow cells was reported for rats administered the

test substance. The authors commented that this might be an interaction between *beta*-myrcene, which is known to induce CYP-450 enzymes, and colchicine, which arrests cell division at metaphase. *beta*-Myrcene may have increased the bioavailability of colchicine leading to the increase in mitotic index observed in the experiment. No significant increases in chromosomal aberrations were reported in the treated animals at either 24 or 48 hours. The authors concluded that given the results, *beta*-myrcene was not clastogenic to the rat when orally administered at dose levels up to 1,000 mg/kg. Based on the results of this *in vivo* genotoxicity assay and the numerous *in vitro* genotoxicity assays, it is unlikely that any of these materials would exhibit a significant genotoxic potential *in vivo*.

Reproductive Toxicity

Selected repeat dose toxicity studies were included in this toxicity profile. For summaries on all conducted studies, see the U.S. HPVIS.

beta-Myrcene was administered *via* gavage to female Wistar rats at dose levels of 250, 500, 1,000 and 1,500 mg/kg of *beta*-myrcene from the 15th day of gestation until weaning of the offspring which was day 21 postnatal. Fertility was impaired in female offspring exposed to 1,000 or 1,500 mg/kg *beta*-myrcene.

In a one-generation reproductive toxicity study, male and female Wistar rats were dosed by oral gavage with 0, 100, 300 or 500 mg/kg *beta*-myrcene. The exposure period was 91 days prior to and during the mating period for the males and 21 days prior to and during the mating period for females, pregnancy, and lactation until 21 days post parturition. Neither deaths nor signs of toxicity were reported in male rats at any dose level. No statistically significant differences in body weight gain were reported between control and test animals. A slight increase in liver and kidney weights was reported for treated male (highest dose only) and female rats. No morphological alterations of the liver or testis tissue were revealed upon microscopic examination. No effects were reported on the number of spermatids in the testis or on the number of spermatozoa in the cauda epididymis. No adverse effects on body weight gain and no other signs of toxicity were observed in treated female rats during the pre-mating or mating periods. No treatment related effects were reported on fertility as measured by the mating index and pregnancy index upon comparison to controls. At the highest dose level, a slight increase in the resorption rate and a parallel decrease in the ratio of live fetuses per implantation site were reported. Increases in the occurrence of fetal skeleton abnormalities between control and treated groups were reported at the 500 mg/kg level. No adverse effects were reported on duration of pregnancy, labor, pup mortality, and maternal or offspring weight changes. Slight delays in incisor eruption (300 mg/kg) and eye opening (100, 300 mg/kg) were reported but were not dose-related. The authors attributed the increase in skeletal abnormalities at the highest dose level tested to known strain-specific anomalies including increases of dislocated sternums, and lumbar extra ribs. The authors concluded that the NOAEL for toxic effects on fertility and general reproductive performance *via* the oral route was 300 mg /kg for *beta*-myrcene.

Female rats were dosed by oral gavage with 0, 375, 750 or 1,500 mg/kg sweet orange peel for seven days prior to and through cohabitation, gestation, delivery and a four day lactation period. No deaths occurred at any dose level. Statistically significant numbers of rats from all three dose groups experienced excess salvation during the pre-mating and gestation periods, and during the lactation period for high-dose animals. The dosed rats had decreased weight gains compared to the control rats during the seven day premating period. Absolute and relative maternal food consumption was significantly decreased for the 750 and 1,500 mg/kg dose groups during the seven day premating period. No treatment related effect on mating performance or fertility was reported at any dose level. A significant increase in stillbirths and pup deaths was reported for the highest dose group compared to the control group (see next section for developmental effects).

Given the results of three reproductive toxicity assays using sweet orange peel oil predominantly composed of *d*-limonene and *beta*-myrcene, it may be concluded that the substances within this chemical category exhibit low reproductive toxicity potential.

Developmental Toxicity

Pregnant female Wistar rats were dosed by oral gavage with 0, 591 or 2,869 mg/kg *d*-limonene on days 9-15 of gestation. At the highest dose level, increases in maternal mortality and decreases in maternal and fetal body weights were reported. Additionally at the highest dose level, delayed ossification of fetal metacarpal bones and proximal phalanx and decreased weights of the thymus, spleen, and ovaries were reported. The NOAEL for both maternal and offspring toxicity was reported to be 591 mg/kg.

Pregnant Japanese white rabbits were administered 0, 250, 500 or 1,000 mg/kg *d*-limonene on days 6 to 18 of gestation. Increased maternal mortality was reported at the highest dose level. Significant decreases in maternal body weight gain and food consumption were temporarily observed at the 500 and 1,000 mg/kg dose levels. No treatment related effects were reported for the offspring. The NOAEL for maternal toxicity was reported to be 250 mg/kg/day. The NOAEL for offspring toxicity was reported to be greater than 1,000 mg/kg/day.

Pregnant ICR mice were administered 0, 591 or 2,363 mg/kg *d*-limonene on days 7 to 12 of gestation. Significant decreases in body weight gain were reported for pregnant ICR mice administered the highest dose level of *d*-limonene. In the offspring, increased incidence of fused ribs compared to that of the controls, delayed ossification of some bones and decreased body weight gain were reported at the highest dose level tested. The NOAEL for both maternal and offspring toxicity was reported to be 591 mg/kg/day.

Pregnant Wistar rats were administered 0, 250, 500 or 1,200 mg/kg *beta*-myrcene on gestational days 6-15. The vehicle was corn oil. Decreased maternal weight gain was reported at the 1,200 mg/kg dose. Increased fetal skeletal malformations were reported at the 1,200 mg/kg dose level. The NOAEL for both maternal and offspring toxicity was

reported to be 500 mg/kg/day.

beta-Myrcene was administered *via* gavage to female Wistar rats at dose levels of 250, 500, 1,000 or 1,500 mg/kg from pregnancy day 15 until weaning of the offspring, which was day 21 postnatal. Mortality, weight gain and post-natal development were evaluated. Reproductive capacity was assessed in the exposed offspring upon reaching maturity (120 days). No adverse effects were noted in the offspring at the lowest dose level tested. Decreased body weight, increased perinatal mortality, and delayed developmental landmarks were noted at the 500, 1000 and 1500 mg/kg dose levels. Fertility was impaired in female offspring exposed to the two highest doses of *beta*-myrcene. The NOAEL for peri- and post-natal development was set at 250 mg/kg/day.

Female rats were dosed by oral gavage with 0, 375, 750 or 1,500 mg/kg sweet orange peel for seven days prior to and through cohabitation, gestation, delivery and a four day lactation period. No deaths occurred at any dose level. Statistically significant numbers of rats from all three dose groups experienced excess salvation during the premating and gestation periods, and during the lactation period for high-dose animals. The dosed rats had decreased weight gains compared to the control rats during the seven-day premating period. Absolute and relative maternal food consumption was significantly decreased for the 750 and 1500 mg/kg/day dose groups during the seven day premating period. No treatment related effects were reported on maternal body weight, changes in body weight, and absolute and relative feed consumption during the lactation period. No treatment related effect on mating performance or fertility was reported at any dose level. A significant increase in stillbirths and pup deaths was reported for the highest dose group compared to the control group. The treatment with sweet orange oil had no effect on the incidence of malformations or gross lesions in the pups. The NOAEL for this study was reported to be less than 375 mg/kg/day for maternal toxicity and 750 mg/kg/day for offspring development.

Given the results of six developmental toxicity assays using limonene, sweet orange oil and *beta*-myrcene, it may be concluded that the substances within this chemical category exhibit low developmental toxicity potential.

Key Study/Critical Effect for Screening Criteria

The toxicity data on d-limonene will be used as read-across to CAS No. 68647-72-3. The kidney changes seen in male rats administered limonene have been well characterized, and are known to be specific to the male rat and of no significance in human risk assessment. Thus, the male rat kidney effects will not be considered in the determining the critical effect for a drinking water guideline value.

In the NTP two-year rat bioassay, the NOAELs for male and female rats were 150 and 300 mg/kg/day, respectively. In the NTP two-year mouse bioassay, the NOAELs for male and female mice were 250 and 500 mg/kg/day, respectively.

The lowest NOAEL is 150 mg/kg/day for male rats in the NTP 2-year bioassay based on liver effects. Adjusting for 5 days/week to 7 days/week, results in a NOAEL for continuous exposure of 107 mg/kg/day.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD = 107/100 = 1.1 mg/kg/day

Drinking water guidance value = 3.8 ppm

Reference

U.S. EPA HPVIS database: http://www.epa.gov/chemrtk/hpvis/index.html

Toxicity Profile

Tetrakis(hydroxymethyl)phosphonium sulfate
(CAS No. 55566-30-8)

Toxicity information is provided on tetrakis(hydroxymethyl)phosphonium sulfate (THPS) and its structural analog tetrakis(hydroxymethyl)phosphonium chloride (THPC)

Metabolism

A metabolism study on rats has been conducted using ^{14}C-radiolabelled THPS. THPS was not found in rat urine. However, three metabolites were present, identified as trihydroxymethyl phosphine oxide, bishydroxymethylphosphonic acid and possibly a formaldehyde adduct of the trihydroxy compound (IPCS, 2000).

Acute Toxicity

No female mice died when given an oral dose of 200 mg/kg THPS (IPCS, 2000). The oral LD_{50} value of THPC (as a 75% solution) was reported to be 282 mg/kg in male rats; 575 mg/kg in male and female rats combined; 185 mg/kg in male rats; and 161 mg/kg in female rats (IPCS, 2000).

No deaths occurred when rats were treated with THPS at 2,000 mg/kg (IPCS, 2000).

The 4-hour LC_{50} in rats was 5.5 mg/L when exposed nose-only to a respirable aerosol (IPCS, 2000).

Irritation

THPS was not irritating to the skin of rabbits; however, repeated application resulted in severe skin irritation (IPCS, 2000). THPS is a severe eye irritant in rabbits (IPCS, 2000).

Sensitization

THPS is a skin sensitizer to guinea-pigs (IPCS, 2000).

Repeat Dose Toxicity

In a 13-week NTP oral gavage study, male and female F344/N rats were given 0, 5, 10, 20, 40 or 60 mg/kg THPS five days/week. Death occurred in the 60 mg/kg male rats (3/10) prior to the end of the study; all other rats survived to the end of the studies. Final mean body weights were 5%, 15%, and 22% lower than those of the vehicle controls for

males that received 20,40,or 60 mg/kg, and from 7% to 19% lower for all groups of dosed female rats. Diarrhea occurred in all groups of dosed rats during weeks 3 and 4. Vacuolar degeneration of the hepatocytes occurred in all males receiving $\geq$10 mg/kg, in all females receiving 40 or 60 mg/kg, and in 5/10 females receiving 20 mg/kg. The severity of this lesion was greatest in the 60 mg/kg group. In other groups, the severity was generally minimal to mild. Lymphoid depletion in the spleen or thymus was observed in the three males in the 60 mg/kg group which died before the end of the studies. Bone marrow hypoplasia was diagnosed in 3/10 male and 4/10 female rats in the 60 mg/kg groups.

In a 13-week NTP oral gavage study, male and female B6C3F$_1$ mice were given 0, 5, 10, 20, 40 or 60 mg/kg THPS 5 days/week. Females (1/10) that received 60 mg/kg and 2/10 males and 1/10 females that received 40 mg/kg died before the end of the studies. Final mean body weights of mice that received 20, 40, or 60 mg/kg were 4%, 7%, and 11% lower than those of the vehicle controls for males and 3%, *5%*, and 11% lower for females. Periportal vacuolar degeneration occurred in all mice that received 60 mg/kg (minimal to moderate severity), 10/l0 male and 9/10 female mice that received 40 mg/kg, and 8/10 male mice that received 20 mg/kg (minimal to mild severity).

In the 2-yr NTP study, male and female F344/N rats were given by oral gavage 0, 5, or 10 mg/kg THPS, 5 days/week for 103 to 104 weeks. Survival of male rats was reduced for the low dose (after week 102) and the high dose (after week 67) groups given THPS compared with that of the vehicle controls; survival at terminal kill was as follows: vehicle control, 28/50; low dose, 13/50; high dose, 16/50. Mean body weights of rats dosed with THPS were comparable to those of the vehicle controls. There was an increase in the incidence of hepatocellular lesions, primarily cytoplasmic vacuolization, which was dose-related. The incidence of these lesions were: in males, 2/50, 4/50, 9/49, at 0, 5, 10 mg/kg; in females, 1/49, 3/50, 8/49 at 0, 5, and 10 mg/kg. The incidences of mononuclear cell leukemia in 5 mg/kg male rats was somewhat greater than those in the vehicle controls (THPS: 30/50; 36/50; 20/50). This marginal increase in the incidences of hematopoietic system tumors was not considered related to chemical exposure, since they were significant only by the life table tests and were not dose related. The incidence of cystic degeneration of the liver was also increased in male rats (7/50, 15/50, and 14/49 at 0, 5, and 10 mg/kg). The LOAEL for this study is 5 mg/kg with no NOAEL.

In the 2-yr NTP study, male and female B6C3F$_1$ mice were given by oral gavage 0, 5, or 10 mg/kg THPS, 5 days/week for 103 to 104 weeks. There was no difference in survival or mean body weights between the vehicle controls and mice dosed with THPS. There was an increase in the incidence of hepatocellular lesions, primarily cytoplasmic vacuolization in female mice only, but it was not dose-related. The incidences of this lesion were: in males, 0/48, 1/49, 0/50 at 0, 5, and 10 mg/kg; in females, 6/50, 13/50, and 7/49 at 0, 5, and 10 mg/kg. The LOAEL for this study was 5 mg/kg, with no NOAEL.

There was also focal hyperplasia of the adrenal medulla in the 10 mg/kg male mice. The 5 mg/kg male mice had an increased incidence of malignant lymphomas when compared with vehicle controls (2/50; 9/50; 0/50). This marginal increase in the incidences of

hematopoietic system tumors was not considered related to chemical exposure, since they were significant only by the life table tests and were not dose related.

Genotoxicity

Salmonella microsomal assays in the presence or absence of metabolic activation have shown uniformly negative results for THPS (IPCS, 2000). THPS induced forward mutations in mouse lymphoma L5178Y cells without metabolic activation; it was not tested in the presence of S9 (NTP, 1987). Another mouse lymphoma assay showed mutations both in the presence and absence of metabolic activation (IPCS, 2000).

Increased chromosomal aberrations were detected at metaphase in CHO cells treated with THPS in the presence or absence of S9 from liver of Aroclor-treated rats (IPCS, 2000). Anaphase analysis of THPS-treated CHO cells also showed that chromosomal aberrations were produced along with abnormal spindles (IPCS, 2000).

The results of an *in vitro* assay for unscheduled DNA synthesis in a primary culture of rat hepatocytes were negative (IPCS, 2000).

THPS was administered to mice by gavage or dermal application or by mixing treated cloth with the animals' feed. The urine of these dosed mice was analyzed for mutagenicity in the Salmonella microsome assay, and frequencies of micronuclei and chromosomal aberrations were evaluated in bone marrow cells. None of these investigations demonstrated mutagenic activity for THPS (NTP, 1987; IPCS, 2000).

THPS was negative in rats and mice in dominant lethal assays (IPCS, 2000).

Carcinogenicity

Two-year NTP studies have been conducted in F344/N rats and $B6C3F_1$ mice by administering 0, 5, or 10 mg/kg THPS by oral gavage, 5 days per week for 103 or 104 weeks (NTP, 1987). The incidences of mononuclear cell leukemia in the low dose male rats administered THPS was somewhat greater than those in the vehicle controls. Low dose male mice administered THPS had an increased incidence of malignant lymphomas when compared with vehicle controls (2/50; 9/50; 0/50). These marginal increases in the incidences of hematopoietic system tumors were not considered related to chemical exposure, since they were significant only by the life table tests and were not dose-related.

Reproductive/Developmental Toxicity

Pregnant CD rats were given by oral gavage 0, 15, 30 or 60 mg/kg THPS (as a 75% solution) during gestational days 6 to 15. Maternal body weight gain was significantly lower from gestational day 12 until the end of the study in the 60 mg/kg group. There

were minor signs of maternal toxicity in the 30 mg/kg group. The incidence of fetuses showing extra thoraco-lumbar ribs was significantly higher in the 60 mg/kg group compared to controls. The maternal and developmental NOAELs for this study were 30 mg/kg-day (IPCS, 2000).

Pregnant New Zealand rabbits were given by oral gavage 0, 6, 18 or 60 mg/kg THPS (as a 75% solution) during gestational days 7 to 19. Maternal body weight gain was significantly lower in the 60 mg/kg group compared to the controls. There was increased incidence (42/120) of fetuses with eye malformation and some with additional hydrocephaly or limb/phalangeal reduction defects in the 60 mg/kg group. An increased incidence of specific skeleton variation was also observed. No adverse effects were noticed in the 6 or 18 mg/kg groups. The maternal and developmental NOAELs for this study is 18 mg/kg-day (IPCS, 2000).

Key Study/Critical Effect for Screening Criteria

The critical effect for a drinking water guideline value is liver effects in male and female rats and female mice at 5 mg/kg/day in the two-year study. To adjust for continuous exposure, the LOAEL is adjusted by converting 5 days/week to 7 days/week.

$LOAEL_{adjusted}$ = 5 * 5/7 = 3.6 mg/kg/day

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (LOAEL to NOAEL)

Oral RfD = 4/1,000 = 0.004 mg/kg/day

Drinking water guideline: 0.01 ppm

References

IPCS (2000). Flame Retardants: Tris(2-butoxyethyl)phosphate, Tris (2-ethylhexyl) phosphate and tetrakis (hydroxymethyl)phosphonium Salts, Environmental Health Criteria 218, International Programme on Chemical Safety, United Nations Environment Programme, International Labour Organisation, World Health Organization.

NTP (1987) NTP Technical Report on the Toxicology and Carcinogenesis Studies of Tetrakis(hydroxymethyl)phosphonium sulfate (THPS) (CAS No. 55566-30-8) and Tetrakis(hydroxymethyl)phosphonium chloride (THPSC) (CAS No. 124-64-1) in F344/N Rats and B6C3F1 mice (Gavage Studies), NTP TR 296, NIH Publication No. 87-2552, National Toxicology Program, U.S. Department of Health and Human Services, Public Health Service, National Institutes of Health.

COFFEE EXTRACT

This dossier on coffee extract does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of coffee extract in its use in hydraulic fracturing fluids. The information presented in this dossier was obtained from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBSTANCE IDENTIFICATION

Chemical Name: Coffee, bean, roasted, extract

CAS RN: 68916-18-7

Molecular formula: UVCB substance

Molecular weight: UVCB substance

Synonyms: Coffee extract; coffee, bean, roasted, extract

Table 1 shows all of the constituents found in roasted arabica and robusta coffees.

Table 1: Composition of Medium-Roasted Coffee (Clarke, 1987; IARC, 1991)

Components	**Typical average content (dry basis, %)**		**% extractable with water, 100°C[a]**
	Arabica	**Robusta**	
Alkaloids (caffeine)	1.3	2.4	75 - 100
Trigonelline (including roasted by-products)	1.0	0.7	85 - 100
Minerals (as oxide ash)	4.5	4.7	90
Acids			
Residual chlorogenic	2.5	3.8	100
Aquinic	0.8	1.0	100
Aliphatic	1.6	1.6	100
Sugars			
Sucrose	0.0	0.0	-
Reducing	0.3	0.3	100

Polysaccharides (unchanged from green)	33	37	10
Lignin	2.0	2.0	0
Pectins	3.0	3.0	-
Proteinaceous compounds			
Protein	10	10	15 – 20
Free amino acids	0.0	0.0	-
Lipids (coffee oil)	17	11	1
Caramelized or condensation products (*e.g.*, melanoidins) by difference	23	22.5	20-25
Volatile substances other than acids	0.1	0.1	40-80

[a]Maier (1981), for normal household brewing

II. PHYSICO-CHEMICAL PROPERTIES

Table 2: Overview of the Physico-chemical Properties of Coffee Extract

Property	**Value**	**Klimisch score**	**Reference**
Physical state at 20°C and 101.3 kPa	Viscous liquid	2	ECHA
Melting point	ca. -16.82 to -15.95°C	1	ECHA
Boiling point	>102.21°C	1	ECHA
Density	1.234 g/cm^3 @ 20°C	1	ECHA
Vapor pressure	21.8 Pa @ 20°C	1	ECHA
Partition coefficient (log K_{ow})	<0.36 @ 25°C	1	ECHA
Water solubility	2.85 mg/L @ 25°C	1	ECHA
Flash point	No flash to boiling.	1	ECHA
Auto flammability	>600°C	1	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Coffee extract is inherently biodegradable and is expected to have a low potential for bioaccumulation. The potential for adsorption is unknown; however, the low octanol water partition coefficient for coffee extract suggests that it is low. The acute toxicity by the oral and dermal routes is low.

B. Biodegradation

Coffee extract is inherently biodegradable. In an OECD 301D test, degradation was 50.2% after 28 days (ECHA) [Kl. score = 1].

C. Environmental Distribution

Adsorption/desorption

No experimental data are available for coffee extract. Coffee extract is an UVCB substance containing a wide range of different constituents (see Table 1); thus, a K_{oc} value cannot be calculated.

D. Bioaccumulation

No bioconcentration studies have been conducted on coffee extract. Coffee extract is not expected to bioaccumulate based on the experimental log K_{ow} of <0.36 (ECHA).

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

The information on the human health hazard for coffee extract includes primarily data on caffeine, the pharmacologically active constituent of coffee extract, as well as the extract itself. Coffee extract is not irritating to the skin or eyes. Caffeine consumption up to 400 mg caffeine/day in healthy adults is not associated with overt, adverse cardiovascular effects, behavioral effects, reproductive and developmental effects, acute effects, or bone status. Also, consumption up to 300 mg caffeine/day in healthy pregnant women is generally not associated with adverse reproductive and developmental effects.

B. Pharmacokinetics

Caffeine is rapidly and completely adsorbed in humans, with approximately 99% absorbed within 45 minutes of consumption (Carillo and Benitez, 2000). Plasma caffeine levels may be influenced by the diet or route of exposure, but peak plasma levels occur approximately 15 to 120 minutes after consumption (Mandel, 2002; Beach *et al.*, 1984; Bonati *et al.*, 1984; Collomp *et al.*,

1991). Caffeine is water soluble and is rapidly distributed throughout the body, detected in all bodily fluids, including saliva, breast milk, urine and semen (Beach *et al.*, 1984). Caffeine elimination follows first-order kinetics (Newton *et al.*, 1981), with the plasma half-life of caffeine at approximately 3 to 6 hours in healthy adults and does not accumulate in body fat or other tissues (Kaplan *et al.*, 1997; Nawrot *et al.*, 2003). Caffeine is rapidly metabolized and excreted (1-3 mg/kg/minute) in the urine (Kaplan *et al.*, 1997), and varies between species, with a slightly different metabolic route noted in rats (Nawrot *et al.*, 2003).

C. Acute Toxicity

Animal Studies

The oral LD_{50} value of an aqueous extract of roasted and ground beans of *Coffea canephora robusta* containing 7.5% caffeine was between 2,000 and 5,000 mg/kg (ECHA) [Kl. score = 1].

No acute inhalation studies are available on coffee extract. The 4-hour LC_{50} value of a caffeine aerosol in rats is 4.94 mg/L (ECHA) [Kl. score = 2].

No acute dermal studies are available on coffee extract. The dermal LD_{50} value of an aqueous solution of caffeine in rats is >2,000 mg/kg (ECHA) [Kl. score = 2].

Human Studies

Studies in human have focused on caffeine, the pharmacologically active component in coffee. The fatal acute oral dose is estimated at 10 and 14 g (approximately 160 to 230 mg/kg for a 60 kg person) (Hodgman, 1998). The serum caffeine concentration is the most reliable indicator of potential caffeine toxicity, with a serum caffeine concentration >100 μg/ml considered lethal in humans (Mrvos *et al.*, 1989). Human caffeine consumption at up to 10 g has caused convulsions and vomiting, with recovery in six hours (Dreisbach, 1974). An acute dose of one gram caffeine can cause adverse effects, progressing from restlessness, nervousness, and irritability to delirium, emesis, neuromuscular tremors and convulsions (IOM, 2004). However, caffeine consumption through the day at up to 900 mg has been reported without adverse effects (Nawrot *et al.*, 2003).

D. Irritation

Coffee silverskin extracts was not considered a skin irritant when tested in an *in vitro* reconstructed human epidermis test (ECHA) [Kl. score = 1].

Coffee, bean, roasted, extract was not considered an eye irritant when tested in a bovine corneal opacity and permeability test (ECHA) [Kl. score = 1].

E. Sensitization

No studies are available.

F. Repeated Dose Toxicity

<u>Oral</u>

Male and female rats were given in their drinking water 0, 25, 50, or 100% with either instant or brewed coffee for 91 days. The average daily intakes of caffeine were 0, 20, 40, or 80 mg/kg-day for the brewed coffee and slightly lower intakes for the instant coffee. At study termination, the kidneys of the 100% male coffee groups had enlarged kidneys based on both absolute and relative weights. In the females, liver and kidneys were enlarged in all rats given brewed coffee, although the relative weights were significantly higher only in the 100% group. In the ≥50% instant coffee groups, both absolute and relative liver and kidney weights were increased, although there was no clear dose-response pattern. Histopathologic examination showed no treatment-related effects. In the absence of corresponding histopathologic changes, the liver and kidney weight changes were considered to be adaptive changes and not adverse. The NOAEL for this study is 100% coffee in drinking water, which corresponds to 80 mg/kg-day (Nolen, 1981; ECHA) [Kl. score = 2].

In an NTP study, male and female F344 rats were dosed by oral gavage with 0, 188, 375, 750, 1,500, or 3,000 ppm caffeine for 90 days. The average daily intakes were: 0, 19.7, 42, 85.4, 151, or 272 mg/kg-day for males; and 0, 23, 51, 104, 174, or 287 mg/kg-day for females). Body weight gain was reduced in all treated groups but was only significant in the 3,000 ppm animals (26% and 20% for males and females, respectively). Water consumption was decreased in the 3,000 ppm animals; it was increased in the 375 and 750 ppm groups. The only treatment-related effects observed was cellular enlargement in the salivary gland, which was dose-dependent. This effect in the salivary gland was considered an adaptive response as a result of the pharmacological effect of caffeine (sympathomimetic) and not an adverse effect. The NOAEL for this study is 1,500 ppm, which corresponds to 151 and 174 mg/kg-day for males and females, respectively (ECHA) [Kl. score = 2].

Inhalation

No studies are available.

Dermal

No studies are available.

G. Genotoxicity

In Vitro Studies

Instant and home brew coffees (caffeinated and decaffeinated) were evaluated for genotoxicity in an in vitro chromosomal aberration test using human lymphocytes with or without metabolic activation (S9 mix). Chromosomal aberrations were increased with all coffee samples with or without S9, although there was less of an increase with S9. Pure caffeine tested with or without S9 at doses equivalent to the levels in the caffeine-containing coffees did not induce a statistically significant increase in chromosomal aberrations (Aeschbacher et al., 1985; ECHA) [Kl. score 2].

Instant and home brew coffees (caffeinated and decaffeinated) were evaluated for mutagenicity in an in vitro bacterial reverse mutation assay with or without metabolic activation (S9 mix). The *S. typhimurium* strains were TA 98, TA 100, TA1535, TA 1537, and TA 1538. A mutagenic response was observed with TA 100 in the absence of S9, but not with S9. None of the other

strains showed a mutagenic response with or without S9 (Aeschbacher and Würzner, 1980; ECHA) [Kl. score = 2].

Five Americano coffees from selected coffee chains were evaluated for mutagenicity in an in vitro bacterial reverse mutation assay with or without metabolic activation (S9 mix). The *S. typhimurium* strains were TA 98, TA 100, and TA 1535. There were no mutagenic responses with or without metabolic activation (Liu et al., 2017; ECHA) [Kl. score = 2].

In Vivo Studies

Male Swiss OF-1 mice were dosed by oral gavage with 0, 500, 1,000, 2,000, or 3,000 mg/kg instant coffee for five consecutive days. There was no treatment-related increase in the frequency of micronuclei in bone marrow cells (Aeschbacher et. al., 1984 ECHA) [Kl. score = 2].

H. Carcinogenicity

No carcinogenicity studies are available.

I. Reproductive/Developmental Toxicity

Animal Studies

A one-generation reproductive toxicity study was conducted in rats. Male and female rats were given in their drinking water 0, 25, 50, or 100% with either instant or brewed coffee. The average daily intakes were 0, 20, 40, or 8 mg/kg-day for the brewed coffee and slightly lower intakes for the instant coffee. Exposure of parental animals were for 91 days and during mating. Exposure continued through the first gestation period and through weaning. Ten days later, the females were mated the second time and were sacrificed on GD 13 or 21. There were no indications of reproductive or developmental toxicity (Nolen, 1981; ECHA) [Kl. score = 2].

Human Studies

Studies in human have focused on caffeine, the pharmacologically active component in coffee. Studies that evaluated the potential teratogenicity of caffeine have been discussed in a review (Christian and Brent, 2001). In animal studies, caffeine administration to pregnant animals has been found to induce teratogenicity and toxic effects on the development of the fetuses only at doses that also caused toxic effects in the dams (Christian and Brent, 2001). Christian and Brent (2001) concluded that studies reporting positive teratogenic effects were administering large doses of caffeine that were far greater than human consumption and were providing the caffeine via gavage, which results in much higher peak serum caffeine levels and therefore overstates toxicity potential. Neither rodents nor humans could attain such peak exposures by consuming solutions of caffeine over several hours, the usual mode of human caffeine consumption.

There have been questions raised on whether high intake of coffee or caffeine may increase the risk of miscarriage. Caffeine crosses the placenta and increases maternal catecholamine levels (Goldstein and Warren, 1962). The American College of Obstetricians and Gynecologists (2010) have concluded the following: “Moderate caffeine consumption (less than 200 mg per day) does not appear to be a major contributing factor in miscarriage or preterm birth. The relationship of

caffeine to growth restriction remains undetermined. A final conclusion cannot be made at this time as to whether there is a correlation between high caffeine intake and miscarriage."

The American College of Obstetricians and Gynecologists (2010) have concluded that moderate caffeine consumption (<200 mg/day) does not appear to be a major contributing factor in miscarriage or preterm birth.

A recent systematic review of the potential adverse effects of caffeine consumptions in humans concluded that consumption up to 400 mg caffeine/day in healthy adults is not associated with reproductive and developmental effects. Also, consumption up to 300 mg caffeine/day in healthy pregnant women is generally not associated with adverse reproductive and developmental effects (Wikoff et al., 2017).

J. Human Studies

Caffeine is a stimulant and has been studied for its physiological and behavioral effects. Caffeine increases heart rate and blood pressure, increases diuresis, increases locomotion and alertness, and decreases sleepiness. Clinical studies indicate that doses <450 mg do not increase the risk or severity of cardiac arrhythmia, while acute doses of 150 mg caffeine may decrease heart rate (James, 1991; Green *et al.*, 1996; Myer, 1998). Studies evaluating effects of caffeine on cardiovascular health or serum cholesterol levels have not provided a consistent adverse effect with caffeine consumption (Nawrot *et al.*, 2003).

Nawrot *et al.* (2003) concluded in their review of the effects of caffeine on human health that "for the healthy adult population, moderate daily caffeine intake at a dose level up to 400 mg/day (equivalent to 6 mg/kg body weight/day in a 65-kg person) is not associated with adverse effects such as general toxicity, cardiovascular effects, effects on bone status and calcium balance (with consumption of adequate calcium), changes in adult behavior, increased incidence of cancer and effects on male fertility." It was indicated that habitual daily use of caffeine at greater than 500-600 mg/day (8.3 - 10 mg/kg) (4-7 cups of coffee or 7-9 cups of tea) could be considered a health risk. For women, caffeine intake greater than 400 mg/day (6.7 mg/kg) "may increase the risk of detrusor instability (unstable bladder) development in women" (Nawrot *et al.*, 2003).

A recent systematic review of the potential adverse effects of caffeine consumptions in humans also concluded that consumption up to 400 mg caffeine/day in healthy adults is not associated with overt, adverse cardiovascular effects, behavioral effects, acute effects or bone status (Wikoff et al., 2017).

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for coffee extract follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

<u>Oral</u>

A 90-day drinking water study on brewed and instant coffee reported no adverse effects up to 80 mg/kg-day (Nolen, 1982). A NTP 90-day oral gavage toxicity study in rats showed no adverse effects up to 174 mg/kg-day (NTP).

In two separate reviews (Nawrot et al., 2003; Wikoff et al., 2017) with the most recent one conducted using a systematic review approach (Wikoff et al., 2003), caffeine consumption in healthy adults up to 400 mg/day is not associated with any adverse health effects. Based on the acceptable daily intake of caffeine in coffee extract, the acceptable daily intake of caffeine of 400 mg/day will be used to derive the oral reference dose and drinking water guidance value for coffee extract.

Oral Reference Dose (oral RfD)

For a 70 kg person, the oral reference dose is 400/70 = 6 mg/kg-day.

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (5.7 x 70 x 0.1)/2 = <u>20 mg/L</u>

B. Cancer

No studies are available. Thus, a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Coffee extract does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Coffee extract has a low acute toxicity concern for aquatic life.

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies conducted on coffee extract.

Table 3: Acute Aquatic Toxicity Studies on Coffee Extract

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Oncorhynchus mykiss	96-hr LL_{50}	>100 WAF	1	ECHA
Daphnia magna	48-hr EL_{50}	>100 WAF	1	ECHA
Pseudokirchneriella subcapitata	72-hr EL_{50}	>100 WAF (growth)	1	ECHA

Chronic Studies

No studies are available.

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for coffee extract follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)L_{50}$ values are available for fish (>100 mg/L WAF), invertebrates (>100 mg/L WAF), and algae (>100 mg/L WAF). On the basis that the data consist of short-term results from three trophic levels, an assessment factor of 100 has been applied to the acute $E(L)L_{50}$ value of 100 mg/L WAF from fish, invertebrates, and algae. The $PNEC_{water}$ is 1 mg/L.

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. The $PNEC_{sed}$ was not calculated using the equilibrium partitioning method because the K_{oc} value cannot be determined.

PNEC soil

There are no toxicity data for terrestrial or soil organisms. The $PNEC_{soil}$ was not calculated using the equilibrium partitioning method because the K_{oc} value cannot be determined.

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008). Coffee extract is not readily biodegradable, but it does appear to be inherently biodegradable; thus, it is not expected to meet the screening criteria for persistence.

Based on a measured log K_{ow} of <0.36, coffee extract does not meet the screening criteria for bioaccumulation.

There are no chronic aquatic toxicity studies on coffee extract. The acute $E(L)L_{50}$ values for coffee extract are >1 mg/L for fish, invertebrates, and algae. Thus, coffee extract does not meet the screening criteria for toxicity.

The overall conclusion is that coffee extract is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Not classified.

B. Labelling

No signal word.

C. Pictogram

None.

X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
In case of contact, immediately flush eyes with plenty of water. If easy to do, remove contact lenses.

Skin Contact
Take off contaminated clothing immediately. Wash thoroughly with soap and water. Get medical attention if irritation develops and persists.

Inhalation
If inhaled, remove from area to fresh air. Get medical attention.

Ingestion
Rinse mouth with water and then drink a glass of water. Get medical attention. Do not induce vomiting. Never give anything by mouth to an unconscious person.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: carbon monoxide, carbon oxides, nitrogen oxides.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Use personal protective clothing.

Environmental Precautions
Do not empty into drains.

Steps to be Taken if Material is Released or Spilled
For small amounts: Pick up with absorbent material. Dispose of contaminated material. For large amounts: pump off product.

D. STORAGE AND HANDLING

General Handling
No special measures necessary provided product is used correctly.

Storage
Keep container tightly closed and dry. Store in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards

Workplace Australia has not established an occupational exposure limit for coffee extract.

Engineering Controls
None

Personal Protection Equipment

Respiratory Protection: Respiratory protection not required.

Hand Protection: Wear chemical resistant protective gloves.

Skin Protection: Body protection must be chosen depending on activity and possible exposure.

Eye protection*:* Wear safety goggles with side shields.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Wearing of closed work clothing is recommended. Ensure that eyewash stations and safety showers are close to the workstation location.

F. TRANSPORT INFORMATION

Coffee extract is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

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Santos

APPENDIX F.3 HALLIBURTON CLEANSTIMAU

Toxicity Profile

Aluminum sulfate
(CAS No. 10043-01-3)

This environmental assessment on aluminum sulfate has been extracted from the 2010 Priority Substances List Assessment Report. Follow-up to the State of the Science Report, 2000 for Aluminum Chloride, Aluminum Nitrate, Aluminum Sulphate, prepared by Environment Canada and Health Canada (Canada, 2010). The report can be downloaded from: http://www.ec.gc.ca/lcpe-cepa/default.asp?lang=En&n=491F0099-1

Aluminum sulfate, also know as alum, has the chemical formula is $Al_2(SO_4)_3$. It is often represented as $Al_2(SO_4)_3 \cdot 14H_2O$. It may be found in different hydrated forms. The commercial product, called cake alum or patent alum, is an octadecahydrate aluminum sulfate, $Al_2(SO_4)_3 \cdot 18H_2O$.

Aluminum sulfate is used primarily as a coagulant and flocculant in water and wastewater treatment.

Toxicokinetics

Even at moderately elevated levels in the environment, exposure of aluminum leads to only small increases of aluminum in human tissues due to its low bioavailability through all routes of exposure.

Acute Toxicity

An oral LD_{50} in mice was reported to be 6,200 mg Al/kg for $Al_2(SO_4)_3$,although it unclear whether the value refers to Al or to the salt (Sorenson *et al.*, 1974). An oral LD_{50} was estimated to be >730 mg Al/kg in rats and mice in a 14-day study of oral and intraperitoneal administration (Llobet *et al.*, 1987).

Genotoxicity

Comprehensive reviews of the genotoxicity data of various aluminum compounds are available (Krewski et al., 2007; ATSDR, 2008). Generally, aluminum compounds have not been mutagenic in a variety of *in vitro* genotoxicity studies.

Aluminum chloride has been shown to induce micronuclei formation and sister chromatid exchange in human blood lymphocytes (Krewski *et al.*, 2007). In a more recent study, aluminum chloride was cytotoxic, reduced the mitotic index and induced DNA damage in a comet assay and a chromosomal aberration assay conducted with cultured human

lymphoctyes (Lima *et al.*, 2007).

In an in vivo rat chromosomal aberration study, male rats dosed with 17 to 171 mg Al/kg in drinking water for 21 days showed increased chromosomal aberrations, characterized mostly by chromatid breaks, with translocations at the higher doses (Roy *et al.*, 1991).

EFSA (2008) has proposed that the genotoxic effects of aluminum occurs by an indirect mechanisms involving cross-linking of DNA with chromosomal proteins, interaction with microtubule assembly and mitotic spindle functioning, induction of oxidative damage, and damage of lysosomal membranes with liberation of DNAase to explain the induction of structural chromosomal aberrations, sister chromatid exchanges, chromosome loss and formation of oxidized bases in experimental systems. It was concluded that these effects occur at relatively high levels of exposure and would not likely be of relevance for humans exposed to aluminum via the diet.

Carcinogenicity

An increase in gross tumors was reported in male rats and female mice in a one-dose study; few study details were reported (Schroeder and Mitchener, 1975a,b; as reported in ATSDR 2008). Two other studies reported no increased incidence of tumors in rats and mice exposed orally to aluminum compounds (Hackenberg, 1972; Oneda *et al.*, 1994).

Subchronic/Chronic Toxicity Studies (Oral Exposure)

Canada (2010) reviewed the results of 49 subchronic and chronic toxicity studies in adult mice, rats, rabbits, monkeys and dogs. Aluminum was administered orally in drinking water, in the diet or by gavage. The aluminum salts include lactate, chloride, sulfate, nitrate, hydroxide, citrate, maltolate, fluoride and KASAL (basic sodium aluminum phosphate).

Many of the subchronic and chronic toxicity studies did not quantify the concentration of aluminum in the base diet. In those studies where the administered dose was substantially less than the possible baseline dose in the diet, the uncertainty associated with the actual combined dose was increased.

Neurobehavioral effects were reported in adult mice and rats following oral exposure for 90 days or more. Decreased spontaneous motor activity was reported, with the lowest LOEL being 1 mg Al/kg-day in male Sprague-Dawley rats who received aluminum maltolate at this dose in drinking water over a period of one year (Huh *et al.*, 2005). In contrast, Domingo *et al.* (1996) and Colomina *et al.* (2002) found no differences in field activity of Sprague-Dawley rats given 100 mg Al/kg-day of aluminum nitrate (with citrate) in drinking water for periods of four to six months. Other studies have reported decreased motor coordination as measured by performance in the rotarod test, decreased grip strength, and effects on temperature sensitivity and negative geotaxis.

Learning and memory deficits (maze performance, passive avoidance tests) have also been reported. The LOEL for these effects was 6 mg Al/kg-day in Long Evans rats exposed for 90 days to aluminum chloride (plus citrate) via gavage, although there was some ambiguity in the reporting of doses in this study (Bilkei-Gorzo, 1993). However, other investigators did not find effects on similar learning or memory tests. For instance, von Linstow Rolloff *et al.* (2002), reported no effects in male Lister hooded rats given 140 mg Al/kg as aluminum sulfate in drinking water.

Histopathological effects reported in rats and mice included increased damaged or abnormal neurons in specific brain regions (*e.g.*, cerebral cortex and hippocampus, neurofibrillary degeneration and vacuolization of nuclei, and vacuolated astrocytes and vacuolization of neuronal cytoplasm. The LOEL in which these effects were observed was <1 mg Al/kg-day in the Varner *et al.* (1998) and Varner *et al.* (1993) studies in which aluminum nitrate and sodium fluoride (to form aluminum fluoride) was administered in drinking water to male Long Evans rats for periods of 45 to 52 weeks. Petterson *et al.* (1990) observed mild to moderate histopathological effects in testes, liver and kidney, including hepatocyte vacuolization, seminiferous tubule germinal epithelial cell degeneration and tubular-glomerular nephritis in beagle dogs receiving a dose of 75 mg Al/kg-day of sodium aluminum phosphate. In this same study, no significant differences between exposure groups and controls were observed at the lower doses of 4 to 27 mg Al/kg-day.

A number of biochemical effects have also been reported in subchronic and chronic studies. The LOEL associated with significant effects on biochemical endpoints was 1 mgAl/kg-day as administered as aluminum maltolate in drinking water for one year (Huh *et al.*, 2005).

Reproductive/Developmental Toxicity

Canada (2010) reviewed the results of 49 studies investigating gestational, lactational and/or post-weaning exposure of rats, mice and guinea pigs to aluminum salts through diet, through drinking water or by gavage. The aluminum salts administered in these studies included chloride, nitrate, sulfate, lactate and hydroxide. In a few studies, citrate or ascorbic acid was added to enhance absorption of aluminum. The lack of information on base diet for some studies is a major source of uncertainty with respect to the potential combined dose, particularly when the administered dose was low in comparison to the possible base diet dose. There is also uncertainty associated with reported LOELs that are of the same magnitude as the reported LD_{50} for the administered salt.

The most commonly observed neurobehavioral effects in the developmental studies were decreased grip strength, reduced temperature sensitivity, reduced or delayed auditory startle responsiveness, and impaired negative geotaxis response. Decreased activity levels, locomotor coordination, as well as impaired righting reflex were also observed, although not consistently. The LOEL for these effects was 100 mg Al/kg-day, observed

in Wistar rats administered aluminum lactate in the maternal diet during gestation (Bernuzzi *et al.*, 1989), as well as in Swiss Webster mice administered aluminum lactate in the maternal diet during gestation, lactation and then in the diet of offspring throughout the lifespan (Golub *et al.*, 2000).

The observations on the effects on learning and memory of developmental exposure to aluminum salts also varied considerably. Improved performance in the maze tasks was observed in some studies, while in others impaired performance or no change was found. Developmental exposure of mice and rats to aluminum salts also produced some evidence of disturbances in brain biochemistry. The LOEL for these biochemical effects was approximately 20 mg Al/kg-day (Kim 2003). Neurodevelopmental histopathological effects have been reported at doses of 85-100 mg Al/kg-day.

In the few reproductive toxicity studies, there was reduced maternal weight gain was reported, but not in others. Some of the studies reported decreased pup body weight, while other studies reported no effects. The LOEL for reproductive parameters, including fetal growth, was 13 mg Al/kg-day (Paternain *et al.*, 1988; Domingo *et al.*, 1987), in which Sprague-Dawley rat dams received this dose via gavage as aluminum nitrate. Other observed reproductive and developmental effects included decreased number of corpora lutea and number of implantation sites as well as skeletal malformations. Colomina *et al.* (2005) reported a delay in sexual maturation in both males and females, although this effect was produced at different dose levels in the two sexes (at 50 mg Al/kg-day in females and at 100 mg Al/kg-day in males). Misawa and Shigeta (1993) observed delayed pinna detachment and eye opening in female pups.

No significant maternal or developmental toxicity, as measured by fetal weight gain, reproductive parameters or fetal malformations, was observed by McCormack *et al.* (1979) at a combined dietary dose of aluminum chloride of 50 mg Al/kg-day, nor by Gomez *et al.* (1990) where 265 mg Al/kg-day of aluminum hydroxide was administered to dams via gavage during gestation.

Human Studies

Neurotoxic effects have been reported in humans from aluminum exposure, as well as bone and blood toxicity, during medical treatment in which the gastrointestinal barrier is bypassed (*e.g.*, aluminum-induced encephalopathy through dialysis treatment in patients with renal failure). Some epidemiological evidence exists for long-term cognitive impairment in pre-term infants receiving aluminum-containing nutritional solution intravenously and also associated with occupational exposures. These exposures are not applicable to the general population, although it does support the identification of neurotoxicity and developmental neurotoxicity as endpoints of concern in the human health risk assessment for aluminum.

With respect to the conditions of exposure in the general population, the most relevant available information is provided by the epidemiological investigations into the

association between exposure to aluminum through drinking water and Alzheimer's disease (AD) and other forms of dementia. The hypothesis of aluminum in drinking water as a risk factor for AD or impaired cognitive function in the elderly is controversial in the scientific community. Recent reviews of the epidemiological literature have reiterated the limitations of the epidemiological data base, in its entirety, in regard to the causality of the occurrence of aluminum in the environment and AD, while also maintaining that the hypothesis cannot be rejected at this time (InVS-Afssa-Afssaps 2003; ATSDR 2008; JECFA 2006; Krewski *et al.*, 2007). As a result of these limitations, JECFA (2006) and ATSDR (2006) chose not to base their regulatory values for aluminum intake on epidemiological studies.

Critical Effect(s)/Basis for Screening Level Criteria

The main focus on aluminum toxicity has been on neurotoxicity and reproductive and developmental toxicity, principally because of the evidence from human case studies and epidemiological studies indicating that these effects may be of concern. Canada (2010) evaluated a total of 138 toxicological studies, published from 1979 to 2007, reporting on neurotoxicity and reproductive/developmental effects of oral aluminum exposure in rodents, monkeys and dogs. No single or limited number of studies provided an adequate basis for characterizing the dose-response relationship. Thus, the entire database was considered in determining the lower range of doses for the adverse effects on the critical endpoints of concern.

Exposure-response analysis

Two subsets of the studies, based primarily on exposure period, were evaluated: (a) neurotoxic effects in adults following subchronic or chronic exposure ($\geq$90 days); and (b) neurodevelopmental and reproductive effects in prenatal/lactation exposure studies. These subsets include studies with highly diverse experimental conditions, notably with respect to the animal species and strain, type of aluminum salt administered, exposure vehicle as well as other aspects of the experimental methodology. There is also variability in the reporting of doses. Some researchers adjust the concentration in drinking water for a constant dose in mg Al/kg bw/d and report this value, while others estimate doses in terms of mg Al/kg bw/d based on measures of animal body weight and food and water intake, but keep the same concentration in the diet throughout the experiment. In other cases, the dose is reported only as a concentration administered via diet, drinking water or gavage, and the intake in mg Al/kg bw/d has been estimated using Health Canada (1994) reference values for animal body weight and intake.

In the case of the developmental studies, the LOELs are reported as the maternal dose at the beginning of gestation. In the studies where the concentration in drinking water or the diet remained constant, this dose would generally be lower than the received dose, due to increased food and water intake during gestation and lactation. For the purpose of human health risk assessment, however, the maternal dose at the beginning of pregnancy was considered, as this provided a common point of comparison between studies.

One condition that was applied to both subsets of studies was that the experimental administered dose constitutes the principal contribution to total aluminum. As previously discussed, the concentration of aluminum in standard laboratory rodent chow may be significant. In the majority of studies, this base diet concentration is not measured. Base diet concentration would considerably impact the exposure-response analysis if: (a) the bioavailability of the aluminum contained in the chow was of a similar magnitude to the bioavailability of the administered aluminum; and (b) the lab chow were to contribute a large percentage of the total aluminum exposure. While it could be hypothesised that the aluminum in the lab chow, associated with ligands in the food matrix, would be less soluble and therefore less bioavailable than added aluminum, no experimental data were identified to assess the relative bioavailabilities of aluminum in lab chow and added aluminum salts. Therefore, with regard to those studies where base diet was not quantified, studies were included in the two subsets only if the administered dose (D_a) likely exceeded the base diet dose (i.e., $D_a > 10$ mg Al/kg-day for rats and $D_a > 30$ mg Al/kg-day for mice). This approach limits the influence of the unknown base diet aluminum concentration on the exposure-response analysis, but does introduce a bias against inclusion of low dose studies in the exposure-response analysis.

The following observations concerning the exposure-response relationship for aluminum may be made based on the studies selected for the exposure response analysis: (1) there is a wide variation in reported LOELs (from 1 to 663 mg Al/kg-day); (2) there is a predominance of single dose studies or studies where the LOEL was observed at the lowest dose; (3) for the 16 subchronic and chronic exposure studies for neurotoxicity in adults (neurobehavioral and biochemical endpoints), the LOELs range between 1 and 500 mg Al/kg-day (administered and combined doses—D_a and D_c—considered together). (4) For the 22 studies of exposure during gestation and lactation (reproductive, developmental, neurodevelopmental, histopathological and biochemical endpoints), the LOELs (D_a and D_c) vary between 2 and 663 mg Al/kg-day.

The following discussion focuses particularly on studies documenting LOELs at the lowest doses, and evaluates the findings in relation to three issues: (a) use of a low administered dose; (b) toxicological significance of different endpoints; and (c) methodological strengths and limitations and consistency of study findings.

(a) Use of a low administered dose

The lowest LOEL was observed by Huh *et al.* (2005), which reported apoptosis and the activation of the catalytic activity of monoamine oxidases A and B in the brains of Sprague-Dawley rats at a reported combined dose of 1 mg Al/kg-day. The aluminum-exposed group received aluminum maltolate in drinking water over a period of 12 months. This study reported an aluminum concentration of 11.5 ppm in the base diet. Although this is a relatively low value for laboratory chow, it does constitute an aluminum dose (0.6 mg Al/kg-day) of nearly twice that of the administered dose (0.38 mg Al/kg-day). The use of an administered dose less than the base diet dose raises the question of exposure misclassification of individual animals, as the normal variability in

intake between animals may create overlap between the two groups with respect to the dose received. This is considered to be a major limitation of this study.

In spite of the extremely low administered dose, the animals receiving aluminum maltolate were found, after one year, to have approximately four times the amount of aluminum in the brain (462 ng/g) as compared to the controls (110 ng/g). This finding suggested a comparable increase in both the fraction of aluminum absorbed into the bloodstream and/or the amount of aluminum distributed to the brain when the aluminum is administered as the maltolate salt. Recently, Zhou *et al.* (2008) found differences in aluminum oral bioavailability, which were not statistically significant, between the citrate, maltolate and fluoride salts in drinking water. The measured bioavailabilities of all the salts were low (estimated means of 0.5%, 0.61% and 0.35% for maltolate, citrate and fluoride, respectively) and approximately twice the estimated bioavailability of aluminum in food (0.1% to 0.3%) as measured with the same experimental protocol.

These findings suggest that while aluminum maltolate may be more bioavailable, the increase would not be sufficient to explain the results of Huh *et al.* (2006). In light of the uncertainty associated with the reported increased brain concentrations in the Huh *et al.* (2005) study, in addition to the methodological limitation of testing an administered dose that is less than the base diet dose, the study by Huh *et al.* (2005) was not retained for the purpose of estimating the lower range of aluminum doses at which neurological effects may be expected to occur.

Other investigations with relatively low doses over periods of 12 weeks or longer have also reported neurotoxic effects. These studies were not considered in the exposure-response analysis as the aluminum content in the laboratory chow was not reported, and thus, unlike the study by Huh *et al.* (2005), the relative contribution of the aluminum in the base diet could not be evaluated. The LOELs for these studies ranged from 0.07 to 22 mg Al/kg-day (administered dose) and were associated with a significant increase in brain aluminum levels as well as significant increases in neurobehavioral or histopathological effects.

(b) Toxicological significance of different endpoints

Considering the 16 subchronic and chronic adult exposure studies, the LOELs range between 19 and 500 mg Al/kg-day(administered and combined doses—D_a and D_c—considered together, and excluding the Huh *et al.* (2005) study). For neurobehavioral endpoints (Morris water maze performance, impaired learning in the shuttle box and motor activity), the LOELs of the seven relevant studies vary between 40 to 500 mg Al/kg-day (D_a and D_c), with four studies having LOELs at D_as of 40 to 70 mg Al/kg-day (Commissaris *et al*. 1982; Lal *et al.* 1993; Gong *et al*. 2005; Mameli *et al.* 2006). The neurobehavioral endpoints examined constitute standard elements of neurobehavioral testing and impaired performance is considered to be toxicologically significant in the experimental animal.

The biochemical effects observed in the remaining studies included alterations in

neurotransmission systems, alterations in synaptosomal membrane fluidity and increased lipid peroxidation in the brain, and were associated with LOELs varying from 19 to 420 mg Al/kg-day. These observations provide supportive evidence for neurotoxicity observed via other endpoints as well as information on mechanisms of action, but are more difficult to evaluate with respect to toxicological significance. For this reason, studies with these endpoints were given less weight in the exposure-response evaluation, in comparison to studies that include neurobehavioral endpoints.

Considering the 22 studies of exposure during gestation and lactation, the LOELs (D_a and D_c) varied between 29 and 663 mg Al/kg-day. For neurobehavioural endpoints (grip strength, auditory startle, negative geotaxis and other reflexes, maze learning and thermal sensitivity, and motor development), the LOELs (administered doses) ranged from 50 to 155 mg Al/kg-day, with the LOELs of two studies falling in the range of 50 to 60 mg Al/kg-day (Colomina *et al.* 2005; Golub and Germann 2001b).

With respect to reproductive parameters, the lowest LOEL was reported by Belles *et al.* (1999), where aluminum nitrate was administered to pregnant mice via gavage at a dose of 29 mg Al/kg-day and observed an increase in the number of early deliveries and reduced fetal body weight. Reduced birth or fetal weight was also observed by Colomina *et al.* (1992) and Sharma and Mishra (2006) at LOELs ranging between 50 and 70 mg Al/kg-day. Morphological effects in offspring were also observed in the latter two studies.

The motor, reflex and learning endpoints examined in the developmental studies as well as the reproductive parameters of fetal growth and morphological variations are all standard endpoints included in neurodevelopmental testing procedures, and considered to be toxicologically significant.

(c) Evaluation of methodology and consistency of results in studies with LOELs of <70 mg Al/kg-day.

The methodologies and findings of the abovementioned studies with LOELs of less than 70 mg Al/kg-day for neurobehavioral or reproductive/developmental endpoints were compared in order to characterize the strength of evidence for the effects observed at these dose levels.

Adult Neurobehavioral Effects

Of the four neurobehavioral studies in adults, all were carried out in rats using aluminum chloride, in drinking water (Gong *et al*. 2005; Mameli *et al*. 2006; Lal *et al.* 1993), or in the diet (Commissaris *et al.* 1982), for periods varying between 90 days and 11 months.

Several weaknesses were identified in the investigations of Commissaris *et al.* (1982) and Gong *et al.* (2005). First, exposure information in these two reports was expressed as concentrations in the food or drinking water, and no information was included on intake rates or body weight of the animals. Thus the administered doses (50 and 60 mg Al/kg-

day, respectively) were calculated on the basis of default intake and body weight values (refer to Health Canada 1994), and are therefore associated with greater uncertainty than had the doses been reported by the researchers on the basis of experimental observations. Moreover, the concentration of aluminum in the base diet was not reported in the two studies, and so the combined dose could not be calculated.

The investigations of Commissaris *et al.* (1982) and Gong *et al.* (2005) were also limited by the use of a single aluminum dose and the absence of a group receiving sodium chloride. Thus, a dose-response relationship could not be examined, and the observed effects could not be definitively attributed to the aluminum ion. It should be added that these two investigations were carried out with the primary objective of examining the influence of other test substances on aluminum toxicity—parathyroid hormone and Ginkgo biloba leaf extract, respectively—and not for the purpose of evaluating aluminum toxicity at different dose levels for different endpoints.

In the study of Lal *et al.* (1993), adult male Druckrey albino rats were exposed to an administered dose of 52 mg Al/kg-day for 180 days in drinking water. Although this dose was not reported directly in this form, information on daily water consumption and average body weight was provided, allowing for calculation of the dose based on experimental data. The investigation included a range of behavioral, biochemical and histopathological endpoints. The researchers observed reduced spontaneous motor activity and impaired learning in the shuttle box and maze tests, in addition to increased lipid peroxidation and decreased Mg^{2+} and $Na^{+}K^{+}$-ATPase activities in the brain. The aluminum concentration in different brain regions was significantly increased in the aluminum-exposed animals, but no pathological alterations were observed.

In the context of evaluating the exposure-response relationship, the study by Lal *et al.* (1993) is more informative than the Commissaris *et al.* (1982) and Gong *et al.* (2005) studies, in that the dose is more accurately reported, brain aluminum content was measured and a range of endpoints were examined, with generally consistent findings reported for the different endpoints. Its limitations include the use of a single dose, the absence of a group exposed to sodium chloride and the lack of information on the aluminum concentration in the base diet. Assuming a concentration of 250 ppm of aluminum in the laboratory chow (ATSDR 2008), the corresponding approximate aluminum dose would be 13 mg Al/kg-day, leading to an estimated combined dose for the Lal *et al.* (1993) study of 65 mg Al/kg-day.

It should be noted that NOELs for impaired learning in the maze and shuttle box tests in aluminum-exposed adults have been observed at doses of 100 and 140 mg Al/kg-day, respectively by Domingo *et al.* (1996) and VonLinstow Roloff *et al.* (2002). In the study by Domingo *et al.* (1996) the aluminum was administered to rats as Al nitrate, with added citrate, in drinking water for a period of 6.5 months. Von Linstow Roloff (2002) administered Al sulfate in drinking water to rats for a period of seven months.

Of these four studies, only Mameli *et al.* (2006) included more than one dose group, and were thereby able to establish a LOEL of 43 mg Al/kg-day and a NOEL of 22 mg Al/kg-

day. At this administered dose the researchers found impairment of the vestibulo-ocular reflex in male rats of different ages (3, 10 and 24 months old) exposed to aluminum chloride in drinking water. Significant increases of aluminum were observed in brain regions (brainstem-cerebellum and cerebrum). This study, which used 20 animals per dose per age group, also included an exposure group for the salt, in this case sodium chloride, such that the observed effects could be more clearly attributed to the aluminum and not the chloride ion. It should be noted, however, that evidence from other studies supporting the effects of aluminum on the vestibulo-ocular reflex is not available, as this endpoint has not been evaluated by other researchers.

In the study by Mameli *et al.* (2006), the base diet aluminum concentration was measured but not clearly reported, nor was food intake measured. The LOEL of 43 mg Al/kg-day is thus the administered dose. The combined dose may be estimated at approximately 50 mg Al/kg-day, based on default values for rat dietary intake.

Considering the observations of LOELs and NOELs associated with neurobehavioral effects in adults as well as the probable combined doses, alterations in learning and reflexes may be observed at approximately 50 to 65 mg Al/kg-day, based on the LOELs of Mameli *et al*. (2006) and Lal *et al.* (1993) expressed as estimated combined dose.

Reproductive Effects

The lowest LOEL presented is from the study by Belles *et al.* (1999). Mice were exposed to aluminum nitrate via gavage from gestational day 6 to 15 at a dose of 29 mg Al/kg-day. In addition to the control group, one group received sodium nitrate at a similar nitrate dose. A high mortality (52%) in the aluminum-exposed pregnant mice was observed in this study, which was not observed in other developmental studies in which aluminum nitrate or other aluminum salts were administered at similar or greater doses. Other observations included reduced body weight gain in the dams during gestation and reduced fetal body weight. The number of early deliveries was also increased in the aluminum-exposed animals as compared to the control group, but there was no significant difference in this regard when compared to the sodium nitrate-exposed group. This study is limited to a single dose, and the aluminum content in the base diet was not measured. The lack of information on base diet is particularly important in studies with mice because of their small body weight. A laboratory chow containing 250 ppm of aluminum would be equivalent to a dose of approximately 33 mg Al/kg-day, which is higher than the administered dose in this investigation.

Reduced maternal body weight gain and reduced fetal weight in aluminum-exposed animals were also observed at the LOELs associated with the Sharma and Mishra (2006) and Colomina *et al.* (1992) studies. A significant reduction in pup weight was also observed at the higher doses tested in the studies of Golub and Germann (2001b) and Colomina et al. (2005), at approximately 100 mg Al/kg-day.

In the study by Sharma and Mishra (2006), rats received 70 mg Al/kg-day as aluminum chloride via gavage during gestation and lactation. In addition to the effects on fetal

weight, the authors observed an increase in skeletal malformations and in oxidative stress in the brains of mothers, fetuses and sucklings. The dose level in this study is based on the measured maternal weights. However, no information on base diet was included. The combined dose, based on a concentration of 250 ppm of aluminum in a typical lab chow and default values of Health Canada (1994), is estimated at approximately 83 mg Al/kg-day.

Colomina *et al.* (1992) administered aluminum lactate to mice through gavage. A LOEL of 57.5 mg Al/kg-day (administered dose) was observed for an increased incidence of morphological effects (cleft palate, delayed ossification of parietals), in addition to reduced fetal weight. This study did not report the aluminum content in the base diet. Considering the reported concentration in the laboratory chow used by this research group in other experiments of 42 ppm of aluminum, the estimated base diet dose would be approximately 5.5 mg Al/kg-day, based on Health Canada (1994) default values for body weight and food intake in mice. The combined dose would then be estimated at 63 mg Al/kg-day.

In contrast to the findings mentioned above, in the study of McCormack *et al.* (1979), rats were fed aluminum chloride in the diet at maternal dose levels of 25 and 50 mg Al/kg-day during gestation, and no differences in fetal growth or skeletal anomalies were observed. Colomina *et al.* (1994) found no differences in dam body weight, fetal growth or morphological variations in mice exposed via gavage to 104 mg Al/kg-day of aluminum hydroxide, during gestation. The latter finding may have resulted from the lower solubility and therefore the lower bioavailability of the hydroxide salt.
Considering the observations of LOELs and NOELs associated with reproductive effects, and the probable combined doses, reductions in fetal and pup body weight may be observed beginning at approximately 60 mg Al/kg-day (e.g., Colomina *et al.* (1992)). The study of Belles *et al.* (1999), in which a LOEL of 29 mg Al/kg-day was observed for reduced fetal weight, is given less weight in this evaluation, in light of the uncertainty associated with the high maternal mortality rate observed in the exposed animals, and the elevated contribution of the base diet to aluminum exposure as compared to the administered dose.

Neurodevelopmental Effects

The lowest LOELs are from the studies of Colomina *et al.* (2005) and Golub and Germann (2001b). Both of these studies included exposure through gestation and lactation. The experimental conditions of the two studies, however, differed in many other respects, and these are described briefly below.

Colomina *et al.* (2005) exposed female Sprague-Dawley rats to 0, 50, or 100 mg Al/kg-day as aluminum nitrate in drinking water with citric acids, in combination with a base diet dose of approximately 3 mg Al/kg-day. Aluminum exposure was maintained through gestation, lactation and the life of the dams. The maternal effects of aluminum administration included decreased food intake (with reduced body weight) during gestation and lactation and decreased water intake during lactation in the 100 mg Al/kg-

day dose group. No effects were observed with respect to the length of gestation, the number of litters or the number of fetuses per litter. With respect to the pups, there was a significant increase in the number of days until sexual maturation in males in the 100 mg Al/kg-day dose group and in females at both 50 and 100 mg Al/kg-day. A significant reduction in forelimb grip strength in males was observed in the 100 mg Al/kg-day dose group on PND 11 compared controls. In the water maze task, assessing spatial learning, the performance of aluminum treated rats (50 mg Al/kg-day) was significantly improved in comparison to the control group. The pups in the 100 mg Al/kg-day dose group were not tested in the water maze test, because of altered maternal food and water intakes in this group. No differences in aluminum-exposed animals were observed with respect to surface righting, negative geotaxis or activity in an open field. The authors also measured aluminum concentration in brain regions but did not find increased levels in any regions in the aluminum-exposed animals.

Golub and Germann (2001b) investigated the long-term consequences of prenatal exposures to aluminum in Swiss Webster mice, in conjunction with a suboptimal base diet. The base diet was designed to simulate the usual diet of young women in the U.S., with respect to estimated phosphate, calcium, iron, magnesium, and zinc intakes. Following breeding, dams were exposed to aluminum in the diet as aluminum lactate. The doses were equivalent to approximately < 1, 10, 50 and 100 mg Al/kg-day, as estimated at the beginning of gestation. The dams were exposed throughout gestation and lactation. Following weaning at 21 days, the pups were fed the same diet as the dams for two weeks (although the per kg dose levels were higher). No effects were observed in the number of dams completing pregnancy, gestation length, weight gain of the dams (GD0 to GD15), litter size or birth weight. By weaning, both males and females in the two highest dose groups weighed significantly less than the controls, although by PND35 only the highest dose group showed this effect. The female offspring of the highest dose group (maternal exposure of 100 mg Al/kg-day) were found to be slower in maze learning at three months old, as indicated by longer latencies during the first three sessions of the four-session learning series. All aluminum treated groups were similar to controls by the fourth session. Differences in aluminum exposed groups were also observed in the cue relocation trials, in which average trial latency was significantly increased at the two highest dose levels (50 and 100 mg Al/kg-day) as compared to the control group. In the motor testing of male offspring at five months old, males in the highest dose group (maternal exposure of 100 mg Al/kg-day) had significantly lower hindlimb grip strength and greater number of rotations in the rotarod test (animal losing footing). When body weight was taken into account, only the findings for the rotarod test remained significant.

The investigations by Colomina *et al.* (2005) and Golub and Germann (2001b) are methodologically superior in many respects to the majority of the studies. Both include two dose levels in addition to the control group, quantify the aluminum dose associated with the base diet, and examine a range of reproductive and neurodevelopmental endpoints. The Colomina *et al.* (2005) study includes measurement of aluminum concentration in different brain regions. The Golub and Germann (2001b) study, however, used an experimental protocol designed to test the influence of a suboptimal

diet, which limits comparisons of the findings with other investigations of aluminum toxicity, particularly as no groups were included with equivalent aluminum dose levels and a standard diet.

Interpretation of cognitive and motor test findings in the studies investigating the effects of aluminum exposure is also complicated by a possible biphasic dose-response relationship. For example, in the study by Roig *et al.* (2006), rats received aluminum nitrate in drinking water during gestation and lactation at administered doses of 50 and 100 mg Al/kg-day. No difference in the motor activity of aluminum-exposed pups and controls was found. However, the animals exposed to 50 mg Al/kg-day showed an improved performance in maze learning. The performance of animals exposed to 100mgAl/kg-day was significantly reduced as compared to the animals exposed to 50 mg Al/kg-day, but not significantly different from controls. Colomina *et al.* (2005) also observed improved maze performance in aluminum-exposed animals, although the highest exposure group in that study was not tested for this endpoint.
Considering the neurodevelopmental studies described above, diminished performance in learning or motor tests may be observed in animals exposed prenatally or through lactation at maternal combined doses beginning at approximately 50 mg Al/kg-day. There is, however, considerable variability in various study results with respect to these endpoints, which also suggest a possible biphasic dose-response relationship in relation to maze learning.

Conclusion

A dose of 50 mg Al/kg-day, expressed as a combined dose of total aluminum, was considered the level at which neurological and reproductive/developmental effects begin to be repeatedly observed in animal studies. While 50 mg Al/kg-day is an estimation of the lower end of a broad range of LOELs observed under different experimental conditions, it is not considered to be an overly conservative estimate of the effect level of concern. There are two sources of bias against consideration of lower values of LOEL in the above characterization: (a) low-dose studies were not considered if the administered dose was less than the probable base diet dose; and (b) LOELs from single-dose studies may be overestimates of the actual effect levels. Thus, 50 mg Al/kg-day has, however, produced neurotoxic, reproductive and developmental effects in laboratory animals more consistently under a wide range of experimental conditions, as compared to lower doses. This exposure level is therefore retained for the purpose of the characterization of human health risks as the level of concern for neurotoxic, neurodevelopmental and reproductive effects.

LOEL [Al] = 50 mg/kg/day

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (LOEL to NOAEL)

Oral RfD [Al] = 50/1,000 = 0.05 mg/kg/day

Drinking water guideline value [Al] = 0.18 ppm

Australian drinking water guideline [sulfate] = 500 ppm (health); 250 ppm (aesthetic)

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Toxicity Profile

Cellulase
(CAS No. 9012-54-8)

Enzymes are catalytic proteins or polypeptides and consist of amino acid residues coupled via peptide bonds. They are primarily characterized by their biocatalytic or enzymatic activity. There is a broad range of detergent cellulases used both from fungal as well as from bacterial origin; all are characterized by ß-1,4-endoglucanase activity.

Acute Toxicity

The oral LD_{50} of a cellulase enzyme was determined to be 8,000 mg/kg for mice and >10,000 mg/kg for rats (HERA, 2005). The inhalation LC_{50} of the same enzyme in rats is >3.48 mg/L, with a mass mean diameter of 7.8 µm and a geometric standard deviation of 2.1 µm (HERA, 2005).

Irritation

Cellulase enzymes are mild to non-irritating to the skin and eyes of rabbits (HERA, 2005). The amount of protease contamination in the enzyme test preparation, however, may affect the irritation potential, particularly with regards to eye irritation.

Sensitization

A cellulase enzyme was not a skin sensitizer to guinea pigs (HERA, 2005).

Repeated Dose Toxicity

Male and female rats were dosed by oral gavage with 0, 300, 1,000 or 3,000 mg/kg of a cellulase enzyme for 4 weeks. There were no treatment-related clinical signs, but a slight dose-related increase in body weight gain (approx. 7%) was seen in the males. No treatment-related changes were noted in the hematology or clinical chemistry. There were no gross or histopathologic changes that were considered treatment-related (HERA, 2005).

Male and female rats were given in their feed concentrations of 0, 120, 600 or 3,000 mg/kg of this enzyme for 13 weeks. There were no treatment-related clinical signs. A reduction in body weight gain was seen in both sexes at the 3,000 mg/kg level (10% in males and 20% in females). A slight reduction in food consumption was also noted for the 3,000 mg/kg dose group. Serum alkaline phosphatase activity was increased in the 600 and 3,000 mg/kg females in a dose-dependent manner. However, there were no organ

weight changes and no effects seen in the gross or histopathologic examination that were considered treatment-related. The NOAEL for this study is considered to be 600 mg/kg/day (HERA, 2005).

Genotoxicity

In an *in vitro* bacterial mutation assay, a cellulase enzyme was not mutagenic to *Salmonella typhimurium* strains TA 1535, TA 100, TA 1537 and TA98 in the presence or absence of metabolic activation. In an *in vivo* bone marrow micronucleus assay, a cellulase enzyme was not genotoxic when given to rats by oral gavage (HERA, 2005).

Carcinogenicity

No data were found.

Reproductive Toxicity

No data were found.

Developmental Toxicity

No data were found.

Key Study/Critical Effect for Screening Criteria

In a 13-week dietary study, there was reduced body weight gain in rats given 3,000 mg/kg of this enzyme. Although there was a dose-related increase in serum alkaline phosphatase activity, there were no significant changes to liver weights, nor were there any accompanying gross or histopathologic changes in the liver. Thus, the changes in serum alkaline phosphatase activity were not considered an adverse effect and the NOAEL for this study is 600 mg/kg/day.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (subchronic to chronic)

Oral Reference Dose = 600/1,000 = 0.6 mg/kg/day

Drinking water guideline value = 2.1 ppm

Reference

Human and Environmental Risk Assessment (HERA) on Ingredients of Household Cleaning Products: α-amylase, CAS No. 9000-90-2; Cellulase (β-(1,4)-glucanase), CAS No. 9012-54-8; Lipase, 9001-62-1, 2005. http://www.heraproject.com

Toxicity Profile

Lactose
(CAS No. 63-42-3)

Lactose is a disaccharide sugar composed of galactose and glucose. It is naturally synthesized in the mammary gland of virtually all mammals, occurring in milk at levels between 1 and 7%. Commercially, lactose is extracted from the whey of cow's milk (whey is the residual liquid of milk following cheese and casein production) and is purified extensively to remove fats, proteins, vitamins and minerals (Baldrick and Bamford, 1997; Goodhart, 1994).

Pharmacokinetics/Metabolism

Lactose *per se* is not readily absorbed by the oral route. After dietary intake, lactose is readily hydrolyzed to galactose and glucose by the enzyme lactase (Hansen, 1974; Williams, 1986). Lactase is a β-galactosidase found in the brush border of the intestinal epithelium. Once hydrolyzed, the monosaccharides are then readily absorbed. Lactose can also be hydrolyzed by other enzymes, such as acid β-galactosidase.

Acute Toxicity

The acute oral LD_{50} in rats is >10,000 mg/kg (Baldrick and Bamford, 1997).

Irritation

No data were located.

Sensitization

No data were located.

Repeated Dose Toxicity/Carcinogenicity

Wistar rats were fed 20% lactose for 12 weeks before mating, and during pregnancy and lactation. At weaning, the animals were fed the same diet and the study was terminated at week 130. There were low body weights; increased blood alkaline phosphatase and urinary calcium; decreased pH of cecum contents; enlargement/increased weight of the cecum; pelvic nephrocalcinosis of the kidneys; increased proliferation of the bile ducts; adrenal medullary hyperplasia and pheochromocytomas; and Leydig cell tumors (Sinkeldam *et al.*, 1992a).

Similar findings were also observed in another study in which rats were fed 20% lactose in their diet for 130 weeks. Findings included loose feces (week one and two only); decreased pH of the feces; low body weights; increased food and water consumption; increased blood alkaline phosphatase and decreased bicarbonate; increased calcium concentration and excretion; reduced urinary pH; increased cecum weight; mineralization of the renal pelvis; increased incidence of basophilic cell foci in the adrenal medulla; and Leydig cell hyperplasia (De Groot *et al.*, 1995).

Genotoxicity

Lactose was negative in an *in vitro* chromosomal aberration study with cultured human lymphocytes in the presence and absence of metabolic activation (Sinkeldam *et al.*, 1992a).

Reproductive/Developmental Toxicity

In a multi-generation study, rats were fed 20% lactose over three successive generations. There were no adverse effects on fertility or reproductive performance. There was a slight decrease in the number of pups born alive, litter size at birth, viability index and pup weight for F_0 and F_1 offspring. There were signs of low body weights in the parental animals, and enlargement and increased weight of the cecum (Sinkeldam *et al.*, 1992b).

Pregnant mice were given 10,000 mg/kg lactose during gestation days 8-12. No maternal toxicity was observed and there were no effects on litter size, body weight on days 1 and 3, or neonate survival (Seidenberg *et al.*, 1986).

Key Study/Critical Effect for Screening Criteria

Many of the findings from the oral studies on lactose can be related to the fact that it is poorly absorbed from the small intestine. This results in a large proportion reaching the cecum and colon where it is readily fermented by the intestinal microflora. Consequently, there is increased production of volatile fatty acids and lactic acid, and a lowering of the pH and increased osmotic pressure. These changes facilitate calcium absorption. The adrenal tumors are thought to be secondary to increased calcium absorption from the intestine. Increased Leydig cell tumors in rats are of questionable relevance to humans.

Adverse effects were noted in rats given 20% in their diet for 130 weeks. Since there was only one dose level, a NOAEL was not identified.

LOAEL (mg/kg/day) = 20,000 ppm * 0.05 = 1,000 mg/kg/day

Where 0.05 is the fraction of body weight that is consumed per day as food for the mouse (U.S. EPA).

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (LOAEL to NOAEL)

Oral Reference Dose = 1,000/1,000 = 1.0 mg/kg/day

Drinking water guideline value = 3.5 ppm

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Toxicity Profile

Maltodextrin
(CAS No. 9050-36-6)

Maltodextrin is a nonsweet nutritive saccharide polymer that consists of D-glucose unites linked primarily by $\alpha,1\rightarrow4$ bonds and that has a dextrose equivalent (D.E.) of <20. Typical commercial maltodextrins contain as few as three and as many as nineteen linked dextrose units. It is prepared as a white powder or concentrated solution by partial hydrolysis of corn starch, potato starch, or rice starch with safe and suitable acids and enzymes.

Maltodextrin is considered to be a biopolymer that is broken down in the gastrointestinal tract to its monomeric units and absorbed. The corresponding monomers are found naturally in the body. Thus, maltodextrin is expected to be safe to human health.

The U.S. FDA lists maltodextrin as GRAS (Generally Recognized as Safe).

No toxicity data could be found on maltodextrin and therefore no oral reference dose or drinking water standard was determined.

References

http://www.sugar.org/other-sweeteners/other-caloric-sweeteners.html#maltodextrin

Toxicity Profile

Potassium chloride
(CAS No. 7447-40-7)

Potassium chloride (KCl) has been reviewed in the OECD-SIDS program (OECD, 2001).

Potassium chloride (KCl) is an inorganic salt that readily dissociates in aqueous media to K^+ and Cl^-.

Acute Toxicity

The oral LD_{50} in rats has been reported to be 3,020 mg/kg (Boyd and Shanas, 1961).

Irritation

Potassium chloride did not produce an irritant response in an *in vitro* skin irritation OECD 439 test or an *in vitro* eye irritation test (ECHA).

Repeated Dose Toxicity

Fourteen female rats were given KCl in their drinking water (approximately 5,250 mg/kg/day) for 105 days. Ten rats were sacrificed after 105 days of exposure for examination of the heart, kidneys and the adrenals; four rats (recovery group) were kept for an additional month. KCl exposure resulted in decreased heart weight, increased kidney weight, and enlargement of part of the adrenals. All changes were reversible within one month of exposure (Bacchus, 1951).

F344/Slc male rats were given 0, 110, 450 or 1,820 mg/kg/day KCl in feed for two years. At the end of the study, survival rates were 48%, 64%, 58% and 84% in the controls, 110, 45 and 1,820 mg/kg/day groups. Nephritis was reported to be predominant in all groups, including the controls. The only treatment-related effect observed was gastritis (inflammation of the stomach lining). The incidence of gastritis and ulcers were 6%, 18%, 18% and 30% in the controls, 110, 450 and 1,820 mg/kg/day groups (Imai *et al.*, 1968).

Male and female Wistar rats were fed diets containing 0 or 3% KCl over a total period of 30 months: Examination after 13 weeks (10 rats/sex/group), after 18 months (15 rats/sex/group) and after 30 months (50 rats/sex /group). Due to the reduction of feed intake the mean test substance intake and mean body weight decreased in time. After 30 months of treatment, there was hypertrophy of the zona glomerulosa in the adrenals (24/50 treated rats versus 4/50 in controls); and cystitis in the urinary bladder (males: 3/59; females 3/50) and single epithelial hyperplasia of the bladder (males 3/50; females

2/50) (Lina *et al.*, 1994; Lina and Kuijpers, 2004)**.**

Genotoxicity

Potassium chloride was not mutagenic to *Salmonella typhimurium* strains TA100, TA 1535, TA 1537 and TA 98 strains in an *in vitro* bacterial mutation assay in the presence or absence of metabolic activation (Mortelmans *et al.*, 1986). KCl was also not mutagenic to *E. coli* in a SOS chromotest (Olivier and Marzin, 1987).

In two different studies, KCl was found to be weakly mutagenic to mouse lymphoma L5178Y cells at high concentrations (Myhr and Caspary, 1988; Mitchell *et al.*, 1988).

Potassium chloride induced a significant increase in chromosomal aberrations in Chinese Hamster lung fibroblasts (V79) cells only at the highest test dose (12,000 µg/ml) in the absence of a metabolic activation system. Measurements of the osmotic pressure of the medium revealed a two-fold increase at this test compound concentration when compared to the normal medium (530 mOsmol/ kg versus 253 mOsmol/kg (Hasegawa *et al.*, 1984). There are two other reports on the effect of KCl on formation of chromosome aberrations in Chinese hamster ovary cells (CHO). In these studies KCl concentrations of 75 and 80 mM (approximately 5500 and 6000 µg/ml) resulted in 19% and 28% aberrant cells respectively. Increased number of chromosome aberrations was observed with KCl concentrations that reduced cell survival 40% and more. It is reasonable to conclude that the increases in mutagenicity and chromosome aberrations observed in these studies are related to cytotoxicity resulting from the high KCl concentrations used. This argument is supported by the studies on the effect of increased osmolarity on genotoxicity in cultured mammalian cells.

The reported mutagenic effect of KCl most probably results from a disruption of osmotic balance of cells with a subsequent interference with chromosomal stability. This may result in the clastogenic effects (DNA breakage and chromosome structural instability) due to K^+ effects on sequestering of Mg^{++} ions required for normal maintenance of chromatin integrity. Other chemicals may also exert such effect (*e.g.*, NaCl, sucrose).

Carcinogenicity

F344/Slc male rats were given 0, 110, 450 or 1,820 mg/kg/day KCl in feed for two years. At the end of the study, survival rates were 48%, 64%, 58% and 84% in the controls, 110, 45 and 1,820 mg/kg/day groups. There was no increased incidence of tumors that were considered to be treatment-related (Imai *et al.*, 1968).

Reproductive/Developmental Toxicity

Pregnant female Wistar rats were given by oral gavage 3.1 to 310 mg/kg KCl during gestation days 5 through 15, and sacrificed on gestation day 20. There were no effects on

survival, total number of corpora lutea, implant sites, resorptions, soft tissue observations (urogenital tract), or live offspring. No treatment-related effects were seen in the offspring with regards to survival, sex ratio, average offspring weight, external congenital abnormalities, soft tissue or skeletal defects. The maternal and developmental NOAELs were 310 mg/kg/day (FDRL, 1975).

Female CD-1 mice were given by oral gavage 2.35 to 235 mg/kg KCL during gestation days 5 through 15, and sacrificed on gestation day 17. There were no effects on survival, total number of corpora lutea, implant sites, resorptions, soft tissue observations (urogenital tract), or live offspring. No treatment-related effects were seen in the offspring with regards to survival, sex ratio, average offspring weight, external congenital abnormalities, soft tissue or skeletal defects. The maternal and developmental NOAELs were 235 mg/kg/day (FDRL, 1975).

Key Study/Critical Effect for Screening Criteria

In a two-year rat feeding study, there was an increased incidence of gastritis and ulcers at dose levels of $\geq$110 mg/kg/day (Imai *et al.*, 1968). There was no NOAEL. Thus, the LOAEL for this study is 110 mg/kgday. Since the gastritis and ulcers are the result of a localized irritation effect of the test substance (site of contact) in the gastrointestinal tract, an uncertainty factor for interspecies variability is deemed unnecessary.

For systemic effects, the NOAEL for the two-year rat feeding study is considered to be 1,820 mg/kg/day, the highest dose tested.

Uncertainty factors: 10 (intraspecies variability); 10 (interspecies variability); 1 (intraspecies variability)

Oral Reference Dose = 1,820/100 = 18.2 mg/kg/day

Drinking water guideline: 64 ppm

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Toxicity Profile

Shellac, Ammonium salt
(CAS No. 68308-35-8)

Lac is the hardened resinous secretion of the insesct *Kerria lacca* (Douglas, 1971; CIR, 1986). The secreted lac or sticklac contains lac resin, erythrolaccin, wax, inset debris, wood materials, sand, dust and water-soluble impurities. The semirefined seedlac of commerce is the yellowish granular material obtained from the processing of sticklac (Douglas, 1971; Misra and Sengupta, 1970; CIR, 1986).

Unrefined shellac can contain shellac wax and erythrolaccin (the yellow material), which both comprise about 6% of Shellac (CIR, 1986). The removal of these constituents yields lac resin that has a soft (30%) and hard (70%) components (CIR, 1986). Mild alkaline hydrolysis of this resin results in a complex mixture of hydroxyaliphatic and alicyclic acids and their polyesters. The composition of the mixture varies with the lac source and the time of collection (CIR, 1986).

The major component of the aliphatic fraction is aleuritic acid. The alicyclic fraction consists of sesquiterpenic acids, primarily jalaric acid and its derivatives. The native form of the pure lac resin molecule has a molecular weight of 2,095, which contains four terpene acids (mostly jalaric acid) and four aleuritic acid units in repeating ester linkage (Singh *et al.*, 1974). The proposed structure for lac resin respresents an average situation since the molecule may not always be homogenous with respect to sequence or ratio of jalaric acid to other sesquiterpenic acid substitutes (Singh *et al.*, 1974). The sesquiterpenic acids in lac resin are jalaric acid, shellolic acid, epishellolic acid, laksholic acid, and epilaksholic acid.

Aqueous shellac solutions can be prepared by neutralization with ethanolamines, alkalies, or borax (CIR, 1986).

Acute Toxicity

The acute oral LD_{50} in rats is >5,000 mg/kg (CIR, 1986).

Irritation

No data were located.

Sensitization

No data were located.

Repeated Dose Toxicity

Male and female Sprague-Dawley rats were fed 0, 1,000, 3,000 or 10,000 ppm Regular Bleached Shellac in commercial feed for 28 days. The rats were then mated, and a single litter (F_1) was delivered. Twenty-five weaned F_1 animals from each group were then fed with the same F_0 diets for an additional 90 days. There was no evidence of treatment-related effects in either generation, including fertility, reproductive performance, and pup development. The NOAEL for this study is 10,000 ppm (CIR, 1986).

Genotoxicity

Shellac and shellac wax were not mutgenic to *Salmonella typhimurium* strains TA1535, TA1537, TA1538, TA98, TA100 with and without metabolic activation (CIR, 1986). Shellac wax was not mutagenic to S. typhimurium strains TA1535, TA1537 and TA1538, or to *Saccharomyces cerevisiae* strain D4 with or without metabolic activation (CIR, 1986).

Carcinogenicity

No studies could be found.

Reproductive/developmental Toxicity

See Repeated Dose Toxicity section.

Key Study/Critical Effect for Screening Criteria

No treatment-related effects were noted in an one-generation rat reproductive toxicity study in which rat were fed shellac in the diet at concentrations up to 1% (10,000 ppm).

NOAEL (mg/kg/day) = 10,000 ppm * 0.05 = 500 mg/kg/day

Where 0.05 is the fraction of body weight that is consumed per day as food for the rat (U.S. EPA).

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (subchronic to chronic)

Oral Reference Dose = 500/1,000 = 0.5 mg/kg/day

Drinking water guideline value = 1.75 ppm (shellac, ammonium salt may be insoluble environmental pH)

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Toxicity Profile

Sodium Carboxymethyl Cellulose
(CAS No. 9004-32-4)

Sodium carboxycellulose is the sodium salt of carboxymethylcellulose. Carboxymethyl cellulose is a cellulose derivative with carboxymethyl groups (-CH_2COOH) bound to some of the hydroxyl groups of the glucopyranose monomers that make up the cellulose backbone.

Sodium carboxycellulase is a listed as GRAS (Generally Regarded as Safe) by the U.S. Food and Drug Administration (FDA GRAS database).

It is an approved food additive in the EU (EC, 1995) and may be added to all foodstuffs following *quantum satis* principle, except in products for the dietary management of metabolic disorders, where the limit of use is 10 g/L or kg (EC, 1999).

The Joint FAO/WHO Expert Committee on Food Additives has determined an Acceptable Daily Intake (ADI) for sodium carboxymethyl cellulose of "Not Specified" (no upper limit) (JECFA, 1989).

References

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JECFA
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Toxicity Profile

Sodium Lauryl Sulfate
(CAS No. 151-21-3)

Sodium lauryl sulfate has been reviewed in the OECD-SIDS program (OECD, 2007a,b).

Acute Toxicity

The acute oral LD_{50} for sodium lauryl sulfate in rats was reported to be 1,200 mg/kg (Henkel KGaA, 1983). The acute dermal LD_{50} of a 33% solution of sodium lauryl sulfate was reported to be 600 mg/kg; this corresponds to 200 mg active substance/kg (Carson and Oser, 1964).

Irritation

A 25% solution of sodium lauryl sulfate was severely irritating to the skin of rabbits when applied for 4 hours under occlusive conditions (Henkel KGaA, 1987a). A 5% solution of sodium lauryl sulfate was moderately to strongly irritating to the skin of rabbits when applied for 4 hours under semi-occlusive conditions (Unilever Research, 1982). In a human repeated 4-hour patch test, a 20% solution of sodium lauryl sulfate was considered moderately irritating to the skin (Proctor and Gamble, 1998). Sodium lauryl sulfate, as a 25% solution, was severely irritating to the eyes of rabbits (Henkel KGaA, 1987b).

Sensitization

Sodium lauryl sulfate has tested positive in two out of three mouse local lymph node assays or LLNAs (Ikarashi *et al.*, 1993; Basketter *et al.*, 1994; Montelius *et al.*, 1994). The positive response in the LLNA is thought to be due to a mechanism associated with the irritation potential of sodium lauryl sulfate and not due to an allergic response (Montelius *et al.*, 1994; Basketter et al., 1994, 2002). Ammonium lauryl sulfate did not show any allergic response in a human repeat insult patch test (OECD, 2007a,b), and other structurally related alkyl sulfates also tested negative in human repeat insult patch tests (OECD, 2007a,b). There have been a few reported contact sensitization cases seen under conditions where also other, possibly sensitizing agents were used or on compromised skin (OECD, 2007a,b).

Repeated Dose Toxicity

Male and female rats were given 0, 40, 200, 1,000 or 5,000 ppm (corresponding to 3, 17, 86 or 430 mg/kg-day) sodium lauryl sulfate in their feed for 90 days. There were

increased liver weights in the high-dose females animals; no other adverse effects were observed. The NOAEL for this study is 1,000 ppm (86 mg/kg/day) (Walker *et al.*, 1967).

Male and female rats were given by oral gavage 0, 30, 100 or 300/600 mg/kg of a 90% aqueous solution of sodium lauryl sulfate for 28 days. The high-dose of 300 mg/kg was changed to 600 mg/kg after 10 days of treatment. At the high-dose, feed intake and body weight were reduced, and water intake was increased. There was bleeding and ulceration of the stomach, and transient alterations of the tongue and myocard. Hematological findings included increased leucocytes and alanine aminotransferase (ALT) activity; and decreased hematocrit and erythrocyte volume (MCV). Relative weights of adrenals, kidneys, brain, gonads and liver were increased; the relative thymus weight was decreased. There were no effects at the 100 mg/kg dose level . The NOAEL for this study is 90 mg/kg/day (90% of the 100 mg/kg dose level) (Henkel KGaA, 1987c).

A sodium $C_{12\text{-}15}$ alkyl sulfate was investigated in 13-week rat dietary study. The dietary concentrations were 0, 0, 0.07, 0.14, 0.28, 0.56, 1.13 or 2.25% (0, 58, 1134, 228, 470, 961, or 1,944 mg/kg/day for males; 0, 66, 131, 261, 506, 1,070 or 2,218 mg/kg/day for females). The LOAEL for this study was 0.28% (245 mg/kg/day) based on hypertrophy of the liver, and the NOAEL was 0.14% (122 mg/kg/day) (Unilever Research, 1976d).

In two separate studies, male and female Wistar rats were given 0, 0.015, 0.15 or 1.5% sodium $C_{12\text{-}15}$ alkyl sulfate in their diet (approximately 0, 11, 113 or 1,125 mg/kg/day) for two years. The findings in both studies were very similar. The survival rate in the high-dose animals for both studies was about 70%. Animals dosed with 1.5% showed decreased growth rates, with also decreases in food and water intake. In the high-dose animals, there was increased absolute and relative liver weights, changes in serum liver enzymes, hypertrophy of the liver parenchyma, and a decrease in the incidence and severity of chronic nephropathy and nephrocalcinosis. The NOAEL for these two studies were considered to be 113 mg/kg/day (Unilever Research, 1995a,b).

Genotoxicity

Sodium lauryl sulfate was not genotoxic in a variety of *in vitro* and *in vivo* genotoxicity tests (OECD, 2007a,b).

Carcinogenicity

In two separate studies, male and female Wistar rats were given 0, 0.015, 0.15 or 1.5% sodium $C_{12\text{-}15}$ alkyl sulfate in their diet (approximately 0, 11, 113 or 1,125 mg/kg/day) for two years. The findings in both studies were very similar. The survival rate in the high-dose animals for both studies was about 70%. There were no increased incidence of tumors that were considered treatment-related (Unilever Research, 1995a,b).

Reproductive Toxicity

In a dominant lethal study, male Swiss albino mice were fed either 1 % sodium lauryl sulfate for 2 weeks or with 0.1 % sodium lauryl sulfate for 6 weeks. Body weights were significantly decreased at the 1% dose level, while the treatment caused no adverse effects on fertility (*i.e.*, impairment of epididymal spermatozoa) (Hemsworth *et al.*, 1981). In the 13-week oral toxicity study with sodium C_{12-15} alkyl sulfates (CAS No. 68890-70-0), there were no indications of adverse effects on the reproductive organs. (Unilever Research, 1976).

Developmental Toxicity

Pregnant female rats were dosed by oral gavage with 0, 0.2, 2, 300 or 600 mg/kg sodium lauryl sulfate during gestational days 6-15. Mortality (3/20 dams) occurred at 600 mg/kg. There was slight to moderate maternal toxicity at >300 mg/kg. No developmental toxicity was noted at any dose level. The maternal and developmental NOAELs were 2 and 600 mg/kg/day, respectively (Palmer *et al.*, 1975).

Pregnant female mice were dosed by oral gavage with 0, 0.2, 2, 300 or 600 mg/kg sodium lauryl sulfate during gestational days 6-15. There were 4/20 maternal deaths at 600 mg/kg, and 1/20 maternal deaths at 300 mg/kg. At 600 mg/kg, there was total resorption and/or increased incidence of litter loss. At <300 mg/kg, there were no adverse effects on fetal morphogenesis. The maternal and developmental NOAELS were 2 and 300 mg/kg/day, respectively (Palmer *et al.*, 1975).

Pregnant female rabbits were dosed by oral gavage with 0, 0.2, 2, 300 or 600 mg/kg sodium lauryl sulfate during gestational days 6-18. There were 11/13 maternal deaths at 600 mg/kg, and 1/13 maternal deaths at 300 mg/kg. Maternal toxicity at 300 mg/kg included diarrhea, anorexia, weight loss, cachexia, and fetal loss. Developmental effects were seen at 600 mg/kg and included abortion, total resorption and/or increased incidence of litter loss. At 300 mg/kg, there were no adverse effects on fetal morphogenesis. The maternal and developmental NOAELs are 2 and 300 mg/kg/day, respectively Palmer *et al.*, 1975).

Key Study/Critical Effect for Screening Criteria

Two chronic rat dietary studies were conducted on sodium lauryl sulfate. The LOAEL for these two studies was 1,125 mg/kg/day based on liver effects. The NOAELs were considered to be 113 mg/kg/day.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral Reference Dose = 113/100 = 1.1 mg/kg/day

Drinking water guideline value = 4 ppm

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Toxicity Profile

Sorbitan, monododecanoate poly(oxy-1,2-diethanediyl)
(CAS No. 9005-64-5)

Sorbitan, monododecanoate poly(oxy-1,2-diethanediyl) or PEG sorbitan monolaurate is a hydrophilic, nonionic surfactant that is also called Polysorbate 20. It has been approved by the U.S. FDA as a direct and indirect food additive for human consumption with certain restrictions.

Metabolism

The metabolism of radiolabeled polysorbates has been studied in rats. After oral administration, the ester linkage of the polysorbate molecule is hydrolyzed by pancreatic lipase and the released fatty acid is absorbed and metabolized. Essentially all of the fatty acid in polysorbate 80 fed as 10% of the diet is hydrolyzed and absorbed (Oser and Oser, 1957). In another study, the labeled lauric acid moiety of polysorbate 20 was rapidly absorbed and oxidized by rats (Treon *et al.*, 1967). After 24 hours, about 75% of the lauric acid was oxidized and expired as CO_2; 4% was not absorbed from the gastrointestinal tract. The approximate distribution of radioactivity 24 hours after oral administration of polysorbate 20 (with radiolabeled lauric acid) was: 80% expired as CO_2; 12% with the carcass; 4% unabsorbed from the gastrointestinal tract; 2.5% in the urine; and 1.2% in the liver (Nelson *et al.*, 1966).

The sorbitol-polyoxyethylene moiety is poorly absorbed and is mostly excreted in the feces. In a study with the radiolabel in the polyoxyethylene portion of polysorbate 20, 90% was excreted in the feces and 8% in the urine. No radioactivity was found in the liver, carcass or expired CO_2 (Nelson *et al.*, 1966).

Following intravenous administration of polysorbates to rats, the ester linkage of the polysorbates is hydrolyzed by blood lipases. Intravenous studies using polysorbate 20 (with radiolabeled lauric acid moiety) in rats showed that the fatty acid portion was metabolized and excreted mostly as expired CO_2. The sorbitol-polyoxyethylene moiety was not catabolized since no radioactivity was recovered as CO_2 when this portion of the molecule was labeled. Most of the radiolabeled polyoxyethylene moiety was excreted in the urine, although a small amount was found in the feces, indicating some biliary excretion; trace amounts were detected in the carcass and liver (Treon *et al.*, 1967).

Metabolism of polysorbates in humans appears to be similar to that in rats. Analysis of urine and feces from human volunteers who consumed 4.5 g of polysorbate 80 daily showed that 95% of the polyoxyethylene portion was excreted in the feces and 5% in urine; apparently, none was retained in the body (Culver *et al.*, 1951).

Acute Toxicity

The acute oral LD_{50} in rats range as high as >38,900 mg/kg (CIR, 1986) and the acute dermal LD_{50} is >3,000 mg/kg (CIR, 1986).

Irritation

Undiluted Polysorbate 20 produced essentially no irritation to the skin of rabbits or humans (CIR, 1986). When tested on human eyes, Polysorbate 20 up to concentrations of 40% produced no adverse effects (Marsh and Maurice, 1971). In rabbits, undiluted Polysorbate 20 produced minimal, transient eye irritation (CIR, 1986).

Sensitization

Polysorbate 20 was a moderate to strong skin sensitizer in the Magnusson-Kligman guinea pig maximization test (CIR, 1986). However, other Polysorbates (65 and 80) were not skin sensitizers when tested in the guinea pig skin sensitization assay (CIR, 1986).

The following is from the CIR report on polysorbates (CIR, 1986):

"Extensive clinical skin testing in the Schwartz prophetic patch test showed little potential for human skin irritation and no evidence of skin sensitization in a total of 580 subjects. A total of 1206 patients with eczema were tested in a chamber method 24-hour occlusive patch test for allergic contact dermatitis to a mixture of 5 percent Polysorbate 60 and 5 percent Polysorbate 80 in petrolatum; allergic reactions were shown by only 2 of the patients (< 0.2 percent). Several product formulations containing the Polysorbates have been tested for human skin sensitization on a total of 3481 subjects using a variety of testing methods; there were no reactions indicative of sensitization to any of the Polysorbates in these assays. Investigations with patients known to have skin disease revealed isolated instances of skin sensitization to Polysorbate 40 or 80. Intravenous injection of Polysorbate 80 produced hemodynamic changes in 5 patients. "

Repeated Dose Toxicity

Numerous long-term feeding studies have been conducted on polysorbates using a variety of animal species; only the key studies which have been the basis for the ADIs on polysorbates are summarized below.

When mixed feed including polysorbate 60 (2%, 5%, 10% or 25%) was administered to both male and female rats for two years, marked diarrhea was observed in the 10% and 25% groups, slight to moderate distention of the cecum in the 25% group, more slight

distention of the cecum in the 10% group and slightly suspicious changes in fat in the liver in the 25% group. The NOAEL is a dietary level of 5% (Fitzhugh *et al.*, 1959).

Rats were given in their feed 0, 5, 10 or 20% Polysorbate 60, 65 or 80 for two years and over four successive generations. At the 20% dose level, the most notable effect was diarrhea; there were also some effects on postnatal survival, lactation efficiency, breeding activity, growth rate, and longevity. The 10% dose level produced only diarrhea. The problems with diarrhea and reproduction at high dose levels were alleviated by the addition of fat to the diet. There were no adverse effects at the 5% level. No other adverse effects were noted. The NOAEL is a dietary level of 5% (Oser and Oser, 1957).

Groups of F344/N rats and $B6C3F_1$ mice of each sex were given diets containing 0, 3,100, 6,200, 12,500, 25,000 or 50,000 ppm polysorbate 80. All animals survived to the end of the studies. The final mean body weights of dosed rats and mice were similar to those of the controls. No clinical findings, changes in absolute or relative organ weights, or gross or microscopic lesions in rats or mice were related to polysorbate 80 administration. The NOAEL is 50,000 ppm (NTP, 1992a).

It is likely that the diarrhea noted in many feeding studies with the polysorbates resulted from having high concentrations of the unabsorbed polyoxyethylene sorbitan moiety within the intestinal lumen.

Genotoxicity

No specific studies were located for Polysorbate 20. One report mentioned a review in which stated that Polysorbate 20 was not mutagenic, but no information was provided (JFSC, 2007).

Based on Evaluation Report of Food Additives for Polysorbates (20, 60, 65 and 80), Polysorbate 60 was not mutagenic in the Ames test. Ames tests using two strains of *S. typhimurium* (TA98 and TA100) were performed in three independent assays and the results were negative both with and without metabolic activation (Kawachi *et al.*, 1981; Morita *et al.*, 1981; Inoue *et al.*, 1980). In addition, it did not induce *in vitro* transformation of hamster embryo cells (Inoue *et al.*, 1980).

A *B. subtilis* rec-assay was performed as a DNA repair study for Polysorbate 60, and while the assay was found to be positive for reverse mutation (JFSC, 2007), others obtained negative results (Kawachi *et al.*, 1981; Morita *et al.*, 1981). Several other studies, including clastogenicity studies, were conducted, but the results were negative (Kawachi *et al.*, 1981).

Polysorbate 80 was negative in rec-assays for DNA damage repair using *B. subtilis* and *E. coli* (Kawachi *et al.*, 1981). Polysorbate 80 was not mutagenic to *S. typhimurium* strains TA98, TA100, TA1535 and TA1537 with or without metabolic activation (Kawachi *et al.*, 1981; Morita *et al.*, 1981). In a chromosomal aberration study using

mammalian cells, the results were negative with or without metabolic activation (Kawachi *et al.*, 1981; Ichidate *et al.*, 1977). Polysorbate 80 was not genotoxic in two rodent micronucleus assays (Jenssen and Ramel, 1980; Scott and Topham, 1982); it was also negative in a dominant lethal study (Anderson *et al.*, 1977).

Carcinogenicity

There are no carcinogenicity studies on Polysorbate 20 that meets current standards.

Male and female Wistar rats were given in their feed 0, 5, 10 or 20% Polysorbate 60 for two years. There was no increased incidence of tumors in the Polysorbate 60-treated animals compared to the controls (Oser and Oser, 1957). In another two-year dietary study, there were no increased incidence of tumors in male and female Osborne-Mendel rats given 2, 5, 10 or 25% Polysorbate 60 (Fitzhugh *et al.*, 1959).

Male and female F344/N rats were given in their diet 0, 25,000, or 50,000 ppm Polysorbate 80 for up to 103 weeks. There were no significant changes in absolute or relative organ weights. The mean body weights in the treated male and female rats were similar to those of the controls throughout the studies. No clinical findings were associated with administration of Polysorbate 80. The survival of the treated males was lower than that of the controls. The incidence of adrenal medulla pheochromocytoma was marginally increased in high-dose males. The slight increase in incidence of pheochromocytoma in the high-dose males was judged to be of questionable significance based on historical control data. The incidence of adrenal medulla hyperplasia was increased in the 25,000 ppm males, but not in the 50,000 ppm males. The marginal increased incidence of pheochromocytoma in combination with increased incidence of hyperplasia were considered to be an equivocal finding (NTP, 1992a).

Male and female B6C3F_1 mice were given 0, 25,000, or 50,000 ppm Polysorbate 80 for up to 103 weeks. There were no significant changes in absolute or relative organ weights. Incidences of hyperplasia and inflammation of the forestomach were increased in females that received 50,000 ppm. The mean body weights in the treated males were similar to those of the controls throughout the studies. The final mean body weight of 50,000 ppm females was 11% lower than that of the controls. No clinical findings were associated with administration of Polysorbate 80. Survival were similar between the treated and control mice. No chemical-related increases in the incidences of neoplasms occurred in male or female mice. The incidences of squamous hyperplasia and inflammation of the forestomach were significantly increased in high-dose male and female mice; forestomach ulcers were significantly increased in high-dose females (NTP, 1992a).

Reproductive/Developmental Toxicity

Pregnant Sprague-Dawley rats were given by oral gavage 0, 500 or 5,000 mg/kg Polysorbate 20 during gestation days (GD) 6-15. There was no maternal toxicity, and

there was no significant differences in body weight between treated and control animals. Maternal weight gain during GD 6-15 was decreased by 14% in the high-dose group relative to control animals. There was no treatment-related effects on organs weights, number of corpora lutea per dam, the number of implantation sites per dam or the percent preimplantation loss per litter. There was also no adverse effects on the growth, viability or morphological development of the conceptuses. The maternal and developmental NOAELS for this study were considered to be 500 and 5,000 mg/kg/day, respectively (NTP, 1992b).

Key Study/Critical Effect for Screening Criteria

In 1973, the Joint FAO/WHO Expert Committee on Food Additives (JECFA) evaluated the effects of Polysorbates 20, 40, 60, 65, and 80 when used as food additives. JEFCA established an ADI of 0-25 mg/kg/day for the group of Polysorbates (JECFA, 1973). The study on which the ADI was based was the two-year feeding study by Fitzhugh *et al.*, 1959, in which the NOAEL was determined to be 5% (equivalent to 2,500 mg/kg/day).

In 1978, the EU's Scientific Committee on Food (SCF) evaluated the safety of polysorbates, mainly based on the two-year feeding study on Polysorbate 60 (SCF, 1978). SCF assigned an interim ADI of 0-25 mg/kg/day for the polysorbate group, but requested data from a 90-day oral toxicity study and a metabolism study in one animal species, which SCF considered necessary for a final evaluation.

In 1983, the SCF conducted a re-evaluation based on a 13-week oral study in which rats were fed 0, 1, 2 or 5% Polysorbate 60 (equivalent to 500, 1,000 or 2,500 mg/kg/day, respectively) (BIBRA, 1981). SCF accepted a review of the existing metabolism data in lieu of the requested data in 1978 (SCF, 1978). A permanent group ADI for the polysorbates was established at 0-10 mg/kg/day, after application of a 100-fold uncertainty factor to the lowest NOAEL of 2% in the diet from the 13-week feeding study. In 1992, SCF further evaluated the ADI for the polysorbates, in light of the recently conducted NTP bioassay on Polysorbate 80 (NTP, 1992), and concluded that the ADI need not be changed (SCF, 1993).

The U.S. FDA has established a group ADI for the polysorbates at 1,500 mg/person/day (0-25 mg/kg/day). (FDA, 1999).

The ADI of 25 mg/kg/day established by JECFA and the U.S. FDA will be the basis of the oral RfD and drinking water guideline for sorbitan, monododecanoate poly(oxy-1,2-diethanediyl) [Polysorbate 20] since the findings of the 13-week rat feeding study (BIBRA, 1981), which was the basis for the ADI established by SCF, is unavailable for review.

Oral RfD = 2,500/100 = 25 mg/kg/day

Drinking water guideline value = 87.5 ppm

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Toxicity Profile

Sulfuric acid
(CAS No. 7664-93-9)

Sulfuric acid (H_2SO_4) will dissociate completely in aqueous media at physiological pH to H^+ and SO_4^{2-}. The pK_a of sulfuric acid is 1.92.

Acute Toxicity

The oral LD_{50} in rats was reported to be 2,140 mg/kg (Smyth *et al.*, 1969). The acute LC_{50} values are: 0.375 to 0.425 mg/L for rats; 0.6 to 0.85 mg/L for mice; and 1.47 to 1.61 mg/L for rabbits (OECD, 2001).

Irritation

Undiluted sulfuric acid is corrosive to the skin and eyes (OECD, 2001). A 10% solution of sulfuric acid in water has been shown to be non-irritating to the skin of rabbits, guinea pigs and humans (Nixon *et al.*, 1975; 1990). Instillation of 0.1 ml of a 10% solution of sulfuric acid was shown to be non-irritating to the eyes of rabbits when added to the conjunctival sac (Jacobs and Martens, 1989; Jacobs, 1992). Other studies which added a 10% solution of sulfuric acid directly to the eyes of rabbits showed severe irritation (Griffith *et al.*, 1980; Murphy *et al.*, 1982).

Sensitization

No animal sensitization studies have been conducted on sulfuric acid. There have been no reported cases of dermal sensitization in humans (OECD, 2001).

Repeated Dose Toxicity

There have been a number of repeat dose toxicity studies conducted by the inhalation route on sulfuric acid, but no studies were located by the oral or dermal routes.

Genotoxicity

Sulfuric acid was not mutagenic in the Ames test using various strains of *S. typhimurium* and in *E. coli* with and without metabolic activation (OECD, 2001). No *in vivo* genotoxicity studies have been conducted on sulfuric acid.

Carcinogenicity

Animal carcinogenicity studies have been conducted with sulfuric acid solutions or mists. These studies cannot be used for risk assessment purposes due to significant methodological deficiencies.

Reproductive/Developmental Toxicity

No studies were found.

Key Study/Critical Effect for Screening Criteria

No toxicity studies on sulfuric acid were identified. The Australian drinking water guideline values are available for pH (H^+) and sulfate which could applicable to sulfuric acid.

References

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Toxicity Profile

Talc
(CAS No. 61789-40-0)

Talc refers to both mineral talc and industrial mineral products that are marketed under the name talc and contain proportions of mineral talc that range from about 35% to almost 100%. Industrial talc generally refers to products that contain abundant minerals other than talc; cosmetic talc now normally contains >98% talc but the content may have been lower in the past. Pharmaceutical talc contains >99% talc. Talcum powder is cosmetic-grade talc.

Talc is a mineral composed of hydrated magnesium silicate with the chemical formula $Mg_3Si4O_{10}(OH)_2$ or $H_2Mg_3(SiO_3)_4$. Talc is not soluble in water.

The U.S. Food and Drug Administration (FDA) regulates talc and states that it is generally recognized as safe for use in color additives in foods, drugs and cosmetics, and in paper, paper products, cotton and cotton fabrics that come into contact with food. The Food Chemical Codex (2003) provides specifications for food-grade talc, including the statement that "talc derived from deposits that are known to contain associated asbestos is not food grade." Under the voluntary guidelines initiated in 1976, the Cosmetic, Toiletry, and Fragrances Association stated that all cosmetic talc should contain at least 90% platy talc (hydrated magnesium silicate) that is free from detectable amounts (<0.5%) of fibrous, asbestos minerals.

Toxicokinetics (Oral)

The absorption and disposition of ^{3}H-labeled talc in rats, mice, and guinea pigs administered a single oral dose was studied by Phillips *et al.* (1978). The oral doses were 50 mg/kg for rats, 40 mg/kg for mice, and 25 mg/kg for guinea pigs. In rats, mice, and guinea pigs, more than 95% of the dose was excreted in the feces 3 to 4 days after dosing. Less than 2% of the radioactivity was recovered in the urine. This radioactivity probably reflected contamination of urine samples with feces. No radioactivity was found in the liver or kidneys of these animals. This information suggests that talc is not absorbed from the gastrointestinal tract following oral exposure.

Acute Toxicity

No data were located.

Repeated Dose Toxicity/Carcinogenicity

Male and female Wistar rats were given in their diet 0 or 50 mg/kg of commercial talc [characteristics unspecified] for the life of the animals (average survival was 702 and 649 days, respectively). There was no significant difference in the talc-fed animals compared with control animals (Gibel *et al.*, 1976).

Male and female Wistar-derived rats were given in their diet 100 mg Italian talc (grade 00000; ready milled; mean particle size, 25 μm; containing 92% talc, 3% chlorite, 1% carbonate minerals and 0.5–1% quartz) per rat per day for 5 months (talc-containing diet was actually given for 101 days) and were then maintained on basal diet for life (average survival, 614 days). No differences in tumor incidence were noted between treated animals and control animals (eight/sex for an average survival of 641 days) (Wagner *et al.*, 1977).

In humans and experimental animals, the effects of talc are dependent on the route of exposure, and the dose and properties of the talc. Talc pneumoconiosis was somewhat more prevalent and severe among miners exposed to talc containing asbestiform minerals and/or asbestos than among those exposed to talc without such contaminants. However, the role of quartz and asbestos in the observed pneumoconiosis could not be ruled out. Among drug users, intravenous injection of talc present as a filler in the drugs resulted in microembolization in a variety of organs and alterations in pulmonary function. In animal studies, talc has been shown to cause granulomas and mild inflammation when inhaled. Observations of the effects that occurred in the lungs of rats exposed by inhalation to talc suggested that the operative mechanisms may be similar to those identified for carbon black, and talc is known to cause the release of cytokines, chemokines and growth factors from pleural mesothelial cells.

IARC: There is *inadequate evidence* in humans for the carcinogenicity of inhaled talc not containing asbestos or asbestiform fibres. There is *limited evidence* in experimental animals for the carcinogenicity of talc not containing asbestos or asbestiform fibres. Inhaled talc not containing asbestos or asbestiform fibres is *not classifiable as to its carcinogenicity (Group 3).*

Genotoxicity

The IARC (1987) review of talc included unpublished results from a 1974 study conducted by Litton Bionetics that showed no mutagenic activity for talc *in vitro* or *in vivo.* Talc did not induce mutations in *Salmonella typhimurium* strains TA1530 or HisG46, or in the yeast, *Saccharomyces cerevisiae.* No chromosomal aberrations were observed in human fibroblasts treated with talc *in vitro. In vivo* tests conducted in rats gave negative results for induction of chromosomal aberrations in bone marrow cells and dominant lethal mutations in germinal cells.

Three samples of respirable talc failed to elicit significant unscheduled DNA synthesis (10, 20 and 50 μg/cm^2, 24 hours), sister chromatid exchange or aneuploidy (2, 5, 10 and 15 μg/cm^2, 48 hours) in rat pleural mesothelial cells, in contrast to various positive controls. The three samples, *i.e.* Spanish talc (No. 5725), Italian talc (No. 5726) and French talc (No. 7841), contained 90–95% talc; the remaining contents were chlorite and dolomite. Electron microscopy analysis revealed that talc particles were taken up by the rat pleural mesothelial cells, but no aneuploidy was observed in metaphases (Endo-Capron *et al.*, 1993).

Reproductive Toxicity

No data are available.

Developmental Toxicity

No teratologic effects were observed in hamsters, rats, mice, or rabbits after oral administration of talc. The doses used were 1,600 mg/kg for rats and mice on days *6* through 15 of gestation; 1,200 mg/kg for hamsters on day 6 through 10 of gestation; and 900 mg/kg for rabbits on days 6 through 18 of gestation.

Key Study/Critical Effect for Screening Criteria

There are no adequate studies for which to derive a oral reference dose. Talc is poorly absorbed from the gastrointestinal tract, if at all, and the limited data available by the oral route indicate that talc is essentially non-toxic by the oral route of exposure.

References

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Toxicity Profile

Tributyl Tetradecyl Phosphonium Chloride [TTPC]
(CAS No. 81741-28-8)

Limited toxicity information was located for this alkyl phosphonium salt.

Acute Toxicity

An oral LD_{50} in rats was reported to be 1,002 mg/kg. The 4-hour LC_{50} to rats is <0.9 mg/L (aerosol).

Irritation

TTPC is corrosive to the skin and eyes.

Sensitization

TTPC is not a skin sensitizer.

Repeated Dose Toxicity

No data were found.

Genotoxicity

TTPC tested negative in an Ames test.

Carcinogenicity

No data were found.

Reproductive Toxicity

No data were found.

Developmental Toxicity

No data were found.

Key Study/Critical Effect for Screening Criteria

No data are available for determining the critical effect and the LOAEL/NOAEL for an oral reference dose.

Reference

Material Safety Data Sheet for Bellacide 350, BWA Water Additives, SDS No. 10794, Report Date: 10/03/2009.

Santos

APPENDIX F.4 SCHLUMBERGER CLEARFRAC XT

Toxicity Profile

Acetic acid
(CAS No. 64-19-7)

Acetic acid dissociates in aqueous media to H^+ and the acetate anion ($CH_3CO_2^-$). It is naturally occurring as the acid in apple cider vinegar and other fruit-derived products. It and several of its salts are commonly used as food additives (*e.g.*, as flavor enhancers) and are listed as Generally Recognized as Safe (GRAS) by the U.S. Food and Drug Administration (FDA).

pH: 2.5 at 50 g/L and 20°C
pK_a: 4.76 @ 20°C

Acute Toxicity

The oral LD_{50} in rats is 4,950 mg/kg, and the dermal LD_{50} in rabbits is 1,060 mg/kg. The 4-hour LC_{50} in rats is 11.4 mg/L.

Irritation

In the EU, acetic acid is classified as a skin and eye irritant at concentrations <25%. At ≥25%, it is classified as corrosive to the skin.

Sensitization

No data are available.

Repeated Dose Toxicity

In an 8-month study, rats dosed with 60 mg/kg acetic acid (three times per week) developed hyperplasia in the esophagus and forestomach.

Genotoxicity

Acetic acid was not mutagenic to *Salmonella typhimurium* strains TA 98, TA 100, TA 1535, TA 1537, and TA 1538 in an *in vitro* bacterial mutation assay with or without metabolic activation. Acetic acid (in media adjusted to a pH of 8.5) was also not genotoxic in an *in vitro* chromosomal aberration test using Chinese Hamster Ovary cells with or without metabolic activation.

Carcinogenicity

No adequate carcinogenicity studies have been conducted on acetic acid.

Reproductive Toxicity

No studies could be located.

Developmental Toxicity

There were no effects on implantations or on maternal or fetal survival in mice, rats, or rabbits at doses up to 1,600 mg/kg.

Key Study/Critical Effect for Screening Criteria

There are no repeat dose toxicity studies that were considered adequate for human health risk assessment. The only study reported on the toxicity of acetic acid by oral gavage showed effects of irritation (probably due to the pH of acetic acid) at the site of contact in the gastrointestinal tract. No systemic effects were reported.

The Joint FAO/WHO Expert Committee on Food Additives (JECFA) has maintained a group ADI of "not limited" for acetic acid and its potassium and sodium salts.

The Australian drinking water guidance value for pH may apply to acetic acid.

References

ECHA REACH: http://apps.echa.europa.eu/registered/registered-sub.aspx

JECFA: http://apps.who.int/ipsc/database/evaluations/chemical.aspx?chemID=4785

U.S. EPA HPVIS database: http://www.epa.gov/chemrtk/hpvis/index.html

Toxicity Profile

Reaction mass of 5-chloro-2-methyl-4-isothiazolin-3-one and 2-methyl-2H-isothiazolin-3-one [3:1]
(CAS No. 55965-84-9)

Acute Toxicity

The oral LD_{50} of Kathon WT (1.5% a.i.) is >5,000 mg/kg (>75 mg a.i./kg) in male rats and >3,310 mg/kg (~49.6 mg a.i./kg) in female rats. The oral LD_{50} of Acticide 14 (14% a.i.) is 472-490 mg/kg (~66 to 69 mg a.i./kg) in rats (combined sexes); and 465 mg/kg (69 mg a.i./kg) in male rats and 393 mg/kg (59 mg a.i./kg) in female rats.

The dermal LD_{50} of Kathon CG is >5,000 mg/kg (>75 mg a.i./kg) in female rabbits. The dermal LD_{50} of Acticide 14 (14% a.i.) is 1,008 mg/kg (141 mg a.i./kg) in rats (combined sexes).

The inhalation LC_{50} of Kathon 886F (13.9% a.i.) in male and female rats is 2.36 mg/L (0.33 mg a.i./L).

Irritation

Undiluted Kathon MW (1.5% a.i.) and Acticide 14 (14% a.i.) were corrosive to rabbit skin. Undiluted Kathon CG was severely irritating to the eyes of rabbits. Kathon RH 886T at 100 ppm (0.01% a.i.) was non-irritating to the eyes of rabbits.

Sensitization

CMI/MI has been tested in the guinea pig Buehler and Magnusson-Kligman tests and has been shown to be a strong skin sensitizer. It is also a strong contact allergen in humans.

Repeat Dose Toxicity

Rats were exposed to CMI/MI in a powdered commercial diet. CMI/MI concentrations were increased over the 13-week period (initial concentration up to week 2, intermediate concentration week 3-4, final concentration week 5 to 13). Concentrations in the control and CMI/MI groups were: 0/0/0, 40/57/80, 132/187/260, 400/570/800 ppm. There were no mortalities and no effects on body weight or food consumption. In each group, some animals showed slight alopecia or reddened raw or scabbed areas on the skin. There were no other differences in general behavior or appearance. There were no treatment-related changes in hematological, biochemical, urinary parameters nor any pathology. No systemic toxicity was observed up to and including the highest dose of either CMI/MI

(800 ppm, equivalent 29.1 mg a.i./kg/day). The NOAEL in this study is 800 ppm (29.1 mg a.i. /kg/day).

Rats were exposed to CMI/MI via their drinking water at concentrations of 25, 75 or 225 ppm a.i. for three months (equivalent to an average intake of 2.38, 6.28 and 16.3 mg/kg/day in males and 4.06, 10.8, and 24.7 mg/kg/day in females). Two additional groups of rats were given tap water or tap water containing the inorganic ions present in the CMI/MI solution, at a concentration equal to that in the high dose group (225 ppm). This solution is referred to as the ion control solution. There were no mortalities in either sex at any dose level. There were no treatment-related effects on body weight up to the mid dose. A significant decrease in body weight was seen in males at the high dose during the first two weeks of the study. Food consumption was significantly decreased in males at all dose levels and in females mid and high dose groups during the first few weeks of dosing. Water consumption was significantly decreased at all concentrations. No overt clinical signs or ophthalmic were seen in any group throughout the 13 week toxicity or the reproductive phase. No adverse effects were seen in the examinations. No hematological treatment-related changes were seen in either sex at any dose level. There was a significant decrease in globulin and an increase in the albumin/globulin (A/G) ratio in males in both the high concentration and in the ion control groups, after 13 weeks of treatment. A significant decrease in total protein was also seen high concentration group, but was not seen in the ion control group. Females in the high concentration group showed a modest (40%) increase in SGOT (AST, aspartate aminotransferase) levels after 13 weeks of dosing. No changes were observed at any dose in mixed-function oxidase activities of the liver. At the end of 13 weeks of treatment, there was a significant increase in relative liver weight in males and in relative kidney weight in females at the high concentration but without any correlative changes in organ pathology. Histology revealed a local irritation of the glandular mucosa of the stomach in 7 of 15 males and 5 of 15 females at the high concentration. These subtle low level changes did not occur at the low or mid concentration nor were they present in either control group. No other compound related changes were seen. Reproductive organs at all doses were comparable to the control. The NOEL in this study was considered to be 75 ppm a.i. (equivalent to 6.28 and 10.8 mg/kg body weight/day in males and females, respectively), based primarily on irritation of the glandular stomach at the high dose. The No Observed Adverse Effect Level (NOAEL) is 225 ppm a.i. (equivalent to 16.3 and 24.7 mg/kg body weight/day in males and females, respectively), the highest dose tested, since no adverse effects were observed on the histopathology of any tissues or organs distant from the site of dosing.

Genotoxicity

The results of the *in vitro* mutagenicity tests were equivocal. In bacterial reverse mutation tests, CMI/MI was positive in *Salmonella* strain TA100 but was predominantly negative in other strains commonly tested strains. CMI/MI was mutagenic in the mouse lymphoma assay with and without metabolic activation. Effects at the Tk locus was seen both with and without S-9, but were enhanced with S9 mix. CMI/MI was not genotoxic

in the *in vitro* unscheduled DNA synthesis (UDS) assay with primary rat hepatocytes or in an *in vitro* chromosomal aberration test with Chinese hamster lung cells.

The *in vivo* studies indicated that CMI/MI does not have relevant mutagenic potential *in vivo*. The positive mutagenic effect of CMI/MI found in *in vitro* gene mutation assays was not confirmed in the sex-linked recessive lethal test in *Drosophila melanogaster* nor in two unscheduled DNA synthesis (UDS) studies in the rat. CMI/MI also did not show any increase in cells with micronuclei in mice nor did it induce chromosomal aberrations in rat bone marrow cells.

Carcinogenicity

In a two-year rat chronic study, Kathon 886 is given as 14.2% active ingredient with a pH between 2-3. In the document with compiled batch information for Kathon the active ingredient is 13.2, [10.13 % CMI/ 3.85% MI] with 15.4% magnesium nitrate and 9.0% magnesium chloride. The dose levels were 0, 30, 100 and 300 ppm (equivalent to: 0, 2.0, 6.6, 17.2 mg a.i./kg/day in males and 0, 3.1, 9.8, 25.7 mg a.i./kg/day in females. There were no deaths. There were no treatment-related effects on body weight or body weight gain at doses or food consumption up to and including the mid dose group. A treatment-related and concentration-dependent decrease in water consumption was seen in both sexes in all treated groups throughout the study. These decreases ranged from 0-22% at low dose 3-30% at mid dose and 15-40% at high dose. These decreases appear to be due to the unpalatability of the CMI/MI and not its inorganic stabilizer salts since the water consumption in the salt control was comparable to the tap water control throughout the study. Based on the average daily water consumption, the high dose was judged to be a maximum tolerated dose. The decreases in body weight and body weight gain were seen in high dose animals throughout the study and may be secondary to decreased water consumption. No treatment-related clinical effects were recorded. No treatment-related ophthalmic, hematological. biochemical or urinary changes were noted. Organ weights were comparable to the control. No effects on type or incidence of neoplasms were seen at up to and including the high dose (males: 17.2 a.i.; females 25.7 mg a.i./kg/day). Slight to moderate forestomach hyperplasia was seen at both mid and high dose groups. Gastric irritation was the primary effect observed. No adverse effects on the histopathology of any other tissues/organs were observed away from the site of dosing. No systemic effects were observed. The NOEL in this study was considered to be 30 ppm a.i. (2.0 to 3.1 mg a.i./kg/day), based primarily on gastric irritation of the stomach at 100 and 300 ppm a.i.. The NOAEL was considered to be 300 ppm a.i. (17.2 to 25.7 mg/a.i./kg/day), since no evidence of systemic toxicity was observed at any dose and there was no adverse effects on the histopathology of any tissues/organs distant from the site of dosing at any dose.

Reproductive/Developmental Toxicity

A one-generation reproductive toxicity study was combined with the 13-week drinking

water study reported above in the repeated dose toxicity section. Reproductive capability was similar in all groups. Litter size and survival at birth was also similar in all groups. One dam at the high concentration lost the entire litter by day 4 due to a lactation problem. This is not uncommon and was not considered treatment related. Pups of the other high concentration group dams, except one, survived and thrived to day 21. Thus, no adverse effects were observed on reproductive capability of male and female rats and no effects were observed on fetal health or pup survival (to day 21) up to and including the high dose (equivalent to 16.3 and 24.7 mg/kg/day in males and females, respectively].

In a two-generation reproductive toxicity study, rats were dosed with CMI/MI (Kathon 886F: 11.1% CMI, 3.7% MI a.i.) at concentrations of 0 (control), 0 (magnesium salt control), 30, 100 or 300 ppm a.i. For the P1 generation, this was equivalent to 0, 2.8-4.4; 8.5-11.8, and 22.7-28.0 mg a.i./kg/day; and in the P2 generation 0, 4.3-5.5, 13.4-16.0, and 35.7-39.1 mg a.i./kg/day. There were no treatment related effects on survival, food consumption or overt signs of toxicity. A decrease in bodyweight gain was noted initially in the P1 generation. This was thought to be linked to reduced water consumption since significant dose-related reduction in water consumption was seen at all concentrations in both the P1 and P2 generations, during the premating, gestation and lactation stages. Treatment-related histopathological changes were seen in the stomach in the P1 and P2 generation. These included erosions of the glandular mucosa, edema and inflammation in the submucosa of the glandular and nonglandular stomach, with hyperplasia and hyperkeratosis of the nonglandular stomach at the 100 and 300 ppm a.i. Other histopathological changes were seen but were not dose dependent.The estrus cycle in P1 or P2 females at any treatment level was comparable with the controls, as was the sperm motility, morphology, testicular sperm count or caudal epididymal reserves of P1 or P2 males. All other endpoints (gestation index, gestation length, number of pups per litter or treatment-related gross findings in F1 or F2 pups) were similar to those in the controls in either generation. The study authors considered that rats exposed to CMI/MI in the drinking water through two generations had a NOAEL of 30 ppm a.i. (2.8-4.4 mg/kg/day in the P1 animals; 4.3-5.5 mg/kg/day in the P2 animals) for parental animal toxicity, based on the gastric irritation of stomach at higher doses. The NOEL for reproductive toxicity is 300 ppm a.i. (22.7-28.0 mg/kg/day in the P1 animals; 35.7-39.1 mg/kg/day in the P2 animals), the highest dose tested. There were no effects on fertility or fetal development at any dose level.

In a rat oral gavage developmental toxicity study on Kathon 886 (13.9% a.i.), the developmental NOEL for CMI/MI is >15 mg a.i./kg during organogenesis (highest dose tested). In a rat oral gavage developmental toxicity study on Acticide 14 (10.2% CMi/ 4% MI), the NOAEL for maternal toxicity is <3.95 mg a.i./kg; the NOAEL for teratogenicity is >19.6 mg a.i./kg; and the NOAEL for embryotoxicity is >19.6 mg a.i./kg. In a rabbit oral gavage developmental toxicity study on Acticide 14 (10.2% CMI/ 4% MI), the developmental NOAEL is >5.49 mg a.i./kg; the NOAELs for maternal toxicity and fetal toxicity are 1.41 mg a.i./kg. In a rabbit oral gavage developmental toxicity study on Kathon MW (13.9% a.i.), the NOEL for maternal toxicity is 2 mg a.i./kg; the developmental NOEL is 8 mg a.i./kg, the highest dose based on severe

maternal toxicity at 20 mg a.i./kg.

Key Study/Critical Effect for Screening Criteria

A two-year dietary study was conducted in rats with CMI/MI (13.2% active ingredient). No systemic effects were observed. There was, however, gastric irritation of the stomach at 100 and 300 ppm. The NOEL for this study is 30 ppm (equivalent to 2.0 and 3.1 mg a.i./kg/day for males and females, respectively). The NOEL of 2.0 mg/kg/day will be used for deriving a drinking water guidance value.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral Reference Dose = 2/100 = 0.02 mg/kg/day

Drinking water guidance value = 0.07 ppm

Reference

EU SCCS (2009). Opinion on the mixture of 5-chloro-2-methyl-4-isothiazolin-3-one and 2-methyl-2H-isothiazol-3-one [3:1], Colipa N^{o} P56, Scientific Committee on Consumer Safety, SCCS/1238/09.

Toxicity Profile

Choline chloride
Cholinium chloride
(CAS No. 67-48-1)

Choline chloride, also known as cholinium chloride, is a quaternary amine salt. It dissociates in water into the corresponding positively charged quaternary hydroxyl alkylammonium ion and the negatively charged chloride ion.

Choline chloride has been reviewed in the OECD-SIDS program (OECD, 2004).

Acute Toxicity

The oral LD_{50} in rats was reported to be between 3,150 and 5,000 mg/kg (BASF AG, 1963a, 1969).

Irritation

Application of a 70% aqueous solution to the skin of rabbits for 20 hours under occlusive conditions resulted in only minor skin irritation (BASF AG, 1963b). Slight eye irritation was seen in the eyes of rabbits after instillation of a 70% aqueous solution of choline chloride; no effects were seen one day after exposure (BASF AG, 1963c).

Sensitization

No data are available in animals. In a Human Repeated Insult Patch Test, there was no evidence of dermal sensitization in two hundred subjects given 0.5% (w/v) aqueous solution of choline chloride during the induction phase and 0.2% (w/v) aqueous solution during the challenge phase (Colgate-Palmolive, 2003).

Repeated Dose Toxicity

A 72-week feeding study was conducted to investigate the impact of choline chloride on the liver tumor promoting activity of phenobarbital and DDT in diethylnitroamine-initiated Fischer 344 rats (Shivapurkar *et al.*, 1986). Animals received approximately 500 mg/kg-day choline chloride. Following the end of the exposure period, the animals were keep on the same untreated diet as the control group until study termination at week 103. Histopathology was limited to the liver and organs that developed gross abnormalities. There were no significant differences between treated and control animals on survival rates, body weights, and relative liver weights. Neither was there any

increased number of neoplastic liver nodules, hepatocellular carcinomas, lung tumors, leukemia nor other tumors between treated and control animals. The NOAEL for choline chloride in this study is 500 mg/kg/day.

In humans, oral administration of 10,000 mg/day choline chloride in a pilot study treating a small number of patients with Alzheimer's disease, resulted in a slight hypotensive effect (Boyd *et al.*, 1977). This dose was regarded as a LOAEL by the Standing Committee on the Scientific Evaluation of Dietary Reference Intake (2000).

Genotoxicity

Choline chloride was not mutagenic to bacteria in reverse mutation assays (Haworth *et al.*, 1984; JETOC, 1997; Litton Bionetics, 1977).

A small, but statistically significant, and dose-related increase in sister chromatid exchanges (SCEs) in Chinese Hamster Ovary (CHO) cells was reported at 50 and 500 μg/ml choline chloride in the absence of S9 only (Bloom *et al.*, 1982). No higher concentrations were examined. These results could not be confirmed in another study using CHO cells at concentrations of choline chloride up to 5,000 μg/ml. (Galloway *et al.*, 1985).

In a gene conversion assay with *Saccharomyces cerevisiae* strain D4, choline chloride was negative in the presence and absence of metabolic activation (Litton Bionetics, 1977).

No *in vivo* genotoxicity studies were available.

Carcinogenicity

No studies were located.

Reproductive Toxicity

No reliable studies have been conducted that address female fertility or reproductive toxicity by a relevant route of exposure.

Developmental Toxicity

Pregnant female mice were given in their feed 1,250 to 20,000 mg/kg choline chloride during gestational days 1 to 18 (BASF AG, 1966). Maternal body weight gain was reduced in all treated groups except for the 1,250 mg/kg group. Determination of maternal weight gain of dams with embryonic/fetal absorptions showed that there was no

almost net weight gain at ≥4,160 mg/kg and net weight loss in the 20,000 mg/kg group. All fetuses were resorbed in the 20,000 mg/kg group. Embryonic/fetal lethality of 35% and 69% were seen in the 4,160 and 10,800 mg/kg groups, respectively. No resorptions occurred in the 1,250 mg/kg group. Developmental toxicity was seen in all but the 1,250 mg/kg group. No statistically significant increases in malformations were observed in any dose group. The NOAELs for maternal and developmental toxicity is 1,250 mg/kg/day.

Key Study/Critical Effect for Screening Criteria

The Standing Committee on the Scientific Evaluation of Dietary Reference Intakes selected hypotension as the critical effect from the study by Boyd *et al.* (1977) when deriving a Tolerable Upper Intake Level. Boyd *et al.* (1977) reported a LOAEL of 10,000 mg/day choline chloride (7,500 mg/day choline). An uncertainty factor of 2 was chosen because of the limited data regarding hypotension and the inter-individual variation in response to cholinergic effects. Thus, the value for the Tolerable Upper Intake Value for repeated exposure of adults to choline is 3,500 mg/day choline.

The oral RfD for choline chloride is derived by using the LOAEL of 10,000 mg/day from the Boyd *et al.* (1977) study, which is divided by an uncertainty factor of 2, to obtain a value of 5,000 mg/day or 71 mg/kg/day for a 70 kg person.

Oral RfD = 71 mg/kg/day

Drinking water guideline value = 248 ppm

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BASF AG (1963c). Toxicity of choline chloride 70% in water; eye irritation. Department of Toxicology. Unpublished results. Study No. XIII 9. 01 Mar. 1963.

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Standing Committee on the Scientific Evaluation of Dietary Reference Intake. Institute of Medicine (2000). Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline. National Academy Press, Washington D.C.

Toxicity Profile

Crystalline Silica, Cristobalite
(CAS No 14464-46-1)

Crystalline Silica, Quartz
(CAS No. 14808-60-7)

Silica is an off-white granule that occurs naturally in various crystalline and amorphous or other non-crystalline forms. Crystalline silica is characterized by silicon dioxide (SiO_2) molecules oriented in fixed, periodic patterns to form stable crystals. The primary crystalline form of silica is quartz. Other crystalline forms of silica include cristobalite, tripoli and tridymite. Particle size is a key determinate of silica toxicity, since toxicity is restricted to particles that are small enough to be deposited into the target regions of the respiratory tract.

Oral Exposure

No oral studies were located; however, crystalline silica is not expected to exhibit toxicity by the oral route. Although absorption studies were not found for crystalline silica, kinetic studies on amorphous silica show no absorption from the gastrointestinal tract.

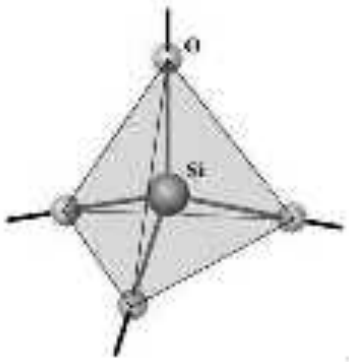
Dermal Exposure

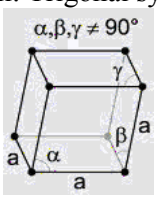
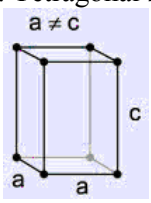
No dermal studies were located; however, crystalline silica is not expected to exhibit toxicity by the dermal route.

Inhalation Exposure

See attached OECD-SIDS Initial Targeted Assessment Profile on Quartz and Cristobalite, SIAM 32, 19-21 April 2011.

INITIAL TARGETED ASSESSMENT PROFILE (Human Health)

CAS No.	Quartz: CAS RN 14808-60-7 Cristobalite: CAS RN 14464-46-1
Chemical Name	Quartz and Cristobalite
Structural Formula	Molecular Formula: SiO_2 

Unit Cell: Trigonal symmetry	Unit Cell: Tetragonal symmetry
	
Quartz: CAS RN 14808-60-7	Cristobalite: CAS RN 14464-46-1

SUMMARY CONCLUSIONS OF THE TARGETED ASSESSMENT

NOTE: The present assessment is targeted to address the following human health endpoints: repeated dose toxicity and carcinogenicity via the inhalation route of exposure, and genotoxicity. It cannot be considered as a full SIDS Initial Assessment. Summary information on exposure is also reported here. Other endpoints for human health and the environment included in the Canadian screening assessment but have not been presented to OECD member countries, and thus are not included in this profile.

The final screening assessment will be published under the responsibility of the Government of Canada.

Rationale for Targeting the Assessment

The Government of Canada "categorized" or prioritized all 23,000 chemical substances on its Domestic Substances List (DSL) from 1999 to September 2006, as required by its *Canadian Environmental Protection Act, 1999* (CEPA 1999). Additional details may be found at http://www.chemicalsubstanceschimiques.gc.ca/about-apropos/categor/index-eng.php. Using information from Canadian industry, academic research and other countries, Government of Canada scientists applied a set of rigorous tools to the 23,000 chemical substances on the DSL. They were categorized to identify those that were: **inherently toxic** to humans or to the environment and that might be **persistent** and/or **bioaccumulative**; and substances to which people might have **greatest potential for exposure**. During this priority-setting exercise, distinct approaches were taken for identifying substances of likely concern for human health and the environment, and subsequent assessment activities may have focused on either human health or ecological endpoints. Through categorization, the Government of Canada has identified approximately 4,000 of the 23,000

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chemical substances on the DSL as priorities for further assessment, research and/or measures to control their use or release. Quartz and cristobalite were identified at that time, applying the categorization criteria, as high priorities for human health risk because they were considered to pose greatest potential for exposure and their respirable forms are classified by the International Agency for Research on Cancer as carcinogenic to humans (quartz and cristobalite) and by the National Toxicology Program as known human carcinogens (crystalline silica). These substances did not meet the ecological categorization criteria for bioaccumulation potential or inherent toxicity to aquatic organisms.

Under the Canadian legislation a determination of whether one or more of the criteria of the CANADIAN ENVIRONMENTAL PROTECTION ACT (CEPA) 1999, section 64 are met is based upon an assessment of potential risks to the environment and/or to human health associated with exposures in the general environment. For humans, this includes, but is not limited to, exposures from ambient and indoor air, drinking water, foodstuffs, and the use of consumer products. A conclusion under CEPA 1999 on the substances in the Chemicals Management Plan (CMP) Challenge is not relevant to, nor does it preclude, an assessment against the hazard criteria specified in the Controlled Products Regulations, which is part of the regulatory framework for the Workplace Hazardous Materials Information System [WHMIS] for products intended for workplace use.

Physical-chemical properties

The silicon dioxide group represents a polymorphic category containing a large number of forms identical in composition but with different atomic arrangements which afford different chemical properties. There are two sub-categories within this group: crystalline silica, to which the present substances quartz and cristobalite belong, and non-crystalline or amorphous silica. The key distinction between these sub-categories is that in crystalline substances, the building blocks are arranged in regular, repeating 3-dimensional pattern having long range order, whereas amorphous materials do not display long range order. In all forms of silica, (crystalline and non-crystalline), the silicon atom is tetrahedral and bound to four neighbouring oxygen atoms.

Quartz and cristobalite are solid at room temperature, existing normally as colourless or white crystals. The melting points for quartz and cristobalite are 1400-2000 ^{o}C and 1713-1728 ^{o}C, respectively and for both compounds, the boiling point is 2230^{o}C. Even though no experimental data were available, their vapour pressure and Henry's Law constant are likely negligible. Log K_{ow} (octanol-water partition coefficient) and log K_{oc} (organic carbon-water partition coefficient) are not applicable to these substances. The densities range from 2500-2700 kg/m^3 for quartz and 2300-2380 kg/m^3 for cristobalite.

The very similar physico-chemical properties of quartz and cristobalite reflect their closely related crystal forms. The solubility of crystalline silicates decreases as a function of silica tetrahedral packing density and long-range crystal order. For example, cristobalite has a more open framework structure than quartz and its density is lower, therefore, its solubility is higher. The water solubility of these minerals is also function of temperature, pH, particle size, and the presence of a disrupted surface layer. This may explain the variability of solubility values reported by many authors. The most probable solubility value for quartz is approximately 3.8 mg Si/L, or 6.4 mg/L expressed as the SiO_2 species, while the solubility of cristobalite is approximately 8.7 mg Si/L, or 18 mg SiO_2/L. The kinetics of dissolution of these substances is slow due to the high activation energy required to hydrolyse the Si-O-Si bond.

Human Health Targeted Endpoints

The majority of the studies described here have been reviewed by the International Agency for Research on Cancer (IARC 1997). However, additional data relevant to the screening assessment were identified up to August 2010.

Repeated dose toxicity/non-neoplastic effects (development of silicosis).

Studies on animals

Significant short-term and subchronic studies have demonstrated adverse effects in the lungs, while one of the 6 studies showed effects on the spleen in mice. Rats were exposed to 0, 10 or 100 mg/m^3 of cristobalite via inhalation for 6 hours/day during 3 days. Animals were observed 3 months after exposure. Elevated levels of granulocytes and elevated markers of cytotoxicity from the lung lavage fluid were noted in all exposed groups. Another study of similar duration (9 days) conducted in mice also identified a LOAEC of 10 mg/m^3. Effects observed included minimal interstitial thickening, accumulations of mononuclear cells and slight lymphoid tissue hypertrophy in the lungs.

In a 4-week inhalation study, female rats were exposed to 0, 0.1, 1 or 10 mg/m^3 of quartz 6 hours/day, 5 days/week. Bronchoalveolar lavage fluid was evaluated at 1, 8, and 24 weeks after exposure. Elevated levels of

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granulocytes and significant elevation of markers of cytotoxicity (Lactate dehydrogenase [LDH] and β-glucuronidase [β-glu]) were observed at 1 mg/m^3 and higher. The increased levels of LDH and β-glu were only significant at 24 weeks after exposure. A LOAEC of 1 mg/m^3 was identified at 24 weeks.

Male rats (4 animals per dose) were exposed to 0 or 3 mg/m^3 of cristobalite via inhalation for 6 hours/day, 5 days/week during 13 weeks. Pulmonary inflammation and fibrosis were observed in the exposed group at the end of treatment. When mice were similarly exposed to 5 mg/m^3 of quartz for 6 hours/day, 5 days/week for 15 or 27 weeks, the authors observed increased spleen weight and formation of plaque in the spleen.

In two separate studies, in which rats or hamsters were exposed to quartz via inhalation for at least 6 months, LOAECs of 2 and 3 mg/m^3 were identified, respectively. All the effects observed were related to inflammation and fibrosis of the lung tissue.

Several chronic studies investigated exposure of the respirable forms (i.e. accumulated via inhalation in the lung tissues) of quartz and cristobalite to rats, mice and hamsters. The following is a description of the study in which the lowest non-neoplastic LOAEC was determined. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz, containing 74% of respirable quartz, through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. The mean mass of particle at the end of the exposure period was 0.91 mg/lung. The LOAEC identified was 0.74 mg/m^3 (adjusted for 74% respirable quartz) based on lipoproteinosis, multifocal, inflammatory cell infiltrate and alveolar hyperplasia.

Human epidemiology data

In humans, the lowest observed adverse effect level was identified in a U.S. cohort study. The study was conducted on 3330 gold miners (all are males), who had an average of 9 years underground exposure during the period 1940 to 1965. The cohort was followed up through 1990. Silicosis[1] was identified through death certificates or chest X-rays. A job-exposure matrix together with work history was used to estimate individual exposure. The total silica content in the respirable dust in the mine was estimated at 13% and the median crystalline silica exposure was 0.05 mg/m^3. In this sub population of miners, 170 cases of silicosis were identified. The best predictor for risk of silicosis was cumulative exposure, which varied from less than 1% for a 0.5 mg/m^3-year exposure to 68-84% when exposed to more than 4 mg/m^3-year (based on the average daily dust exposure during the workday each year and summed over time for each miner). The main limitations identified by the authors include the limited number of radiographic surveys, the potential bias from death certificates

[1] Silicosis: Lung disease caused by inhalation of crystalline silica dust, and resulting in inflammation and scarring in forms of nodular lesions in the upper lobes of the lungs. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics). It does not follow that a history of exposure to silica necessarily results in silicosis (Nonsilicotics). The typical "Silicotic" lung nodule is shown in Figure 1.

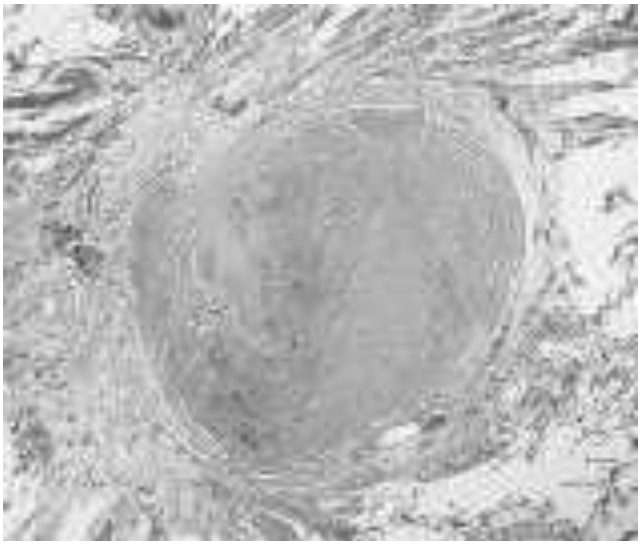


Figure 1. Silicotic nodule characterised by a central zone of hyalinised collagen with a whorled appearance and peripheral dust-containing macrophages (Rees and Murray, 2007).

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(relying on death certificates instead of relying on repeated x-rays, which were lacking for each miner, may have underestimated the number of cases) and the fact that the conversion of dust counts to

gravimetric measurements may not be accurate based on the estimation of 13% silica content in the respirable dust (although based on a relatively large number of samples (n = 82) collected in two different surveys, there was broad range of content in these samples (1% to 48%, SD = 9), and the percentage of respirable quartz may have differed in earlier years, but data were lacking for these years).

Two other human studies have identified similar LOAECs based on the critical endpoint of radiographic confirmed silicosis. A LOAEC of 0.053 mg/m^3 (mean exposure) was identified in a cross sectional study of South African gold miners and a LOAEC of 0.064 mg/m^3 (mean exposure) was derived in a mining community population-based random sample survey in Colorado.

Carcinogenicity studies

Studies on animals

Experimental studies conducted in rats have shown clear and consistent increases in lung tumours after chronic inhalation exposure. In the nine rat studies identified, five were inhalation studies and four were intratracheal instillation studies. All studies except one inhalation study showed increased incidence of lung tumours. For the inhalation studies with treatment related tumours, concentrations ranged from 1 to 50 mg/m^3 (1, 6, and 30 mg/m^3 of DQ-12 quartz; 12 and 50 mg/m^3 of Min-U-Sil 5 quartz) and duration of exposure ranged from 29 days to 2 years. In the inhalation study with no treatment-related tumours, exposure was 60 mg/m^3 of Sikron F300 quartz for 13 weeks. The following is a description of the neoplastic results in the study also identified as the critical study for non-neoplastic results. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. In the exposed group, 18 animals developed tumours (12 in females, 5 in males), as opposed to 3 and 2 for the control and positive control groups respectively. The majority (10/18) of the tumours observed were adenocarcinomas. The mean mass of particles in the lungs at the end of the exposure period was 0.91 mg/lung.

For the intratracheal instillation studies, doses ranged from 4 to 57 mg/kg-bw (based on 7, 12 or 20 mg/animal of Min-U-Sil (5) quartz or 20 mg/animal of novaculite quartz). Exposure regimes were diverse and included single instillation with observation for up to two years, to weekly instillation for 10 weeks. It is noteworthy that the single intratracheal administration of a 95% pure quartz particles (<5 μm) resulted in an increased incidence of silicotic granulomas after 3 weeks and lung tumours after 11 months. The most common tumours reported across the long term rat studies were adenocarcinomas, however other tumours such as squamous-cell carcinoma, alveolar carcinoma and bronchiole-alveolar adenoma were also reported, and all animals that developed tumours also showed some degree of fibrosis.

Of particular interest is the intratracheal instillation study, investigating the sequence of pathological events leading to lung tumors. An unspecified number of rats/sex/dose received a single intratracheal instillation of various crystalline silica dusts or ferric oxide, allowing direct administration into the bronchial tree. The doses were 12 or 20 mg of Min-U-Sil 5 quartz (MQZ), 12 mg of hydrofluoric-acid-etched Min-U-Sil 5 quartz (HFMQZ), 12 mg of cristobalite, 12 mg of tridymite and 12 mg of ferric oxide suspended in saline. All groups were observed until six months post exposure, except for both MQZ groups, the HFMQZ and the ferric oxide group which were observed up until 17 months post-exposure. Interim sacrifices were conducted at 6, 11 and 17 months. The rat lungs showed a clear progression of effects. The sequence of pathological events were, an initial inflammatory response leading to a marked hyperplasia and hypertrophy of alveolar cells after one month, and at six months hyperplasia was evident but no lung tumours were observed. In this study, lung tumours were observed starting at the 11 month sacrifice with a 17% and 42% incidence in males and females (based on 3/18 males and 8/19 females), respectively, and at 17 months incidences were 32% and 59% (based on 6/19 males and 10/17 females, respectively). No lung tumours were found in ferric oxide treated rats. Similar studies have also been conducted in hamsters and mice. Although treated mice and hamsters showed treatment related signs (inflammation or fibrosis), no tumours were observed in hamsters. No increase in the incidence of lung tumours was seen in mice treated with quartz; however silicotic granulomas and lymphoid cuffing around airways but no fibrosis were seen in the lungs of quartz-treated mice.

Human epidemiology data

There is an extensive dataset of human studies investigating the link between crystalline silica exposure and cancer. IARC (1997) identified over 50 epidemiological studies based on occupational exposure to dust containing respirable crystalline silica. Main industry sectors from which the human data is derived include gold mines, foundries, granite/stone industry, pottery workers and refractory brick workers. From the least confounded studies, it was noted that lung cancer tended to increase with the following parameters: cumulative

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exposure; duration of exposure; peak intensity of exposure; presence of radiographically defined silicosis; and length of follow-up time from date of silicosis diagnostic. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics).

Since the 1997 IARC report, a large number of epidemiological studies have been published, with the more recent studies being updates from supplementary follow-up of results from previously assessed case-control studies cohorts, new results based on refined exposure assessments or adjustment for confounders or meta-analyses of the pooled data from these epidemiology studies

In a meta-analysis of the data from 10 cohort studies of gold, tin and tungsten miners, granite workers, industrial sand, diatomaceous earth and pottery workers with quantitative exposure estimates for crystalline silica were pooled in order to analyse the risk related to lung cancer. The pooled cohort standardized mortality ratio (SMR, against national rates) [See Appendix 1 for definition] was 1.2 (Confidence Interval [CI] 1.1-1.3). The results from the case-control analyses show a statistically significant trend with duration of exposure (odds ratios (ORs) [See Appendix 1] by quintile of cumulative exposure increased from 1.0 to 1.6 [CIs of 0.85 to 2.1] and by quintile of average concentration increased from 1.0 to 1.7 [CIs of 1.1 to 2.3]), supporting the importance of the increasing lung burden of silica in the occurrence of cancer. Overall, the authors concluded that the results support the carcinogenicity conclusion presented by IARC (1997).

To investigate the link between crystalline silica, silicosis and lung cancer, epidemiological data published between 1966 and 2001 were gathered. Over 50 studies were selected and pooled according to type of study and the parameter being linked to lung cancer (i.e. silica exposure, presence of silicosis in subjects). The quality of study, adjustment for confounding factors, co-exposure to other carcinogens and availability of a more recent analysis of a same cohort were taken into consideration in the final selection of the studies. Analysis of the relationship between exposure to silica and lung cancer included 17 cohort and 13 case-control studies. For the analysis of lung cancer versus silicosis, 11 cohort and 5 case-control studies were selected. The third analysis included 6 cohort and 2 case-control studies to evaluate the risk of lung cancer in non-silicotics. A random effect model was used to conduct each meta-analysis. Pooled cancer risk ratios (RRs) were 1.32 (CI 1.23-1.41) for crystalline silica exposure, 2.37 (CI 1.98-2.84) for individuals exposed to silica with confirmed silicosis (Silicotics) and 0.96 (CI 0.81-1.15) for individuals with no evidence of silicosis (non-silicotics) with confirmed exposure to silica, supporting the general observation that silicosis has a stronger temporal relationship with crystalline silica exposure and furthermore support the view that a human silicotic response could be a preliminary stage in the development of cancer.

A more recent meta-analysis included 28 cohort, 15 case-control and two proportionate mortality ratio (PMR) [See Appendix 1] studies from a variety of occupational settings conducted between 1996 and 2005. Risk ratios (RRs) were calculated based on type of study and silicosis status using fixed and random effect models (results presented here are from the random model). RRs for all cohort studies was 1.34 (CI 1.25-1.45), and were 1.69 (CI 1.32-2.16) for silicotics, 1.25 (CI 1.18-1.33) for those with undefined silicosis status and 1.19 (CI 0.87-1.57) for non-silicotics. In the case-control studies, the general RR was 1.41 (CI1.18-1.67), and the same sub-groups as mentioned above resulted in RRs of 3.27 (CI 1.32-8.2), 1.41 (CI1.18-1.70) and 0.97 (CI 0.68-1.38), respectively. The proportionate mortality ratio for the last two studies was 1.24 (CI 1.05-1.47). The authors noted that the association between lung cancer and exposure to crystalline silica was more consistent for silicotics, i.e., those diagnosed with silicosis and RR values split into type of occupational settings in which participants worked.

Based upon the above three meta-analysis studies and the epidemiology studies discussed in IARC (1997), the following can be concluded. Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis. Cancer risk is often more significant in workers exposed to crystalline silica over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours. Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles.

There have been reports of tumours outside of the lungs in persons with high silica exposure; however, these reports are sparse and the data inconsistent and have not been unequivocally linked to exposure to either one of the crystalline forms (quartz or cristobalite). Some of the reported locations are: oesophagus, stomach, liver, skin and bone. Sufficient epidemiological or toxicological data do not currently exist for quantitative assessment of the exposure-response relationship on these other tissues or organs.

Genotoxicity

Potential genotoxicity has been assessed in multiple *in vitro* and *in vivo* assays. Table 1 below gives a brief summary of the positive results observed in each type of assay.

Table 1. Summary of positive results over total number of results for each assay and each category (all studies

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conducted with crystalline silica: quartz, except where indicated).

Assay	Animal data		Human data		Positives/Total	
	In vitro	In vivo	In vitro	In vivo[d]	In vitro	In vivo
Rec Assay	0/1				0/1	
DNA strand break	1/1	2/2	5/5[b]	1/1	6/6	3/3
Sister chromatid exchange	0/1		0/1[c]	1/1	0/2	1/1
Micronucleus	2/3	0/1	2/2[b]	1/1	4/5	1/2
Chromosome aberration	0/1			1/1	0/1	1/1
Aneuploidy/polyploidy	0/3				0/3	
Cell transformation	4/4				4/4	
Hprt mutation	1/2	2/2[a]	1/1[b]		2/3	2/2
Oxidative DNA damage		4/5	2/2		2/2	4/5
DNA binding		1/1				1/1
p53 activation		0/1				0/1

a. one assay conducted with crystalline silica: cristobalite
b. one assay conducted with "ultrafine crystalline silicon dioxide".
c. crystalline silica: tridymite
d. crystalline silica dust (subtypes not provided).

All the *in vivo* human genotoxicity studies are based on three independent studies that used blood samples from workers from diverse occupational settings with confirmed exposures to crystalline silica dust; however, quantification of exposure was not provided. After stratification by smoking status, sister chromatid exchange remained statistically significant in both smokers and non-smokers although the frequency was higher in smokers. For the chromosome aberration assay conducted as part of the same study (blood samples from workers in the stone crusher industry), the increased frequency was no longer significant after stratification. In the DNA damage study of foundry and pottery workers and the micronucleus assay of workers involved in sandblasting and related jobs, results were positive when compared to controls. However, in both studies, smoking status influenced the results, contributing to the increased DNA damage observed since results were greater in smokers versus non-smokers, and the frequency of micronuclei in nasal epithelial cells was higher in smokers (p=0.002) but when using peripheral blood lymphocytes did not differ statistically between smokers and non-smokers who were similarly exposed to silica dust,

The role of *in situ* generation of reactive oxygen species (ROS) and reactive nitrogen species (RNS) has been well established in the following types of DNA damage: small scale insertions, DNA base pair deletion, base modification, chromosomal change/loss, microsatellite instability, DNA strand break, 8-hydroxydeoxyguanosine (8-OHdG) mutation and point mutations. ROS and RNS generation is postulated to be (a part of) the DNA damage mechanism for crystalline silica. Studies are described below to support this hypothesis.

DNA was exposed *in vitro* to various crystalline silica dusts, to H_2O_2, or to both. Results show that DNA damage was limited when dust or H_2O_2 were administered alone but increased with the co-exposure. When the reactive oxygen scavenger, dimethylsulfoxide, was added to the test system, DNA strand break was inhibited, data supporting the viewpoint that it is the presence of radicals generated in response to quartz and cristobalite that causes the DNA damage and not quartz or cristobalite themselves.

Hprt mutation assays in rat alveolar epithelial cells, both *in vitro* and *in vivo,* were positive in response to quartz. The positive results *in vivo* were seen only in the presence of significant inflammatory responses in the treated animals. Also, in a parallel *in vitro* experiment, rat alveolar epithelial cells were incubated with the bronchoalveolar lavage fluid from the rats exposed to quartz. Both macrophage and neutrophil enriched lavage cells induced mutation in the exposed alveolar epithelial cells. Addition of catalase (an enzyme which inactivates H_2O_2) before incubation inhibited the increase in *hprt* mutation.

Rats were exposed to either crystalline or amorphous silica in a manner to induce the same level of

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inflammation in the lungs. The inflammatory response was assessed by measuring the proportion of neutrophils in the bronchiolar lavage fluid. The actual concentrations were 3 and 50 mg/m^3 for crystalline and amorphous silica respectively. The animals were exposed for 13 weeks. *Hprt* mutation frequency was measured in the alveolar epithelial cells at the end of the exposure period. Mutation frequency was greatly increased only in the crystalline silica treated rats; no treatment related increase was found in the rats treated with the amorphous form.

In an 8-OHdG assay conducted to monitor DNA damage by reactive oxygen species, female rats were exposed to 0, 0.3, 1.5 and 7.5 mg/animal of quartz via intratracheal instillation. Effects were observed 90 days post-exposure. A clear dose-response relationship was identified between quartz exposure and various inflammation markers (differential cell count, protein, lung surfactant lipids and tumour necrosis factor alpha). Inflammation was present starting at the lowest dose. However, 8-OHdG showed a statistically significant increase starting at 1.5 mg/animal only. Similarly, in another study, 8-OHdG and DNA strand breaks were observed at concentrations of or above 10 ug/m^3 in rat lung epithelial cells.

In the aim of investigating the role of ROS in lung carcinogenesis, rat lung epithelial cells were incubated with polymorphonuclear (PMN) leukocytes (involved in the inflammatory process and responsible for the release of certain ROS) or hydrogen peroxide. Statistically significant increases in 8-OHdG were observed in the presence of PMN or hydrogen peroxide in a dose-response manner.

In a series of experiments which used *in vitro* stimulation of macrophages with crystalline silica and *in vivo* intranasal instillation of crystalline silica in mice, it was demonstrated that that the chronic fibrosis seen in a murine model of silicosis *in vivo* is dependent on the presence of adaptor molecule ASC and Nalp3 inflammazome. These data support a potential mode of action whereby silica triggers cellular responses that in turn activate alveolar macrophages, resulting in an inflammatory response and silicosis. In mice deficient in Nalp3 inflammazome, the development of inflammation and collagen deposition was significantly reduced compared with normal mice 3 months after the initial intranasal instillation of silica.

Analysis of Lung Tumour Data

The weight of evidence for both rats and humans indicates that fibrotic and silicotic lesions in the lung result from inhalation exposure to crystalline silica and that lung cancer is secondary to those lesions in the lung. Although the mechanism of induction for the lung tumours has not been fully elucidated, there is sufficient supportive mode of action evidence from the data presented to demonstrate that a threshold approach to risk assessment is appropriate based on an understanding of the key events in the pathogenesis of crystalline silica induced lung tumours. The body of evidence include the following:

- In experimental studies, all rats that developed tumours also showed fibrosis.
- Adenocarcinomas, the most common type of tumour identified in rats, are commonly associated with fibrosis and deeply scarred lung tissue.
- Experimental rat studies showed a clear progression of the effects from initially mild inflammation, followed by fibrosis over-time, leading eventually to lung tumours.
- Tumours are not present in all treated species dosed in the same way.
- The tumours, both in rats and humans, are concentrated in the lungs only, although other organs are indirectly exposed.
- In human studies, cancer risk is often more significant in workers exposed over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours.
- Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles
- Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis.
- For genotoxicity, in vitro results were mostly mixed and in vivo results were mostly positive. However, the vast majority of the positive genotoxicity assay results can be explained by the generation of reactive oxygen species, as demonstrated experimentally, where ROS scavenging prevents the genotoxicity.
- *In vivo*, macrophage deficient mice (macrophages produce ROS in response to crystalline silica) do not develop silicosis nor do they develop tumours and the Nalp3 inflammazome, a key player in the macrophage initiated inflammatory response, is required for the development of pulmonary fibrosis after

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inhalation of silica.

- Though inhalation exposure to crystalline silica in multiple occupational settings is clear, the increase in risk, based on the several recent meta-analyses of the multiple human epidemiological studies, remains low.

It is worth noting that where aggressive engineering controls have been made to reduce silica dust levels in the workplace (Sweden), silicosis has been eliminated. By corollary, existing exposures outside of the workplace in such areas do not pose a risk for silicosis to the general population.

The respirable forms of quartz and cristobalite possess properties indicating a hazard for human health (repeated dose toxicity, carcinogenicity and genotoxicity). The mode of action in the lungs involves irritation, inflammation and reactive species formation, leading to silicosis, and eventually to tumour formation.

Exposure

Uses

Consistent with oxygen and silicon being the two most abundant elements in the Earth's crust, silicon-oxide minerals, including quartz are ubiquitous in the natural environment. In particular, as a component of sand, quartz may find use in a diverse array of applications. Several high volume uses include, but are not limited to, the use of sand as a filling material for the construction of roads and in general building activities, the use of sand and gravel aggregates as abrasives on roads in winter and the use of fly-ash, which may contain 4-14% quartz and 0.5-1% cristobalite, as a cement additive. These abrasives when used on winter roads are usually mixed with road salts and may be sand only, stone dust, sand and gravel aggregates, or pre-treated sand. They are used mainly by rural municipalities or in areas where cold temperatures diminish the efficiency of salts for de-icing. Quantities of abrasives used in Canada were 5.73×10^9 kg, 4.59×10^9 kg, and 4.93×10^9 kg for 2007, 2008 and 2009, respectively.

Industrial sand, high purity silica sand products with closely controlled sizing are expected to contain quartz and cristobalite, include lump silica (2-3mm up to 15 cm or more), silica sand (75µm to 2-3mm) and silica flour (less than 75µm). Lump silica may be used in the production of silicon alloys, silica bricks, and the linings of certain types of pulverizers (eg. ball mills and tube mills).

Silica sand may be used in the manufacture of glass and glass fibres, silicate chemicals and silicon carbide, the hydraulic fracturing of wells, foundry moulding, and for sandblasting. Silica flour may find use in the ceramics and cement industries, as a filler and extender in rubber and coatings, and as an abrasive in soaps.

Natural clays, such as bentonite and fuller's earth, are used in cat litters for their high water absorbance capacities. Quartz is a natural component of these clays, and consequently, it may be present in cat litter products. High purity α-quartz is a piezoelectric material, which means that application of a voltage induces a distortion in the crystal shape and vice versa. This ability to interconvert electrical and mechanical energy has led to the use of quartz crystals in electronic devices requiring precise timing control, for example telephones, radios, watches and computers.

According to a survey conducted in Canada, quartz and cristobalite are also used in abrasives, adsorbents, filter products (diatomaceous earth), grout and cement. These substances reportedly also find use as fillers, which add bulk and improve wear resistance, in paints and coatings, adhesives, sealants, polymer films, caulking, epoxy resins and silicones. Also, quartz is listed as an ingredient in 60 cosmetic products in Canada. The types of products include anti-wrinkle preparation, eye and face makeup, lipstick, hair dyes, shampoos and grooming products, as well as skin cleansers, moisturizers and tanning preparations.

Natural Sources

In Canada, quartz naturally occurs in many types of rock formations. Those with high silicon dioxide content (95% SiO_2 or more) include vein and massive intrusion bodies, quartz pebbles, silica sand, sandstone and quartzite. Sandstone is a sedimentary rock mostly composed of quartz grains cemented by a bonding material such as clay, calcite or iron oxide. Quartzite is a hard, compact, metamorphosed sandstone made of grains of quartz firmly bonded with a siliceous cement. Mineral aggregates (e.g., sand and gravel) have variable silicon dioxide content. Quartz is also found as crystals, aggregates or discrete particles in certain igneous rocks (e.g., granites and pegmatites), soils, sediments, air and surface water. This omnipresence is consistent with the fact that silicon is the second most abundant chemical element on Earth.

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Cristobalite is naturally produced in the ashes of volcanic eruptions, and by combustion metamorphism which is a local phenomenon of spontaneous combustion of naturally occurring substances such as bituminous rocks, coal or oil. It may be found in cavities in volcanic rocks and in thermally metamorphosed sandstones and may also be a transient stage in the diagenesis of diatomaceous shale with the result that soils made of these geologic formations may be rich in cristobalite. Unlike quartz, the natural occurrence of cristobalite is limited to specific geographic regions and mineral types.

Anthropogenic Sources

Natural quartz is isolated from ore via beneficiation, which involves milling or grinding the material into particles that are separated into desired mineral and waste. The materials obtained are either used directly or further purified. In Canada, in 2006, 2.146×10^{9} kg of pure quartz were mined, and 2.385×10^{11} kg of sand and gravel aggregates were produced. The proportion of quartz in silica sand deposits and gravel aggregates will vary from one site to another.

Cristobalite can form from silica melts during the preparation of silica glass; quartz is not obtained from melts but is manufactured at elevated temperature and pressure via a hydrothermal process. Cristobalite also forms during the calcination[2] of diatomaceous earth.

Human Exposure Estimate

Ambient air

The exposure assessment is focussed on respirable quartz and cristobalite, which in ambient air comprises a component of total particulate matter (PM). In Canada, data on the concentrations of silicon in PM was available and used as a surrogate for quartz and cristobalite. This approach is conservative because the measured silicon includes all silicon-containing substances and therefore represents the upper limit for quartz and cristobalite in ambient air.

The National Air Pollution Surveillance (NAPS) Program measured concentrations in $\mu g/m^3$ of silicon in PM with aerodynamic radii less than 2.5 µm ($PM_{2.5}$ (dichot)), and from 2.5 to 10 µm (PM_{10} (dichot)) (the total particulate matter with aerodynamic radii less than 10 µm (PM_{10}) is obtained by adding these values) in Canada. In 2009, as part of the NAPS Program, silicon concentrations were determined on over 1600 samples of $PM_{2.5}$(dichot) and over 1500 samples of PM_{10}(dichot) at 24 urban locations across Canada. An estimate of exposure to quartz and cristobalite can be obtained by assuming that all the silicon in the PM is represented stoichiometrically as SiO_2, and multiplying the reported concentration of silicon by 2.14 to obtain a value for silica.

The intake of respirable quartz and cristobalite by the general population of Canada is estimated using a range covering the lowest 50^{th} percentile SiO_2 concentration in PM_{10}, measured in Pt. Petre, ON, (0.12 $\mu g/m^3$) to the highest 50^{th} percentile concentration in PM_{10} measured in Calgary, AB (2.1 $\mu g/m^3$). The 50^{th} percentile SiO_2 concentrations ranged from 0.1 to 2.1 $\mu g/m^3$ across the survey sites; the top of this range is quite close to the average of the maximum values for the 24 sites (3.7 $\mu g/m^3$). The outdoor data were used to represent the indoor levels, because information on indoor silicon concentrations was not available, and the range of PM_{10} measured indoors is generally lower than the outdoor range. Thus, this approach conservatively overestimates indoor exposure in homes.

The highest exposure group based on these calculations is children ages 0.5 to 4 years with an estimated daily intake ranging from 0.07 to 5.26 µg/kg-bw per day; the estimated daily intake decreases with age due to changes in the ratio of inhalation rates to body weights; the daily intake of adults, 20-59 years old, is estimated to range from 0.03 to 2.00 µg/kg-bw per day.

Consumer Products

Exposure to respirable quartz from the use of cosmetic products, which contained quartz as an ingredient, was considered low because they are not formulated for spray application, the loose powders were reported to contain less than 0.1% quartz, and in these products the substance is not expected to be associated with other components of the formulation and not available in a free form.

For consumer Do It Yourself (DIY) activities around the home, the highest mean breathing zone concentration of particles from sanding dry wall (median cut-point of 10µm) of 6.31 mg/m^3, was used to derive an upper-

[2] Calcinations: Heat treating a substance, but without fusion, to bring about change in its physical or chemical constitution.

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bound exposure estimate ranging from 2 to10 µg/kg-bw per event.

Quartz is used to formulate a large number of paints and coatings. To estimate potential inhalation exposure to quartz from these products, the spray painting of wall paints with an airless spray gun was considered appropriate as a conservative scenario. Exposure to respirable paint particles was estimated using data from controlled a laboratory study in which walls of poorly ventilated test rooms were painted by professional painters using an airless sprayer to apply interior latex paint. The maximum concentration of 13% quartz in paint in Canada was used to estimate exposure. The upper-bound estimate of exposure to quartz, based on the maximum concentration of 13% quartz in paint in the Canadian market and the maximum concentration of respirable paint particles measured in these controlled studies when recommended personal protective equipment is used, is 0.954 µg/kg-bw per event.

Inhalation of ambient air containing quartz and cristobalite is the dominant pathway of chronic exposure (excluding that from DIY activities) for the general population. Because SiO_2 makes up only approximately 5% of PM_{10}, silicon concentrations (expressed as SiO_2) measured in the Canadian NAPS survey of 24 urban locations were considered most relevant to the estimation of exposure by the general population. Quartz and cristobalite comprise only a portion of the total SiO_2 in PM_{10}, therefore, the use of the total silicon concentration to represent the upper bound crystalline silica concentrations results in an overestimation of exposure.

Appendix 1: Definitions of Epidemiological Terms in the ITAP

SMR (Standardized Mortality Ratio): The ratio (x 100) of observed to expected deaths in a study population. Expected deaths are calculated by applying a set of standard age-specific mortality rates to the age distribution of the study population. Standardized ratios are only useful for comparisons. They have no intrinsic meaning.

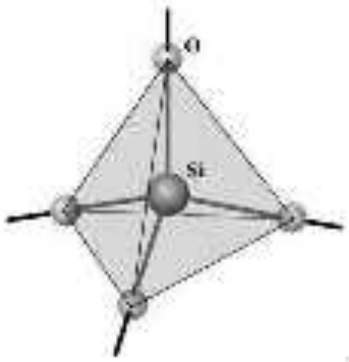
OR (Odds Ratio): In epidemiological case-control studies, a relative measure of disease occurrence. The odds in favour of a particular disease occurring in an exposed group are divided by the odds in favour of its occurring in an unexposed group. If the condition being studied is rare, the odds ratio is a close approximation to the relative risk.

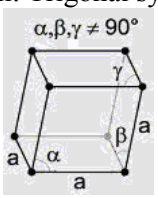
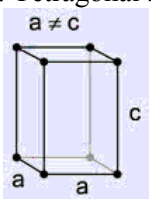
RR (Risk Ratio): The probability of the occurrence of a disease in a group that has been exposed to some environmental, medicinal, microbial, or toxic influence, relative to its probability in a randomly selected population.

PMR (Proportionate Mortality Ratio): Proportionate mortality is the proportion of deaths in a specified population over a period of time attributable to different causes. Each cause is expressed as a percentage of all deaths, and the sum of the causes must add to 100%. These proportions are not mortality rates, since the denominator is all deaths, not the population in which the deaths occurred. Thus, proportionate mortality ratio is a measure of the frequency of occurrence of the proportionate mortality in a defined population during a specified interval of time.

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INITIAL TARGETED ASSESSMENT PROFILE (Human Health)

CAS No.	Quartz: CAS RN 14808-60-7 Cristobalite: CAS RN 14464-46-1
Chemical Name	Quartz and Cristobalite
Structural Formula	Molecular Formula: SiO_2 

Unit Cell: Trigonal symmetry	Unit Cell: Tetragonal symmetry
	
Quartz: CAS RN 14808-60-7	Cristobalite: CAS RN 14464-46-1

SUMMARY CONCLUSIONS OF THE TARGETED ASSESSMENT

NOTE: The present assessment is targeted to address the following human health endpoints: repeated dose toxicity and carcinogenicity via the inhalation route of exposure, and genotoxicity. It cannot be considered as a full SIDS Initial Assessment. Summary information on exposure is also reported here. Other endpoints for human health and the environment included in the Canadian screening assessment but have not been presented to OECD member countries, and thus are not included in this profile.

The final screening assessment will be published under the responsibility of the Government of Canada.

Rationale for Targeting the Assessment

The Government of Canada "categorized" or prioritized all 23,000 chemical substances on its Domestic Substances List (DSL) from 1999 to September 2006, as required by its *Canadian Environmental Protection Act, 1999* (CEPA 1999). Additional details may be found at http://www.chemicalsubstanceschimiques.gc.ca/about-apropos/categor/index-eng.php. Using information from Canadian industry, academic research and other countries, Government of Canada scientists applied a set of rigorous tools to the 23,000 chemical substances on the DSL. They were categorized to identify those that were: **inherently toxic** to humans or to the environment and that might be **persistent** and/or **bioaccumulative**; and substances to which people might have **greatest potential for exposure**. During this priority-setting exercise, distinct approaches were taken for identifying substances of likely concern for human health and the environment, and subsequent assessment activities may have focused on either human health or ecological endpoints. Through categorization, the Government of Canada has identified approximately 4,000 of the 23,000

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chemical substances on the DSL as priorities for further assessment, research and/or measures to control their use or release. Quartz and cristobalite were identified at that time, applying the categorization criteria, as high priorities for human health risk because they were considered to pose greatest potential for exposure and their respirable forms are classified by the International Agency for Research on Cancer as carcinogenic to humans (quartz and cristobalite) and by the National Toxicology Program as known human carcinogens (crystalline silica). These substances did not meet the ecological categorization criteria for bioaccumulation potential or inherent toxicity to aquatic organisms.

Under the Canadian legislation a determination of whether one or more of the criteria of the CANADIAN ENVIRONMENTAL PROTECTION ACT (CEPA) 1999, section 64 are met is based upon an assessment of potential risks to the environment and/or to human health associated with exposures in the general environment. For humans, this includes, but is not limited to, exposures from ambient and indoor air, drinking water, foodstuffs, and the use of consumer products. A conclusion under CEPA 1999 on the substances in the Chemicals Management Plan (CMP) Challenge is not relevant to, nor does it preclude, an assessment against the hazard criteria specified in the Controlled Products Regulations, which is part of the regulatory framework for the Workplace Hazardous Materials Information System [WHMIS] for products intended for workplace use.

Physical-chemical properties

The silicon dioxide group represents a polymorphic category containing a large number of forms identical in composition but with different atomic arrangements which afford different chemical properties. There are two sub-categories within this group: crystalline silica, to which the present substances quartz and cristobalite belong, and non-crystalline or amorphous silica. The key distinction between these sub-categories is that in crystalline substances, the building blocks are arranged in regular, repeating 3-dimensional pattern having long range order, whereas amorphous materials do not display long range order. In all forms of silica, (crystalline and non-crystalline), the silicon atom is tetrahedral and bound to four neighbouring oxygen atoms.

Quartz and cristobalite are solid at room temperature, existing normally as colourless or white crystals. The melting points for quartz and cristobalite are 1400-2000 ^{o}C and 1713-1728 ^{o}C, respectively and for both compounds, the boiling point is 2230^{o}C. Even though no experimental data were available, their vapour pressure and Henry's Law constant are likely negligible. Log K_{ow} (octanol-water partition coefficient) and log K_{oc} (organic carbon-water partition coefficient) are not applicable to these substances. The densities range from 2500-2700 kg/m^3 for quartz and 2300-2380 kg/m^3 for cristobalite.

The very similar physico-chemical properties of quartz and cristobalite reflect their closely related crystal forms. The solubility of crystalline silicates decreases as a function of silica tetrahedral packing density and long-range crystal order. For example, cristobalite has a more open framework structure than quartz and its density is lower, therefore, its solubility is higher. The water solubility of these minerals is also function of temperature, pH, particle size, and the presence of a disrupted surface layer. This may explain the variability of solubility values reported by many authors. The most probable solubility value for quartz is approximately 3.8 mg Si/L, or 6.4 mg/L expressed as the SiO_2 species, while the solubility of cristobalite is approximately 8.7 mg Si/L, or 18 mg SiO_2/L. The kinetics of dissolution of these substances is slow due to the high activation energy required to hydrolyse the Si-O-Si bond.

Human Health Targeted Endpoints

The majority of the studies described here have been reviewed by the International Agency for Research on Cancer (IARC 1997). However, additional data relevant to the screening assessment were identified up to August 2010.

Repeated dose toxicity/non-neoplastic effects (development of silicosis).

Studies on animals

Significant short-term and subchronic studies have demonstrated adverse effects in the lungs, while one of the 6 studies showed effects on the spleen in mice. Rats were exposed to 0, 10 or 100 mg/m^3 of cristobalite via inhalation for 6 hours/day during 3 days. Animals were observed 3 months after exposure. Elevated levels of granulocytes and elevated markers of cytotoxicity from the lung lavage fluid were noted in all exposed groups. Another study of similar duration (9 days) conducted in mice also identified a LOAEC of 10 mg/m^3. Effects observed included minimal interstitial thickening, accumulations of mononuclear cells and slight lymphoid tissue hypertrophy in the lungs.

In a 4-week inhalation study, female rats were exposed to 0, 0.1, 1 or 10 mg/m^3 of quartz 6 hours/day, 5 days/week. Bronchoalveolar lavage fluid was evaluated at 1, 8, and 24 weeks after exposure. Elevated levels of

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granulocytes and significant elevation of markers of cytotoxicity (Lactate dehydrogenase [LDH] and β-glucuronidase [β-glu]) were observed at 1 mg/m^3 and higher. The increased levels of LDH and β-glu were only significant at 24 weeks after exposure. A LOAEC of 1 mg/m^3 was identified at 24 weeks.

Male rats (4 animals per dose) were exposed to 0 or 3 mg/m^3 of cristobalite via inhalation for 6 hours/day, 5 days/week during 13 weeks. Pulmonary inflammation and fibrosis were observed in the exposed group at the end of treatment. When mice were similarly exposed to 5 mg/m^3 of quartz for 6 hours/day, 5 days/week for 15 or 27 weeks, the authors observed increased spleen weight and formation of plaque in the spleen.

In two separate studies, in which rats or hamsters were exposed to quartz via inhalation for at least 6 months, LOAECs of 2 and 3 mg/m^3 were identified, respectively. All the effects observed were related to inflammation and fibrosis of the lung tissue.

Several chronic studies investigated exposure of the respirable forms (i.e. accumulated via inhalation in the lung tissues) of quartz and cristobalite to rats, mice and hamsters. The following is a description of the study in which the lowest non-neoplastic LOAEC was determined. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz, containing 74% of respirable quartz, through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. The mean mass of particle at the end of the exposure period was 0.91 mg/lung. The LOAEC identified was 0.74 mg/m^3 (adjusted for 74% respirable quartz) based on lipoproteinosis, multifocal, inflammatory cell infiltrate and alveolar hyperplasia.

Human epidemiology data

In humans, the lowest observed adverse effect level was identified in a U.S. cohort study. The study was conducted on 3330 gold miners (all are males), who had an average of 9 years underground exposure during the period 1940 to 1965. The cohort was followed up through 1990. Silicosis[1] was identified through death certificates or chest X-rays. A job-exposure matrix together with work history was used to estimate individual exposure. The total silica content in the respirable dust in the mine was estimated at 13% and the median crystalline silica exposure was 0.05 mg/m^3. In this sub population of miners, 170 cases of silicosis were identified. The best predictor for risk of silicosis was cumulative exposure, which varied from less than 1% for a 0.5 mg/m^3-year exposure to 68-84% when exposed to more than 4 mg/m^3-year (based on the average daily dust exposure during the workday each year and summed over time for each miner). The main limitations identified by the authors include the limited number of radiographic surveys, the potential bias from death certificates

[1] Silicosis: Lung disease caused by inhalation of crystalline silica dust, and resulting in inflammation and scarring in forms of nodular lesions in the upper lobes of the lungs. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics). It does not follow that a history of exposure to silica necessarily results in silicosis (Nonsilicotics). The typical "Silicotic" lung nodule is shown in Figure 1.

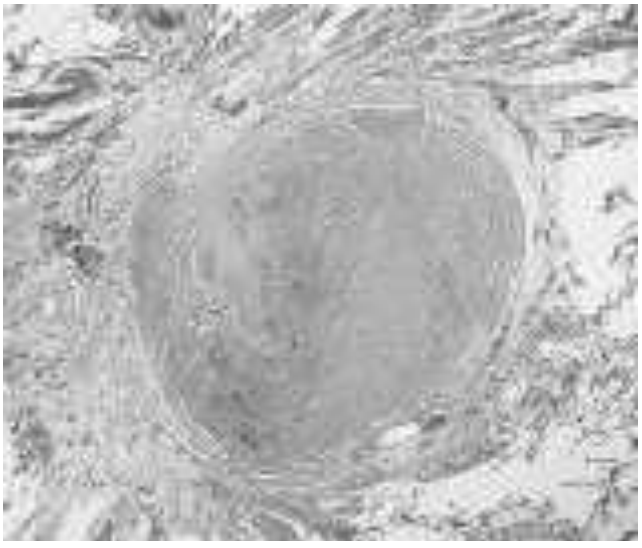


Figure 1. Silicotic nodule characterised by a central zone of hyalinised collagen with a whorled appearance and peripheral dust-containing macrophages (Rees and Murray, 2007).

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(relying on death certificates instead of relying on repeated x-rays, which were lacking for each miner, may have underestimated the number of cases) and the fact that the conversion of dust counts to

gravimetric measurements may not be accurate based on the estimation of 13% silica content in the respirable dust (although based on a relatively large number of samples (n = 82) collected in two different surveys, there was broad range of content in these samples (1% to 48%, SD = 9), and the percentage of respirable quartz may have differed in earlier years, but data were lacking for these years).

Two other human studies have identified similar LOAECs based on the critical endpoint of radiographic confirmed silicosis. A LOAEC of 0.053 mg/m^3 (mean exposure) was identified in a cross sectional study of South African gold miners and a LOAEC of 0.064 mg/m^3 (mean exposure) was derived in a mining community population-based random sample survey in Colorado.

Carcinogenicity studies

Studies on animals

Experimental studies conducted in rats have shown clear and consistent increases in lung tumours after chronic inhalation exposure. In the nine rat studies identified, five were inhalation studies and four were intratracheal instillation studies. All studies except one inhalation study showed increased incidence of lung tumours. For the inhalation studies with treatment related tumours, concentrations ranged from 1 to 50 mg/m^3 (1, 6, and 30 mg/m^3 of DQ-12 quartz; 12 and 50 mg/m^3 of Min-U-Sil 5 quartz) and duration of exposure ranged from 29 days to 2 years. In the inhalation study with no treatment-related tumours, exposure was 60 mg/m^3 of Sikron F300 quartz for 13 weeks. The following is a description of the neoplastic results in the study also identified as the critical study for non-neoplastic results. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. In the exposed group, 18 animals developed tumours (12 in females, 5 in males), as opposed to 3 and 2 for the control and positive control groups respectively. The majority (10/18) of the tumours observed were adenocarcinomas. The mean mass of particles in the lungs at the end of the exposure period was 0.91 mg/lung.

For the intratracheal instillation studies, doses ranged from 4 to 57 mg/kg-bw (based on 7, 12 or 20 mg/animal of Min-U-Sil (5) quartz or 20 mg/animal of novaculite quartz). Exposure regimes were diverse and included single instillation with observation for up to two years, to weekly instillation for 10 weeks. It is noteworthy that the single intratracheal administration of a 95% pure quartz particles (<5 μm) resulted in an increased incidence of silicotic granulomas after 3 weeks and lung tumours after 11 months. The most common tumours reported across the long term rat studies were adenocarcinomas, however other tumours such as squamous-cell carcinoma, alveolar carcinoma and bronchiole-alveolar adenoma were also reported, and all animals that developed tumours also showed some degree of fibrosis.

Of particular interest is the intratracheal instillation study, investigating the sequence of pathological events leading to lung tumors. An unspecified number of rats/sex/dose received a single intratracheal instillation of various crystalline silica dusts or ferric oxide, allowing direct administration into the bronchial tree. The doses were 12 or 20 mg of Min-U-Sil 5 quartz (MQZ), 12 mg of hydrofluoric-acid-etched Min-U-Sil 5 quartz (HFMQZ), 12 mg of cristobalite, 12 mg of tridymite and 12 mg of ferric oxide suspended in saline. All groups were observed until six months post exposure, except for both MQZ groups, the HFMQZ and the ferric oxide group which were observed up until 17 months post-exposure. Interim sacrifices were conducted at 6, 11 and 17 months. The rat lungs showed a clear progression of effects. The sequence of pathological events were, an initial inflammatory response leading to a marked hyperplasia and hypertrophy of alveolar cells after one month, and at six months hyperplasia was evident but no lung tumours were observed. In this study, lung tumours were observed starting at the 11 month sacrifice with a 17% and 42% incidence in males and females (based on 3/18 males and 8/19 females), respectively, and at 17 months incidences were 32% and 59% (based on 6/19 males and 10/17 females, respectively). No lung tumours were found in ferric oxide treated rats. Similar studies have also been conducted in hamsters and mice. Although treated mice and hamsters showed treatment related signs (inflammation or fibrosis), no tumours were observed in hamsters. No increase in the incidence of lung tumours was seen in mice treated with quartz; however silicotic granulomas and lymphoid cuffing around airways but no fibrosis were seen in the lungs of quartz-treated mice.

Human epidemiology data

There is an extensive dataset of human studies investigating the link between crystalline silica exposure and cancer. IARC (1997) identified over 50 epidemiological studies based on occupational exposure to dust containing respirable crystalline silica. Main industry sectors from which the human data is derived include gold mines, foundries, granite/stone industry, pottery workers and refractory brick workers. From the least confounded studies, it was noted that lung cancer tended to increase with the following parameters: cumulative

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exposure; duration of exposure; peak intensity of exposure; presence of radiographically defined silicosis; and length of follow-up time from date of silicosis diagnostic. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics).

Since the 1997 IARC report, a large number of epidemiological studies have been published, with the more recent studies being updates from supplementary follow-up of results from previously assessed case-control studies cohorts, new results based on refined exposure assessments or adjustment for confounders or meta-analyses of the pooled data from these epidemiology studies

In a meta-analysis of the data from 10 cohort studies of gold, tin and tungsten miners, granite workers, industrial sand, diatomaceous earth and pottery workers with quantitative exposure estimates for crystalline silica were pooled in order to analyse the risk related to lung cancer. The pooled cohort standardized mortality ratio (SMR, against national rates) [See Appendix 1 for definition] was 1.2 (Confidence Interval [CI] 1.1-1.3). The results from the case-control analyses show a statistically significant trend with duration of exposure (odds ratios (ORs) [See Appendix 1] by quintile of cumulative exposure increased from 1.0 to 1.6 [CIs of 0.85 to 2.1] and by quintile of average concentration increased from 1.0 to 1.7 [CIs of 1.1 to 2.3]), supporting the importance of the increasing lung burden of silica in the occurrence of cancer. Overall, the authors concluded that the results support the carcinogenicity conclusion presented by IARC (1997).

To investigate the link between crystalline silica, silicosis and lung cancer, epidemiological data published between 1966 and 2001 were gathered. Over 50 studies were selected and pooled according to type of study and the parameter being linked to lung cancer (i.e. silica exposure, presence of silicosis in subjects). The quality of study, adjustment for confounding factors, co-exposure to other carcinogens and availability of a more recent analysis of a same cohort were taken into consideration in the final selection of the studies. Analysis of the relationship between exposure to silica and lung cancer included 17 cohort and 13 case-control studies. For the analysis of lung cancer versus silicosis, 11 cohort and 5 case-control studies were selected. The third analysis included 6 cohort and 2 case-control studies to evaluate the risk of lung cancer in non-silicotics. A random effect model was used to conduct each meta-analysis. Pooled cancer risk ratios (RRs) were 1.32 (CI 1.23-1.41) for crystalline silica exposure, 2.37 (CI 1.98-2.84) for individuals exposed to silica with confirmed silicosis (Silicotics) and 0.96 (CI 0.81-1.15) for individuals with no evidence of silicosis (non-silicotics) with confirmed exposure to silica, supporting the general observation that silicosis has a stronger temporal relationship with crystalline silica exposure and furthermore support the view that a human silicotic response could be a preliminary stage in the development of cancer.

A more recent meta-analysis included 28 cohort, 15 case-control and two proportionate mortality ratio (PMR) [See Appendix 1] studies from a variety of occupational settings conducted between 1996 and 2005. Risk ratios (RRs) were calculated based on type of study and silicosis status using fixed and random effect models (results presented here are from the random model). RRs for all cohort studies was 1.34 (CI 1.25-1.45), and were 1.69 (CI 1.32-2.16) for silicotics, 1.25 (CI 1.18-1.33) for those with undefined silicosis status and 1.19 (CI 0.87-1.57) for non-silicotics. In the case-control studies, the general RR was 1.41 (CI1.18-1.67), and the same sub-groups as mentioned above resulted in RRs of 3.27 (CI 1.32-8.2), 1.41 (CI1.18-1.70) and 0.97 (CI 0.68-1.38), respectively. The proportionate mortality ratio for the last two studies was 1.24 (CI 1.05-1.47). The authors noted that the association between lung cancer and exposure to crystalline silica was more consistent for silicotics, i.e., those diagnosed with silicosis and RR values split into type of occupational settings in which participants worked.

Based upon the above three meta-analysis studies and the epidemiology studies discussed in IARC (1997), the following can be concluded. Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis. Cancer risk is often more significant in workers exposed to crystalline silica over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours. Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles.

There have been reports of tumours outside of the lungs in persons with high silica exposure; however, these reports are sparse and the data inconsistent and have not been unequivocally linked to exposure to either one of the crystalline forms (quartz or cristobalite). Some of the reported locations are: oesophagus, stomach, liver, skin and bone. Sufficient epidemiological or toxicological data do not currently exist for quantitative assessment of the exposure-response relationship on these other tissues or organs.

Genotoxicity

Potential genotoxicity has been assessed in multiple *in vitro* and *in vivo* assays. Table 1 below gives a brief summary of the positive results observed in each type of assay.

Table 1. Summary of positive results over total number of results for each assay and each category (all studies

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conducted with crystalline silica: quartz, except where indicated).

Assay	Animal data		Human data		Positives/Total	
	In vitro	In vivo	In vitro	In vivo[d]	In vitro	In vivo
Rec Assay	0/1				0/1	
DNA strand break	1/1	2/2	5/5[b]	1/1	6/6	3/3
Sister chromatid exchange	0/1		0/1[c]	1/1	0/2	1/1
Micronucleus	2/3	0/1	2/2[b]	1/1	4/5	1/2
Chromosome aberration	0/1			1/1	0/1	1/1
Aneuploidy/polyploidy	0/3				0/3	
Cell transformation	4/4				4/4	
Hprt mutation	1/2	2/2[a]	1/1[b]		2/3	2/2
Oxidative DNA damage		4/5	2/2		2/2	4/5
DNA binding		1/1				1/1
p53 activation		0/1				0/1

a. one assay conducted with crystalline silica: cristobalite
b. one assay conducted with "ultrafine crystalline silicon dioxide".
c. crystalline silica: tridymite
d. crystalline silica dust (subtypes not provided).

All the *in vivo* human genotoxicity studies are based on three independent studies that used blood samples from workers from diverse occupational settings with confirmed exposures to crystalline silica dust; however, quantification of exposure was not provided. After stratification by smoking status, sister chromatid exchange remained statistically significant in both smokers and non-smokers although the frequency was higher in smokers. For the chromosome aberration assay conducted as part of the same study (blood samples from workers in the stone crusher industry), the increased frequency was no longer significant after stratification. In the DNA damage study of foundry and pottery workers and the micronucleus assay of workers involved in sandblasting and related jobs, results were positive when compared to controls. However, in both studies, smoking status influenced the results, contributing to the increased DNA damage observed since results were greater in smokers versus non-smokers, and the frequency of micronuclei in nasal epithelial cells was higher in smokers (p=0.002) but when using peripheral blood lymphocytes did not differ statistically between smokers and non-smokers who were similarly exposed to silica dust,

The role of *in situ* generation of reactive oxygen species (ROS) and reactive nitrogen species (RNS) has been well established in the following types of DNA damage: small scale insertions, DNA base pair deletion, base modification, chromosomal change/loss, microsatellite instability, DNA strand break, 8-hydroxydeoxyguanosine (8-OHdG) mutation and point mutations. ROS and RNS generation is postulated to be (a part of) the DNA damage mechanism for crystalline silica. Studies are described below to support this hypothesis.

DNA was exposed *in vitro* to various crystalline silica dusts, to H_2O_2, or to both. Results show that DNA damage was limited when dust or H_2O_2 were administered alone but increased with the co-exposure. When the reactive oxygen scavenger, dimethylsulfoxide, was added to the test system, DNA strand break was inhibited, data supporting the viewpoint that it is the presence of radicals generated in response to quartz and cristobalite that causes the DNA damage and not quartz or cristobalite themselves.

Hprt mutation assays in rat alveolar epithelial cells, both *in vitro* and *in vivo,* were positive in response to quartz. The positive results *in vivo* were seen only in the presence of significant inflammatory responses in the treated animals. Also, in a parallel *in vitro* experiment, rat alveolar epithelial cells were incubated with the bronchoalveolar lavage fluid from the rats exposed to quartz. Both macrophage and neutrophil enriched lavage cells induced mutation in the exposed alveolar epithelial cells. Addition of catalase (an enzyme which inactivates H_2O_2) before incubation inhibited the increase in *hprt* mutation.

Rats were exposed to either crystalline or amorphous silica in a manner to induce the same level of

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inflammation in the lungs. The inflammatory response was assessed by measuring the proportion of neutrophils in the bronchiolar lavage fluid. The actual concentrations were 3 and 50 mg/m^3 for crystalline and amorphous silica respectively. The animals were exposed for 13 weeks. *Hprt* mutation frequency was measured in the alveolar epithelial cells at the end of the exposure period. Mutation frequency was greatly increased only in the crystalline silica treated rats; no treatment related increase was found in the rats treated with the amorphous form.

In an 8-OHdG assay conducted to monitor DNA damage by reactive oxygen species, female rats were exposed to 0, 0.3, 1.5 and 7.5 mg/animal of quartz via intratracheal instillation. Effects were observed 90 days post-exposure. A clear dose-response relationship was identified between quartz exposure and various inflammation markers (differential cell count, protein, lung surfactant lipids and tumour necrosis factor alpha). Inflammation was present starting at the lowest dose. However, 8-OHdG showed a statistically significant increase starting at 1.5 mg/animal only. Similarly, in another study, 8-OHdG and DNA strand breaks were observed at concentrations of or above 10 ug/m^3 in rat lung epithelial cells.

In the aim of investigating the role of ROS in lung carcinogenesis, rat lung epithelial cells were incubated with polymorphonuclear (PMN) leukocytes (involved in the inflammatory process and responsible for the release of certain ROS) or hydrogen peroxide. Statistically significant increases in 8-OHdG were observed in the presence of PMN or hydrogen peroxide in a dose-response manner.

In a series of experiments which used *in vitro* stimulation of macrophages with crystalline silica and *in vivo* intranasal instillation of crystalline silica in mice, it was demonstrated that that the chronic fibrosis seen in a murine model of silicosis *in vivo* is dependent on the presence of adaptor molecule ASC and Nalp3 inflammazome. These data support a potential mode of action whereby silica triggers cellular responses that in turn activate alveolar macrophages, resulting in an inflammatory response and silicosis. In mice deficient in Nalp3 inflammazome, the development of inflammation and collagen deposition was significantly reduced compared with normal mice 3 months after the initial intranasal instillation of silica.

Analysis of Lung Tumour Data

The weight of evidence for both rats and humans indicates that fibrotic and silicotic lesions in the lung result from inhalation exposure to crystalline silica and that lung cancer is secondary to those lesions in the lung. Although the mechanism of induction for the lung tumours has not been fully elucidated, there is sufficient supportive mode of action evidence from the data presented to demonstrate that a threshold approach to risk assessment is appropriate based on an understanding of the key events in the pathogenesis of crystalline silica induced lung tumours. The body of evidence include the following:

- In experimental studies, all rats that developed tumours also showed fibrosis.
- Adenocarcinomas, the most common type of tumour identified in rats, are commonly associated with fibrosis and deeply scarred lung tissue.
- Experimental rat studies showed a clear progression of the effects from initially mild inflammation, followed by fibrosis over-time, leading eventually to lung tumours.
- Tumours are not present in all treated species dosed in the same way.
- The tumours, both in rats and humans, are concentrated in the lungs only, although other organs are indirectly exposed.
- In human studies, cancer risk is often more significant in workers exposed over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours.
- Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles
- Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis.
- For genotoxicity, in vitro results were mostly mixed and in vivo results were mostly positive. However, the vast majority of the positive genotoxicity assay results can be explained by the generation of reactive oxygen species, as demonstrated experimentally, where ROS scavenging prevents the genotoxicity.
- *In vivo*, macrophage deficient mice (macrophages produce ROS in response to crystalline silica) do not develop silicosis nor do they develop tumours and the Nalp3 inflammazome, a key player in the macrophage initiated inflammatory response, is required for the development of pulmonary fibrosis after

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inhalation of silica.

- Though inhalation exposure to crystalline silica in multiple occupational settings is clear, the increase in risk, based on the several recent meta-analyses of the multiple human epidemiological studies, remains low.

It is worth noting that where aggressive engineering controls have been made to reduce silica dust levels in the workplace (Sweden), silicosis has been eliminated. By corollary, existing exposures outside of the workplace in such areas do not pose a risk for silicosis to the general population.

The respirable forms of quartz and cristobalite possess properties indicating a hazard for human health (repeated dose toxicity, carcinogenicity and genotoxicity). The mode of action in the lungs involves irritation, inflammation and reactive species formation, leading to silicosis, and eventually to tumour formation.

Exposure

Uses

Consistent with oxygen and silicon being the two most abundant elements in the Earth's crust, silicon-oxide minerals, including quartz are ubiquitous in the natural environment. In particular, as a component of sand, quartz may find use in a diverse array of applications. Several high volume uses include, but are not limited to, the use of sand as a filling material for the construction of roads and in general building activities, the use of sand and gravel aggregates as abrasives on roads in winter and the use of fly-ash, which may contain 4-14% quartz and 0.5-1% cristobalite, as a cement additive. These abrasives when used on winter roads are usually mixed with road salts and may be sand only, stone dust, sand and gravel aggregates, or pre-treated sand. They are used mainly by rural municipalities or in areas where cold temperatures diminish the efficiency of salts for de-icing. Quantities of abrasives used in Canada were 5.73×10^9 kg, 4.59×10^9 kg, and 4.93×10^9 kg for 2007, 2008 and 2009, respectively.

Industrial sand, high purity silica sand products with closely controlled sizing are expected to contain quartz and cristobalite, include lump silica (2-3mm up to 15 cm or more), silica sand (75µm to 2-3mm) and silica flour (less than 75µm). Lump silica may be used in the production of silicon alloys, silica bricks, and the linings of certain types of pulverizers (eg. ball mills and tube mills).

Silica sand may be used in the manufacture of glass and glass fibres, silicate chemicals and silicon carbide, the hydraulic fracturing of wells, foundry moulding, and for sandblasting. Silica flour may find use in the ceramics and cement industries, as a filler and extender in rubber and coatings, and as an abrasive in soaps.

Natural clays, such as bentonite and fuller's earth, are used in cat litters for their high water absorbance capacities. Quartz is a natural component of these clays, and consequently, it may be present in cat litter products. High purity α-quartz is a piezoelectric material, which means that application of a voltage induces a distortion in the crystal shape and vice versa. This ability to interconvert electrical and mechanical energy has led to the use of quartz crystals in electronic devices requiring precise timing control, for example telephones, radios, watches and computers.

According to a survey conducted in Canada, quartz and cristobalite are also used in abrasives, adsorbents, filter products (diatomaceous earth), grout and cement. These substances reportedly also find use as fillers, which add bulk and improve wear resistance, in paints and coatings, adhesives, sealants, polymer films, caulking, epoxy resins and silicones. Also, quartz is listed as an ingredient in 60 cosmetic products in Canada. The types of products include anti-wrinkle preparation, eye and face makeup, lipstick, hair dyes, shampoos and grooming products, as well as skin cleansers, moisturizers and tanning preparations.

Natural Sources

In Canada, quartz naturally occurs in many types of rock formations. Those with high silicon dioxide content (95% SiO_2 or more) include vein and massive intrusion bodies, quartz pebbles, silica sand, sandstone and quartzite. Sandstone is a sedimentary rock mostly composed of quartz grains cemented by a bonding material such as clay, calcite or iron oxide. Quartzite is a hard, compact, metamorphosed sandstone made of grains of quartz firmly bonded with a siliceous cement. Mineral aggregates (e.g., sand and gravel) have variable silicon dioxide content. Quartz is also found as crystals, aggregates or discrete particles in certain igneous rocks (e.g., granites and pegmatites), soils, sediments, air and surface water. This omnipresence is consistent with the fact that silicon is the second most abundant chemical element on Earth.

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Cristobalite is naturally produced in the ashes of volcanic eruptions, and by combustion metamorphism which is a local phenomenon of spontaneous combustion of naturally occurring substances such as bituminous rocks, coal or oil. It may be found in cavities in volcanic rocks and in thermally metamorphosed sandstones and may also be a transient stage in the diagenesis of diatomaceous shale with the result that soils made of these geologic formations may be rich in cristobalite. Unlike quartz, the natural occurrence of cristobalite is limited to specific geographic regions and mineral types.

Anthropogenic Sources

Natural quartz is isolated from ore via beneficiation, which involves milling or grinding the material into particles that are separated into desired mineral and waste. The materials obtained are either used directly or further purified. In Canada, in 2006, 2.146×10^{9} kg of pure quartz were mined, and 2.385×10^{11} kg of sand and gravel aggregates were produced. The proportion of quartz in silica sand deposits and gravel aggregates will vary from one site to another.

Cristobalite can form from silica melts during the preparation of silica glass; quartz is not obtained from melts but is manufactured at elevated temperature and pressure via a hydrothermal process. Cristobalite also forms during the calcination[2] of diatomaceous earth.

Human Exposure Estimate

Ambient air

The exposure assessment is focussed on respirable quartz and cristobalite, which in ambient air comprises a component of total particulate matter (PM). In Canada, data on the concentrations of silicon in PM was available and used as a surrogate for quartz and cristobalite. This approach is conservative because the measured silicon includes all silicon-containing substances and therefore represents the upper limit for quartz and cristobalite in ambient air.

The National Air Pollution Surveillance (NAPS) Program measured concentrations in $\mu g/m^3$ of silicon in PM with aerodynamic radii less than 2.5 µm ($PM_{2.5}$ (dichot)), and from 2.5 to 10 µm (PM_{10} (dichot)) (the total particulate matter with aerodynamic radii less than 10 µm (PM_{10}) is obtained by adding these values) in Canada. In 2009, as part of the NAPS Program, silicon concentrations were determined on over 1600 samples of $PM_{2.5}$(dichot) and over 1500 samples of PM_{10}(dichot) at 24 urban locations across Canada. An estimate of exposure to quartz and cristobalite can be obtained by assuming that all the silicon in the PM is represented stoichiometrically as SiO_2, and multiplying the reported concentration of silicon by 2.14 to obtain a value for silica.

The intake of respirable quartz and cristobalite by the general population of Canada is estimated using a range covering the lowest 50^{th} percentile SiO_2 concentration in PM_{10}, measured in Pt. Petre, ON, (0.12 $\mu g/m^3$) to the highest 50^{th} percentile concentration in PM_{10} measured in Calgary, AB (2.1 $\mu g/m^3$). The 50^{th} percentile SiO_2 concentrations ranged from 0.1 to 2.1 $\mu g/m^3$ across the survey sites; the top of this range is quite close to the average of the maximum values for the 24 sites (3.7 $\mu g/m^3$). The outdoor data were used to represent the indoor levels, because information on indoor silicon concentrations was not available, and the range of PM_{10} measured indoors is generally lower than the outdoor range. Thus, this approach conservatively overestimates indoor exposure in homes.

The highest exposure group based on these calculations is children ages 0.5 to 4 years with an estimated daily intake ranging from 0.07 to 5.26 µg/kg-bw per day; the estimated daily intake decreases with age due to changes in the ratio of inhalation rates to body weights; the daily intake of adults, 20-59 years old, is estimated to range from 0.03 to 2.00 µg/kg-bw per day.

Consumer Products

Exposure to respirable quartz from the use of cosmetic products, which contained quartz as an ingredient, was considered low because they are not formulated for spray application, the loose powders were reported to contain less than 0.1% quartz, and in these products the substance is not expected to be associated with other components of the formulation and not available in a free form.

For consumer Do It Yourself (DIY) activities around the home, the highest mean breathing zone concentration of particles from sanding dry wall (median cut-point of 10µm) of 6.31 mg/m^3, was used to derive an upper-

[2] Calcinations: Heat treating a substance, but without fusion, to bring about change in its physical or chemical constitution.

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bound exposure estimate ranging from 2 to10 µg/kg-bw per event.

Quartz is used to formulate a large number of paints and coatings. To estimate potential inhalation exposure to quartz from these products, the spray painting of wall paints with an airless spray gun was considered appropriate as a conservative scenario. Exposure to respirable paint particles was estimated using data from controlled a laboratory study in which walls of poorly ventilated test rooms were painted by professional painters using an airless sprayer to apply interior latex paint. The maximum concentration of 13% quartz in paint in Canada was used to estimate exposure. The upper-bound estimate of exposure to quartz, based on the maximum concentration of 13% quartz in paint in the Canadian market and the maximum concentration of respirable paint particles measured in these controlled studies when recommended personal protective equipment is used, is 0.954 µg/kg-bw per event.

Inhalation of ambient air containing quartz and cristobalite is the dominant pathway of chronic exposure (excluding that from DIY activities) for the general population. Because SiO_2 makes up only approximately 5% of PM_{10}, silicon concentrations (expressed as SiO_2) measured in the Canadian NAPS survey of 24 urban locations were considered most relevant to the estimation of exposure by the general population. Quartz and cristobalite comprise only a portion of the total SiO_2 in PM_{10}, therefore, the use of the total silicon concentration to represent the upper bound crystalline silica concentrations results in an overestimation of exposure.

Appendix 1: Definitions of Epidemiological Terms in the ITAP

SMR (Standardized Mortality Ratio): The ratio (x 100) of observed to expected deaths in a study population. Expected deaths are calculated by applying a set of standard age-specific mortality rates to the age distribution of the study population. Standardized ratios are only useful for comparisons. They have no intrinsic meaning.

OR (Odds Ratio): In epidemiological case-control studies, a relative measure of disease occurrence. The odds in favour of a particular disease occurring in an exposed group are divided by the odds in favour of its occurring in an unexposed group. If the condition being studied is rare, the odds ratio is a close approximation to the relative risk.

RR (Risk Ratio): The probability of the occurrence of a disease in a group that has been exposed to some environmental, medicinal, microbial, or toxic influence, relative to its probability in a randomly selected population.

PMR (Proportionate Mortality Ratio): Proportionate mortality is the proportion of deaths in a specified population over a period of time attributable to different causes. Each cause is expressed as a percentage of all deaths, and the sum of the causes must add to 100%. These proportions are not mortality rates, since the denominator is all deaths, not the population in which the deaths occurred. Thus, proportionate mortality ratio is a measure of the frequency of occurrence of the proportionate mortality in a defined population during a specified interval of time.

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Toxicity Profile

Erucic amidopropyl dimethyl betaine
(CAS No. 149879-98-1)

Erucic acid is the fatty acid of erucic amidopropyl dimethylbetaine. It is a mono-unsaturated omega-9 fatty acid (22:1 ω9). No toxicity data could be located on erucic amidopropyl dimethyl betaines. Thus, this toxicity profile is based on the data on cocoamidopropyl betaines.

Cocamidopropyl betaines are mainly a mixture of C_{12}-C_{18} fatty acids from hydrolysis of coconut oil. Coconut oil has a mixed fatty acid composition, which varies slightly, as it is a natural product. Lauric acid - resulting in lauramidopropyl betaine - is the major ingredient of coconut oil.

Acute Toxicity

The acute toxicity of cocoamidopropyl betaine (30-35.5% aqueous solution) in rats is low. The oral LD_{50} is $\geq$4,900 mg/kg, and the dermal LD_{50} is >2,000 mg/kg.

Irritation

A 30% aqueous solution of cocoamidopropyl betaine was only very slightly irritating to the skin of rabbits. In human studies, up to 3% solutions were weakly irritating. A 5-10% solution of cocamidopropyl betaine produced mild to moderate irritation to the eyes of rabbits; solutions containing 15% were irritating to highly irritating; and a 30% aqueous solution was irritating with irreversible damage.

Sensitization

The sensitizing potential of cocoamidopropyl betaine in humans is low. Commercial cocoamidopropyl betaine may, however, contain impurities identified as sensitizers (amidoamine and/or 3-dimethylaminopropylamine) which may explain positive results in human patch tests. There is no evidence for a photosensitizing potential.

Repeated Dose Toxicity

Rats were given a 30% aqueous solution of cocoamidopropyl betaine by oral gavage at doses of 0, 250, 500 or 1,000 mg/kg/day (corresponding to about 0, 75, 150, and 300 mg active substance/kg/day, respectively) 5 days/week for 28 days (Henkel KgA, 1991). The only treatment-related findings were forestomach lesions at the highest dose level,

probably as a result of the irritant effect of the test substance. The NOAEL for this study is 500 mg/kg/day (150 mg cocoamidopropyl betaine/kg/day).

Rats were given a 30% aqueous solution of cocoamidopropyl betaine by oral gavage at doses of 0, 250, 500 or 1,000 mg/kg/day (corresponding to about 0, 75, 150, and 300 mg active substance/kg/day, respectively) five days/week for 90 days (Th. Goldschmidt AG, 1991). The only treatment-related findings were forestomach lesions at the 500 and 1,000 mg/kg dose levels , probably as a result of the irritant effect of the test substance. The NOAEL for this study is 250 mg/kg day (75 mg cocoamidopropyl betaine/kg/day).

Genotoxicity

There is no evidence for a genotoxic potential of cocoamidopropyl betaine. A 30% aqueous solution of cocoamidopropyl betaine was not genotoxic i*n vitro* in either a bacteria mutation test or in a mouse lymphoma test. A limited intraperitoneal mouse micronucleus test with 27 % active cocamidopropyl betaine was negative.

Carcinogenicity

No valid carcinogenicity studies have been conducted.

Reproductive Toxicity

No reproductive toxicity studies have been conducted on cocoamidopropyl betaine. However, there was no evidence of an adverse effect on the reproductive organs in rats given oral doses of up to 1,000 mg/kg/day of a 30% aqueous solution of cocoamidopropyl betaine (300 mg active substance/kg/day) for 90 days (Th. Goldschmidt AG, 1991).

Developmental Toxicity

A 28.9% aqueous solution of cocoamidopropyl betaine was tested in a rat developmental toxicity at doses of 330, 990, and 3,300 mg/kg/day (corresponding to 95, 286, and 950 mg/kg/day, respectively) (CESIO, 2004). There were dose-related maternal toxic effects (reduced body weights and stomach ulcers) at 990 mg/kg/day and above. Embryotoxic effects (increased numbers of resorptions, decreased number of viable fetuses, decreased fetal body weight) were found only at the maternal toxic dose level of 3,300 mg/kg/day. The NOAEL for maternal toxicity was 330 mg/kg/day (corresponding to 95 mg active substance/kg-day) and the NOAEL for developmental toxicity was 990 mg/kg/day (corresponding to 286 mg active substance/kg/day).

Key Study/Critical Effect for Screening Criteria

The key study is a 90-day rat oral gavage study in which forestomach lesions were seen at dose levels of 500 and 1,000 mg/kg of a 30% aqueous solution of cocoamidopropyl betaine. The NOAEL was 250 mg/kg (75 mg active substance/kg).

$NOAEL_{adjusted}$ = 75 * 5/7 = 53.6 mg/kg/day

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (subchronic to chronic)

Oral RfD = 53.6/1000 = 0.05 mg/kg/day

Drinking water guideline = 0.19 ppm

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Toxicity Profile

Hydrochloric acid
(CAS No. 7647-01-0)

Hydrochloric acid has been reviewed in the OECD-SIDS program (OECD, 2002a,b).

Hydrochloric acid (HCl) or hydrogen chloride is readily dissociated in water into hydrated protons and chloride ion.

Acute Toxicity

The oral LD_{50} value of hydrogen chloride is reported to be 238 to 277 mg/kg for female rats (Hoechst AG, 1966), and 900 mg/kg for rabbits (Loewy and Munzer, 1923). The lethal dose by dermal exposure is >5,010 mg/kg for rabbits (Monsanto, 1976). The LC_{50} values for HCl are reported to be 23.7 - 60.9 mg/L/5min, 5.7- 7.0 mg/L/30min and 4.2 4.7 mg/L/60min for rats; and 20.9 mg/L/5min, 3.9 mg/L/30min and 1.7 mg/L/60min for mice (Darmer *et al.*, 1974; Hartzell *et al.*, 1990; MacEwean *et al.*, 1974).

Irritation

Concentrations >3.3% cause skin irritation, and concentrations >17% cause corrosion in animal studies (OECD, 2002a,b). An aqueous solution (4%) of hydrogen chloride was slightly irritating (Agner and Serup, 1988), and a 10% solution was determined to be 'Irritating to skin' for the EU Dangerous Preparations Directive, in human volunteer experiments (York *et al.*, 1996).

0.1 mL of 10% aqueous solution of HCl was highly irritating to the eyes of rabbits (Jacobs, 1992); 0.03 mL or more of 5% HCl was corrosive to the eyes of rabbits (Griffith *et al.*, 1980); 0.1 mL of a 3.3% aqueous solution of HCL was slightly irritating the eyes of rabbits (Hoechst AG, 1966); and 0.1 mL of a 0.33% aqueous solution of HCl was not irritating to the eyes of rabbits. (Hoechst AG, 1966).

Sensitization

Hydrogen chloride is not a skin sensitizer to guinea pigs and humans (Gad *et al.*, 1986).

Repeated Dose Toxicity

Rats were fed diets containing 280 to 1,250 mmol/kg hydrochloric acid (10.2 to 45.6 mg/kg) for 7-12 weeks. There was increased water intake in all treated groups. All

animals fed diet containing 937 mmol/kg and above for 9 weeks, and half of the animals fed diet containing 900 mmol/kg for 12 weeks died. Also at doses ≥937 mmol/kg, there was decreased body weight, food consumption, blood pH, femur length, rate of ash in bone (Upotn and L'Estrange, 1977). In another study with rats, hydrochloric acid was administered via drinking water at pH 2-3 (study duration not provided). Decreased protein levels in urine and decreased urine volumes were observed in the treatment groups (Clausing and Gottschalk, 1989).

Genotoxicity

While consistent negative results have been obtained in the bacterial systems, positive results have been obtained in the non-bacterial systems (OECD, 2002a,b). The positive results were observed at high concentrations, but they were considered to be artifacts due to the low pH. Positive results were obtained in a sex-linked recessive lethal study with *D. melanogaster*; only one dose level was tested (Stumm-Tegethoff, 1966) There are no mammalian studies on *in vivo* mutagenicity with hydrogen chloride

Carcinogenicity (Oral Studies only)

A ten-month study has been conducted using mice (Dyer *et al.*, 1946). Because the methods such as strain used, duration and dose of administration, presence of co-administration substance, were not appropriate, it cannot be used for the assessment of carcinogenicity of hydrochloric acid.

Reproductive Toxicity

No reliable studies were identified by the oral route.

Developmental Toxicity

No reliable studies were identified by the oral route.

Key Study/Critical Effect for Screening Criteria

The Australian drinking water guideline value for pH may apply to hydrochloric acid.

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Toxicity Profile

2-Propanol or Isopopranol
(CAS No. 67-63-0)

Acute Toxicity

The acute oral LD_{50} has been reported as 4,700 mg/kg, 5,300 mg/kg, 5,500 mg/kg, and 5,8400 mg/kg in rats; 4,500 mg/kg in mice; and 5,030 mg/kg, 7,800 mg/kg, and 7,900 mg/kg in rabbits (31, 272, 274, 275, 144, 35 Kimura et al., 1971; WHO, 1990; Smyth and Carpenter, 1948; Lehman and Chase, 1994; Munch and Schwartze, 1925; Munch, 1972). The acute dermal LD_{50} in rabbits has been reported to be 12,900 mg/kg (Smyth and Carpenter, 1948). The acute inhalation 8-h LC_{50} in rats was 19,000 ppm in females and 22,500 ppm in males (Laham *et al.*, 1980). Exposure of rats to 16,000 ppm for 8 h resulted in four deaths out of six animals (Smyth and Carpenter, 1948).

Irritation

Isopropanol applied to the intact or abraded skin of rabbits and guinea pigs produced negligible irritation (Nixon *et al.*, 1975). Liquid isopropanol is moderately irritating to the eyes of rabbits (Griffith *et al.*, 1980; WHO, 1990). Isopropanol produced little irritation when tested on the skin of six human subjects (Bevan, 2012).

Sensitization

There have been reports of isolated cases of dermal irritation and/or skin sensitization (Bevan, 2012). Except for three case reports, the positive reactions were observed on patch testing patients with contact dermatitis due to ethanol. These patients also had a positive reaction to ethanol.

Repeated Dose Toxicity (Oral Studies only)

In a drinking water study, rats ingested 0.5 to 10% of isopropanol for 27 weeks and showed decreased body weight gain but no gross or microscopic tissue abnormalities (Lehman and Chase, 1975). Increased formation of hyaline droplets in the proximal tubules was reported in male rats given 1–4% isopropanol in drinking water for 12 weeks (Pilegaard and Ladefoged, 1993). In another study, daily application of a 50% solution to the heads of rats for 187 days produced no apparent injury to the skin (Boughton, 1944). Isopropanol was administered in drinking water to three dogs for 7 months. The alcohol concentration was 4% from the end of the first month until the conclusion of the experiment. Tolerance to the alcohol developed as manifested by an increased degree of neuromuscular coordination at similar blood levels in habituated versus control animals

and by increased elimination of the alcohol. The only significant histopathological changes were noted in the kidneys of one dog that died (Lehman *et al.*, 1945).

Genotoxicity

All genotoxicity assays conducted so far with isopropanol have been negative (OECD, 1997a,b; Bevan, 2012). Isopropanol was not mutagenic in the *Salmonella* microsomal assay using the spot test, in strains TA98, TA100, TA1535, and TA1537 with and without S9 from the livers of Aroclor-induced rats (Abbondandolo *et al.*, 1980). Isopropanol was not mutagenic in *Salmonella* strains TA97, TA98, TA100, TA102, TA104, TA1535, TA1537, and TA1538 with and without metabolic activation, when tested using a plate-incorporation modification of this assay (Zeiger *et al.*, 1992).

Isopropanol was inactive in mutagenicity tests in *Neurospora crassa* (Brockman *et al.*, 1984) and isopropanol did not enhance adenovirus (SA7) transformation using Syrian hamster embryo cells (Heidelberger *et al.*, 1983). Isopropanol was inactive in a sister chromatid exchange assay with and without S9 metabolic activation (von der Hude *et al.*, 1987). Isopropanol was inactive in an *in vitro* CHO/HGPRT gene mutation assay and in an *in vivo* bone marrow micronucleus assay in mice (Kapp, Jr. *et al.*, 1993).

Carcinogenicity

No carcinogenicity studies have been conducted by the oral route.

CD-1 mice were exposed by inhalation to 0, 500, 2500, or 5000 ppm of isopropanol vapor for 6 h/day, 5 days/week for 18 months. An additional group of mice (all exposure levels) were assigned to a recovery group which were exposed to isopropanol for 12 months and then retained until study termination at 18 months. There was no increased frequency of neoplastic lesions in any of the isopropanol-exposed animals. Nonneoplastic lesions were limited to the testes (males) and the kidney. In the testes, enlargement of the seminal vesicles occurred in the absence of associated inflammatory or degenerative changes. The kidney effects included tubular proteinosis and/or tubular dilatation. The incidence of testicular and kidney effects was not increased in the isopropanol-exposed recovery animals (Burleigh-Flayer *et al.*, 1997).

Fischer 344 rats were exposed to 0, 500, 2500, or 5000 ppm of isopropanol vapor for 6 h/day, 5 days/week for 24 months. The mortality rates for all male rats were 82, 83, 91, and 100% for the 0-, 500-, 2500-, and 5000-ppm groups, respectively. The corresponding values for the female rats were 54, 48, 55, and 69%. The main cause of death for the 5000-ppm rats (both sexes), as well as for much of the mortality of the 2500-ppm male rats, was chronic progressive nephropathy. Isopropanol exposure resulted in impaired kidney function, as indicated by various urine chemistry changes in male (2500- and 5000-ppm) and female (5000-ppm) rats. Animals in these groups also exhibited histopathological effects in the kidneys which appeared to be an exacerbated form of

chronic progressive nephropathy. The only neoplastic lesion noted was increased interstitial (Leydig) cell adenomas in male rats. The frequency of these tumors, although elevated above the control animals, was within the historical control range of the testing facility and within the range reported for control animals from the National Toxicology Program carcinogenicity studies (Burleigh-Flayer *et al.*, 1997).

The carcinogenic potential of isopropanol was evaluated via inhalation using three strains of mice. Male mice were exposed to 7.5 ppm of isopropanol for 3 to 7 h/day, 5 days/week for 5 to 8 months. Animals were killed at either 8 or 12 months. There was no significant increase in the number of lung tumors observed. Similarly, no increases in lung tumors were observed in the same strains of mice that received subcutaneous injections of isopropanol once weekly for 20 to 40 weeks (Weil *et al.*, 1952).

Reproductive Toxicity

In a two-generation reproductive toxicity study, Sprague–Dawley rats were dosed by oral gavage with 0, 100, 500, or 1,000 mg/kg isopropanol. There were seven parental deaths that were considered treatment-related: two high-dose F_0 females, two F_1 high-dose females, one mid-dose F_0 female, and two low-dose F_1 males. Lactation body weight gain was increased in the 500- and 1000-mg/kg females in both generations, and liver and kidney weights were increased in the 500- and 1,000-mg/kg groups in both sexes. Centrilobular hepatocyte hypertrophy was noted in some 1,000 mg/kg F_1 males. There were some kidney effects in the 500- and 1000-mg/kg F_0 males and in all treated F_1 male rats. The kidney effects were characterized by an increased number of hyaline droplets in the convoluted proximal tubular cells, epithelial degeneration and hyperplasia, and proteinaceous casts. Increased mortality occurred in the high-dose F_1 offspring during the early postnatal period; no other clinical signs of toxicity were observed in the offspring from either generation. Offspring body weight, however, in the 1,000-mg/kg group was reduced during the early postnatal period. There was significant mortality in the F_1 weanlings (18/70) before the selection of the F_1 adults. A statistically significant reduction was observed in the F_1 male mating index of the 1,000-mg/kg group (73 versus 97% in the controls). There were no other treatment-related effects on reproduction, including fertility and gestational indices, or histopathology of the reproductive organs (Bevan *et al.*, 1995). A benchmark dose level of 420 mg/kg/day (lower bound on dose associated with a 5% response rate for the decrease in the male mating index was calculated (Allen *et al.*, 1998).

In a one-generation reproductive/embryotoxicity study, male and female Wistar rats were given 0, 0.5%, 1.0% or 2.0% isopropanol in their drinking water. The calculated intakes for males were 383, 686 and 1107 mg/kg-day (pre-mating) and 347, 625 and 1030 mg/kg-day (18 weeks of treatment). The calculated intakes for females were 456, 835 and 1206 mg/kg-day (premating); 668, 1330 and 1902 mg/kg-day (gestation); and 1053, 1948 and 2768 mg/kg-day (postpartum). An immediate, statistically significant dose-dependent decrease occurred in water intake in the male rats. Intake was reduced ~5-14% (1% group; premating period) and ~30% (2% group; days 7-11 to end of study).

Overall mean feed consumption was significantly lower in treated versus control animals. Male body weights (2% only) were reduced throughout the study. Water consumption was initially reduced in the 1% and 2% females, but the 2% group recovered to only ~70% of the control values (premating); it continued to be reduced during the gestation and lactation period. Mean maternal body weights were reduced (all treated groups) at the start of gestation, with partial recovery during the gestation period except for the 2% group. Overall weight gain during gestation in these groups were similar to the controls. Following parturition from PND 4 onward, the 2% dams had significantly lower body weights. There were no infertile males in any group, and no treatment-related effect on female fertility or on length of gestation. The number of pups/litter on GD 1 was reduced in the 2% group; because it was not replicated in the embryotoxicity portion, an increase in pup mortality during partuition or GD 0, followed by cannibalism of the dead pups by the dam was suggested. No macroscopic abnormalities were seen in females; nor was there any treatment-related histopathological changes seen in the reproductive tissue in the 2% parental animals. Absolute kidney weight and relative kidney, liver, and spleen weights were increased in the 2% F0 males; increased absolute liver and kidney weights and relative liver weights in the 2% F0 females. In the embryotoxicity portion, there was a statistically significant increase in the total number of preimplantation losses in the 2% animals. Whole body edema was seen in 40% of the fetuses in 3/8 litters in the 2% group. No macroscopic abnormalities of the viscera of these fetuses were detected, and the incidence of edema was not related to gender. In the one-generation portion, postnatal pup survival and in the average pup weight (by PND 7) were decreased in the 2% group. F1 generation animals of both sexes showed increased relative liver weights at all dose levels, and the 2% males had higher relative kidney weights. A slight but significant decrease in absolute brain weight and increase in relative empty cecum weights in both sexes of the 2% F1 generation group. No treatment-related gross abnormalities were observed in the F1 generation animals at necropsy (BIBRA, 1988).

The effects of isopropanol (2.5% in drinking water) on the reproduction and growth of rats was assessed in a multigenerational study. No reproductive toxicity was observed (Lehman *et al.*, 1945).

Isopropanol was administerd as a 3% solution in drinking water to Wistar rats. Reduced parental body weight gain, food, and water consumption was observed in the treated animals compared with the controls. Fertility, litter size, and pup weights at postnatal days 4 and 21 were reduced in treated animals compared with the controls. In the second generation, the isopropanol concentration was reduced to 2%, and there were essentially no effects (Gallo *et al.*, 1977).

Developmental Toxicity

Isopropanol was given at concentrations of 0, 0.5%, 1.25% or 2.5% in the drinking water to female Wistar rats on GD 6 to 16. The calculated intakes of isopropanol during GD 6-16 were 596, 1242 and 1605 mg/kg/day. There was an immediate reduction in water intake in the 2.5% dose group, and this was statistically significant throughout the

treatment period when compared to controls. A smaller reduction in water intake was also seen in the 1.25% females (statistically significant during GD 6-9), with no change in the 0.5% females. Palatability of the drinking water may have been the problem since water intake significantly increased the first day following the end of the treatment period for all dose groups. Feed consumption patterns paralleled the water consumption during and after treatment in the mid- and high-dose groups. Overall, mean body weights of the 2.5% females were lower than the controls from GD 7 to termination. Effects on weight gain in the 0.5% and 1.25% females were limited to a failure to gain weight during the first (0.5%) and second (1.25%) day of treatment. There were no treatment-related effects in postimplantation loss, mean number of implantation sites or live fetuses. There was a slight dose-dependent decrease in mean litter weight and a significant decrease in mean fetal weight in the 1.25% and 2.5% groups. A statistically significant increase in variations was observed, indicative of a lower degree of ossification in the treated animals There was a dose-dependent decrease in the number of fetuses with the 4^{th} sacral arch and a dose-dependent increase in the number of fetuses with less than 2 caudal arches. The sternum also showed reduced ossification because there were increased numbers of fetuses with small, absent, or incompletely ossified sternebrae (BIBRA, 1987).

In a rat developmental study, female Sprague–Dawley rats were dosed by oral gavage with either 0, 400, 800, or 1200 mg/kg of isopropanol during gestational days 6 to 15. Two dams (8%) died at 1200 mg/kg and one dam (4%) died at 800 mg/kg. At 1200 mg/kg, maternal body weights were reduced throughout gestation (GS 0-20; 89.9% of control value), associated with reduced gravid uterine weight. There were no other treatment-related effects on the dams. Fetal body weights per litter were also significantly reduced at the 800 and 1200 mg/kg dose levels, but there were no teratogenic effects. There were no adverse maternal or developmental effects at 400 mg/kg (Tyl *et al.*, 1994).

In a rabbit developmental study, female New Zealand white rabbits were dosed by oral gavage with either 0, 120, 240, or 480 mg/kg of isopropanol during gestational days 6 to 18. At 480 mg/kg, isopropanol was unexpectedly toxic to pregnant female rabbits, resulting in the deaths of four does (26%). Maternal body weights were significantly reduced during treatment (gestational days 6–18) and were associated with reduced maternal food consumption during this period. Profound clinical signs were noted at 480 mg/kg and included flushed and/or warm ears, cyanosis, lethargy, and labored respiration. No adverse maternal effects were noted at 120 or 240 mg/kg. There were no developmental or teratogenic effects at any dose tested (Tyl *et al.*, 1994).

Isopropanol was given by oral gavage to Sprague–Dawley rats from gestational days 6 to 21 in doses of 0, 200, 700, or 1200 mg/kg. The dams were allowed to deliver, litters were culled on postnatal day (PND) 4, pups were weaned on PND 22, and their dams were killed. Weaned pups were assessed for day of testes descent or vaginal opening, motor activity, auditory startle, and active avoidance. The pups were killed on PND 68. Some of the pups were taken from each dose group and were perfused in situ for pathological examination of the central nervous system. There were no biologically significant findings in the behavioral tests, no changes in organ weights, and no pathological

findings of note. Thus, there was no evidence of developmental neurotoxicity from isopropanol exposure (Bates *et al.*, 1994).

Key Study/Critical Effect for Screening Criteria

The benchmark dose level of 420 mg/kg/day from the two-generation reproductive toxicity study will be used to derive a drinking water guidance value for 2-propanol.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral Reference Dose = 420/100 = 4 mg/kg/day

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Toxicity Profile

Magnesium chloride
(CAS No. 7786-30-3)

Acute Toxicity

The oral LD_{50} of magnesium chloride hexahydrate in rats is >2,000 mg/kg. The dermal LD_{50} of magnesium chloride hexahydrate in rats is >2,000 mg/kg.

Irritation

Magnesium chloride hexahydrate was applied topically to the EPISKIN-SMätissue for 15 min followed by a 42 hour post-incubation period and immediate determination of cytotoxic effects via MTT reduction assay. The test item showed no irritant effects.

Single ocular instillation of magnesium chloride hexahydrate to rabbits at a dose of 0.1 g produced irritant effects, which were fully reversible within 6, 4 and 2 days post-instillation in animal no. 1, 2 and 3, respectively. Based on these findings, magnesium chloride hexahydrate is not an eye irritant.

Sensitization

Magnesium chloride hexahydrate was not a skin sensitizer when tested in guinea pigs.

Repeated Dose Toxicity

In an OECD 422 study, Wistar rats at dosages of 250, 500 and 1,000 mg/kg magnesium chloride hexahydrate revealed no major toxicological findings. The cause of death of animals during the conduct of the study could not be determined (a plausible cause may be gavage error or regurgitation). The NOAEL for this study is 1,000 mg/kg/day.

Groups of 50 male and 50 female $B6C3F_1$ mice were given magnesium hexahydrate at dose levels of 0, 0.5% and 2% in the diet for 96 weeks, after which all animals received the control diet for 8 weeks and were then necropsied. In the 2% females, a decrease in body weight was observed. However, survival rates did not differ between the treatment and control groups for males or females and clinical signs and urinary, hematological or serum clinical chemistry parameters showed no treatment-related effects. Therefore, this change was considered not to be of biological significance. The NOAEL for female and male mice was 2% in feed, which corresponded to 3,930 and 2,810 mg/kg/day, respectively.

Genotoxicity

Magnesium chloride was not genotoxic in the *in vitro* mouse lymphoma assay and in the *in vitro* chromosomal aberration assay using human lymphocytes.

Carcinogenicity

Male and female $B6C3F_1$ mice were given in their fed 0, 0.5% or 2% magnesium chloride hexahydrate for 96 weeks, after which all animals received the control diet for 8 weesk and were then necropsied. Tumors were mainly found in the skin/subcutis, liver and lymphatic system. With the exception of a significant decrease in the incidence of liver tumors among the 2% males, there were no differences in the tumor incidences between the treated and control animals.

Reproductive/Developmental Toxicity

In an OECD 422 study, Wistar rats at dosages of 0, 250, 500 or 1,000 mg/kg showed no treatment-related reproductive or developmental effects. The NOAEL for this study is 1,000 mg/kg/day.

Key Study/Critical Effect for Screening Criteria

The Australian drinking water guideline value for chloride may apply to magnesium chloride.

Reference

ECHA REACH database: http://apps.echa.europa.eu/registered/registered-sub.aspx

Toxicity Profile

Magnesium nitrate
(CAS No. 10377-60-3)

Acute Toxicity

The acute oral LD_{50} in rats is >5,000 mg/kg.

Irritation

No studies are available.

Sensitization

Magnesium nitrate is not a skin sensitizer based on results of a Local Lymph Node Assay (LLNA).

Repeat Dose Toxicity Studies

No studies are available.

Genotoxicity

Magnesium nitrate hexahydrate is not mutagenic in the *Salmonella typhimurium* reverse mutation assay and in the *Escherichia coli* reverse mutation assay.

Carcinogenicity

No data are available.

Reproductive Toxicity

No data are available.

Developmental Toxicity

No data are available.

Key Study/Critical Effect for Screening Criteria

The Australian drinking water guidance value for nitrates may apply to magnesium nitrate.

Reference

ECHA REACH database: http://apps.echa.europa.eu/registered/registered-sub.aspx

Benzenesulfonic acid, 4-ethyenyl-, sodium salt, homopolymer
(CAS No. 25704-18-1)

Acetic acid ethenyl ester, polymer with ethanol
(CAS No. 25213-24-5)

Vinylidene chloride/methacrylate copolymer
(CAS No. 25038-72-6)

Polyvinyl acetate, partially hydrolyzed
(CAS No. 30443-60-5) THIS IS NOT THE CORRECT CASRN

All of the these substances are polymers.

Mammalian toxicity data was located for only for acetic acid, ethenyl ester, polymer with ethanol (CAS No. 25213-24-5) on a supplier's MSDS. However, all of the polymers listed above are expected to exhibit similar toxicity profiles.

As polymers, they are not expected to be absorbed by the oral, dermal or inhalation routes of exposure due to their large molecular weights. They are also expected to be stable in biological media and resistant to metabolism.

This polymers are expected to be essentially acutely non-toxic by the oral, dermal and inhalation routes of exposure. The oral LD_{50} in rats for CAS No. 25213-24-5 was reported to be >11,000 mg/kg. Under certain conditions, dusts may be formed, which is to be considered as a nuisance dust. The polymers are expected to be non-irritating and not dermal sensitizers. No irritation or sensitization was observed in guinea pigs from CAS No. 25213-24-5.

These polymers are not expected to exhibit any systemic toxicity.

Reference

DuPont (2006). MSDS for "ELVANOL" 60-30, revised 27-Oct-2006.

Toxicity Profile

Sodium chloroacetate
(CAS No. 3926-62-3)

Sodium chloroacetate has been reviewed in the OECD-SIDS program (OECD, 1994).

Acute Toxicity

The oral LD_{50} is 76 mg/kg in rats (Woodard *et al.*, 1941); 165 mg/kg (Morrison, 1946) and 225-339 mg/kg (Woodard *et al.*, 1941) in mice; and 79 mg/kg in guinea pigs (Woodard *et al.*, 1941). The dermal LD_{50} is >2,000 mg/kg in rats (Hofmann and Jung, 1988).

A number of cattle died after accidental exposure to sodium chloroacetate. The doses involved were at least 17 to 70 mg/kg and probably in the order of 170 mg/kg. Extensor paralysis of the limbs, tremors, and convulsions were observed in three cows before death (Quick *et al.*, 1983). In cows exposed to 50 mg/kg, lethargy lasting 24 hours was observed. A doubling of the dose resulted in severe symptoms of intoxication (diarrhea, muscular twitching and loss of muscle tone) with recovery after two weeks. Death occurred within nine hours later (Dalgaard-Mikkelsen and Rasmussen, 1961).

Irritation

When tested in an OECD 404 guideline study, 500 mg of sodium chloroacetate was not irritating to the skin of rabbits (Kreling and Jung, 1988). When tested in an OECD 405 guideline study, 100 mg of sodium chloroacetate was not irritating to the eyes of rabbits (Kreiling and Jung, 1988).

Sensitization

No data are available.

Repeated Dose Toxicity

Sprague-Dawley rats (10/sex/dose) were dosed by oral gavage with 0, 15, 30, 60 or 120 mg/kg sodium chloroacetate for 90 consecutive days. At 120 mg/kg, 30% of the females and 80% of the males died within the first two days of treatment. Hemorrhagic and congested lungs (possibly a postmortem change) were observed in early deaths (1-3 days), whereas liver lesions were observed in later deaths. The levels of creatine, blood calcium and blood urea nitrogen were significantly elevated in males in all dose groups, but creatine levels were elevated in the 30 and 60 mg/kg females. Increased serum levels

of alanine aminotransferase and separate aminotransferase were seen in both males and females, but a significant trend could not be demonstrated. Chronic heart inflammation was present in both sexes, particularly at the higher dose levels. Relative liver and kidney to bodyweight ratios were increased in both sexes. Histopathological examination showed a significant increase in chronic renal nephropathy and increased splenic pigmentation in the 60 mg/kg males.

Chronic progressive nephropathy (CPN) is a common spontaneous kidney disease of laboratory rat strains (Gray, 1977) that is both a degenerative and regenerative entity exhibiting a high rate of tubule cell proliferative activity throughout its progression (Hard and Khan, 2004; Short *et al.*, 1989). It is a progressive disease with known physiological factors that modify disease progression, such as high dietary protein. Hard et al. (2009) compared CPN in rats and human nephropathies and concluded that CPN is a distinctive entity in rats with no counterpart in human disease. A number of chemicals have been shown to exacerbate CPN in rats, particularly in Sprague-Dawley rats (Hard et al., 2012). Because of the uniqueness of CPN to rats, the chemical-induced exacerbation of CPN in male rats should not be considered relevant to human health risk assessments (Hard et al., 2012)

Thus, the LOAEL for this study is considered to be 60 mg/kg/day based on the increased incidence of splenic pigments, brown and localized in splenic macrophages, which were statistically significant in the 60 mg/kg/day male rats. The NOAEL is 30 mg/kg/day.

Genotoxicity

No data are available.

Carcinogenicity

No data are available.

Reproductive Toxicity

No data are available.

Developmental Toxicity

An unpublished study was cited in the OECD-SIDS dossier on chloroacetate (OECD, 2004). Female rats were dosed with 0, 17, 35, 70 or 140 mg/kg sodium chloroacetate during GD 6-15. Mean adjusted percentage weight gain for GD 0 to 20 was reduced in the 140 mg/kg dams. Reduction in weight gain was also observed in the 35, 70 and 140 mg/kg groups for the first three days of dosing. Mean cardiovascular malformations,

comprising of levocardia, were significantly elevated over controls for the 140 mg/kg group. The mean frequency per litter of soft tissue malformations ranged from 1.2% (controls) to 6.37% (140 mg/kg); there was no dose-related effect. The NOAELs for maternal and developmental effects were 70 mg/kg/day.

Key Study/Critical Effect for Screening Criteria

A 90-day rat oral gavage toxicity study was conducted. The LOAEL for this study is considered to be 60 mg/kg/day based on the increased incidence of splenic pigments, brown and localized in splenic macrophages, which were statistically significant in the 60 mg/kg/day male rats. The NOAEL is 30 mg/kg/day.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (subchronic to chronic)

Oral Reference Dose = 30/1,000 = 0.03 mg/kg/day

Drinking water guideline value = 0.11 ppm

References

Dalgaard-Mikkelsen, S., and Rasmussen, F. (1961). Nordisk Veterinaermedicin (Scandinavian Veterinary Medicine) 13: 271.

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Gray, J.E. (1977). Crit. Rev. Toxicol. 5: 115-144.

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Hard, G.C., Betz, L.J., and Seely, J.C. (2012). Toxicol. Pathol. 40: 473-481.

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Short, B.G., Burnett, V.J., and Swenberg, J.A. (1989). Toxicol. Appl. Pharmacol. 101: 414-431.
Woodard, G. *et al.* (2004). J. Ind. Hyg. Toxicol. 23: 78-82.

Toxicity Profile

Talc
(CAS No. 61789-40-0)

Talc refers to both mineral talc and industrial mineral products that are marketed under the name talc and contain proportions of mineral talc that range from about 35% to almost 100%. Industrial talc generally refers to products that contain abundant minerals other than talc; cosmetic talc now normally contains >98% talc but the content may have been lower in the past. Pharmaceutical talc contains >99% talc. Talcum powder is cosmetic-grade talc.

Talc is a mineral composed of hydrated magnesium silicate with the chemical formula $Mg_3Si4O_{10}(OH)_2$ or $H_2Mg_3(SiO_3)_4$. Talc is not soluble in water.

The U.S. Food and Drug Administration (FDA) regulates talc and states that it is generally recognized as safe for use in color additives in foods, drugs and cosmetics, and in paper, paper products, cotton and cotton fabrics that come into contact with food. The Food Chemical Codex (2003) provides specifications for food-grade talc, including the statement that "talc derived from deposits that are known to contain associated asbestos is not food grade." Under the voluntary guidelines initiated in 1976, the Cosmetic, Toiletry, and Fragrances Association stated that all cosmetic talc should contain at least 90% platy talc (hydrated magnesium silicate) that is free from detectable amounts (<0.5%) of fibrous, asbestos minerals.

Toxicokinetics (Oral)

The absorption and disposition of ^{3}H-labeled talc in rats, mice, and guinea pigs administered a single oral dose was studied by Phillips *et al.* (1978). The oral doses were 50 mg/kg for rats, 40 mg/kg for mice, and 25 mg/kg for guinea pigs. In rats, mice, and guinea pigs, more than 95% of the dose was excreted in the feces 3 to 4 days after dosing. Less than 2% of the radioactivity was recovered in the urine. This radioactivity probably reflected contamination of urine samples with feces. No radioactivity was found in the liver or kidneys of these animals. This information suggests that talc is not absorbed from the gastrointestinal tract following oral exposure.

Acute Toxicity

No data were located.

Repeated Dose Toxicity/Carcinogenicity

Male and female Wistar rats were given in their diet 0 or 50 mg/kg of commercial talc [characteristics unspecified] for the life of the animals (average survival was 702 and 649 days, respectively). There was no significant difference in the talc-fed animals compared with control animals (Gibel *et al.*, 1976).

Male and female Wistar-derived rats were given in their diet 100 mg Italian talc (grade 00000; ready milled; mean particle size, 25 μm; containing 92% talc, 3% chlorite, 1% carbonate minerals and 0.5–1% quartz) per rat per day for 5 months (talc-containing diet was actually given for 101 days) and were then maintained on basal diet for life (average survival, 614 days). No differences in tumor incidence were noted between treated animals and control animals (eight/sex for an average survival of 641 days) (Wagner *et al.*, 1977).

In humans and experimental animals, the effects of talc are dependent on the route of exposure, and the dose and properties of the talc. Talc pneumoconiosis was somewhat more prevalent and severe among miners exposed to talc containing asbestiform minerals and/or asbestos than among those exposed to talc without such contaminants. However, the role of quartz and asbestos in the observed pneumoconiosis could not be ruled out. Among drug users, intravenous injection of talc present as a filler in the drugs resulted in microembolization in a variety of organs and alterations in pulmonary function. In animal studies, talc has been shown to cause granulomas and mild inflammation when inhaled. Observations of the effects that occurred in the lungs of rats exposed by inhalation to talc suggested that the operative mechanisms may be similar to those identified for carbon black, and talc is known to cause the release of cytokines, chemokines and growth factors from pleural mesothelial cells.

IARC: There is *inadequate evidence* in humans for the carcinogenicity of inhaled talc not containing asbestos or asbestiform fibres. There is *limited evidence* in experimental animals for the carcinogenicity of talc not containing asbestos or asbestiform fibres. Inhaled talc not containing asbestos or asbestiform fibres is *not classifiable as to its carcinogenicity (Group 3).*

Genotoxicity

The IARC (1987) review of talc included unpublished results from a 1974 study conducted by Litton Bionetics that showed no mutagenic activity for talc *in vitro* or *in vivo.* Talc did not induce mutations in *Salmonella typhimurium* strains TA1530 or HisG46, or in the yeast, *Saccharomyces cerevisiae.* No chromosomal aberrations were observed in human fibroblasts treated with talc *in vitro. In vivo* tests conducted in rats gave negative results for induction of chromosomal aberrations in bone marrow cells and dominant lethal mutations in germinal cells.

Three samples of respirable talc failed to elicit significant unscheduled DNA synthesis (10, 20 and 50 μg/cm^2, 24 hours), sister chromatid exchange or aneuploidy (2, 5, 10 and 15 μg/cm^2, 48 hours) in rat pleural mesothelial cells, in contrast to various positive controls. The three samples, *i.e.* Spanish talc (No. 5725), Italian talc (No. 5726) and French talc (No. 7841), contained 90–95% talc; the remaining contents were chlorite and dolomite. Electron microscopy analysis revealed that talc particles were taken up by the rat pleural mesothelial cells, but no aneuploidy was observed in metaphases (Endo-Capron *et al.*, 1993).

Reproductive Toxicity

No data are available.

Developmental Toxicity

No teratologic effects were observed in hamsters, rats, mice, or rabbits after oral administration of talc. The doses used were 1,600 mg/kg for rats and mice on days *6* through 15 of gestation; 1,200 mg/kg for hamsters on day 6 through 10 of gestation; and 900 mg/kg for rabbits on days 6 through 18 of gestation.

Key Study/Critical Effect for Screening Criteria

There are no adequate studies for which to derive a oral reference dose. Talc is poorly absorbed from the gastrointestinal tract, if at all, and the limited data available by the oral route indicate that talc is essentially non-toxic by the oral route of exposure.

References

Endo-Capron, S., Renier, A., Janson, X. *et al*. (1993). In vitro response of rat pleural mesothelial cells to talc samples in genotoxicity assays (sister chromatid exchanges and DNA repair). Toxicol. In Vitro 7: 7-14.

Gibel, W., LOhs, K., Horn, K.H., Wildner, G.P., and Hoffman, F. (1976) Experimental study on carcinogenic activity of asbestos filters (Ger.). Arch. Geschwulstforsch. 46: 437-442.

IARC (1987) IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Volume 42, International Agency for the Research on Cancer, World Health Organization, Lyon, France; cited in NTP (1993).

IARC (2010). IARC Monographs on the Evaluation of Carcinogenic Risks to Humans: Carbon Black, Titanium Dioxide, and Talc, Volume 93, International Agency for the Research on Cancer, World Health Organization, Lyon, France.

NTP (1993). Toxicology and Carcinogenesis of Talc (CAS No. 14807-96-6) in F344/N Rats and B6C3F$_1$ Mice (Inhalation Studies), NTP TR 421, NIH Publication No. 93-3152, National Toxicology Program, U.S. Department of Health and Human Services, Public Health Service, National Institutes of Health.

Phillips, J.C., Young, P.J., Hardy, K., and Gangolli, S.D. (1978). Studies on the absorption and disposition of 'H-labelled talc in the rat, mouse, guinea-pig and rabbit. Food Cosmet. Toxicol. 16: 161-163.

Wagner, J.C., Berry, G., Cooke, T.J., Hill, R.J., Pooley, F.D., and Skidmore, J.W. (1977). Animal experiments with talc. In: Inhaled Particles (W.H. Walton and B. McGovern, Eds.), Vol. IV, Part 2, pp. 647-654, Pergamon Press, Oxford.

Toxicity Profile

Tetramethylammonium chloride
(CAS No. 75-57-0)

Surrogates:
Didecyldimethylammonium chloride
(CAS No. 7173-51-5)
Dodecyltrimethylammonium chloride
(CAS No. 112-00-5)

No data could be located on tetramethylammonium chloride. Toxicity data are available for didecyldimethylammonium chloride (DDAC) and dodecyltrimethyl-ammonium chloride (DTAC). Thus, these two substances have been used as surrogates for the alkylated quaternary chloride.

Acute Toxicity

The oral LD_{50} of 100% DDAC has been reported to be 84 mg/kg in rats and 268 mg/kg in mice. The oral LD_{50} of a 5-25% solution of DDAC in rats was reported to be 1,190 mg/kg (595 to 297 mg a.i./kg). The acute dermal LD_{50} of a 80% solution of DDAC in rats is 3,342 mg/kg (2674 mg a.i./kg).

The acute oral LD_{50} of DTAC (24.7% aq. soln.) in rats is 490 mg/kg. The acute oral LD_{50} of DTAC (37.35% aq. soln.) in rats is 560 mg/kg.

Irritation

DDAC is a severe skin and eye irritant to rabbits.

Sensitization

DDAC is not a dermal sensitizer to guinea pigs or to humans.

Repeatd Dose Toxicity

Mice were given in their diet 0, 100, 300, 600, 1,000 or 3,000 ppm DDAC for 89-90 days. For the lowest four dose groups, these doses correspond to mean intake levels of approximately 18, 52, 107, and 182 mg/kg for males, and 23, 68, 134, and 224 mg/kg for females. High mortality in the 3,000 ppm groups prohibited calculation of daily intakes. Treatment of mice with 3,000 ppm DDAC in the diet for several days resulted in virtually

100% mortality in both sexes, with only one male surviving to termination of the study. Death was attributed to treatment-related severe wasting and dehydration resulting from gastrointestinal effects. Treatment with 1,000 ppm DDAC produced a 5% decrease in body weight in males with associated decreases in body weight gain. Similar depressed body weight in females from this group was assumed to be related to DDAC exposure. No other changes were observed in males or females in the other dose groups. The NOEL for this study is 600 ppm (107 and 134 mg/kg/day for males and females, respectively).

Rats were given in their diet 0, 100, 300, 600, 1,000 or 3,000 ppm DDAC for 89-90 days. For the lowest four dose groups, these doses correspond to mean intake levels of approximately 6, 18, 37, and 61 mg/kg for males, and 8, 22, 44, and 74 mg/kg for females. High mortality in the 3,000 ppm group prohibited calculation of mean daily intakes. Dietary exposure to 3,000 ppm DDAC resulted in 80% mortality in both sexes. The three rats of each sex of this group that survived to the end of the study exhibited markedly reduced body weights, fluid- or gas-filled intestines at necropsy, and inflammation of the beginning of the large intestines (typhlitis). Pathological changes in clinical chemistry included decreased serum glucose and protein concentrations in both sexes, decreased albumin and globulin concentrations in females, and increased erythrocyte count and hemoglobin and hematocrit concentrations in males. Administration of 1,000 ppm of less of DDAC resulted in no treatment-related effects. The NOEL for this study is 61 and 74 mg/kg/day for males and females, respectively.

Male and female beagle dogs were given DDAC in their diet at doses of 0, 5, 15 and 50 mg/kg for 90 days. There was marked decrease in body weight gain, food consumption and food efficiency in the 50 mg/kg dose group. Clinical chemistry, hematology, urinalysis, and pathological results did not reveal any treatment-related effects. The NOAEL for this study is 15 mg/kg/day.

Beagle dogs were dosed orally with 0, 3, 10, or 30 mg/kg DDAC for 52 weeks. During the first four and a half weeks of the study, several dogs in the 30 mg/kg group showed potentially life threatening decreases in body weight and food consumption. The dose was therefore decreased to 20 mg/kg/day. In some cases, depressions in weight and food consumption were so severe that the dogs in this group were removed from treatment completely during study days 31-36, and then reinstated at the 20 mg/kg/day. Administration of 3 or 20 mg/kg/day was not associated with mortality, changes in organ weights, gross pathological findings, ophthalmologic changes, or microscopic changes in selected organs and tissues. The 20 mg/kg/day dose was associated with decreases in mean erythrocyte counts; hemoglobin and hematocrit values; and mean total cholesterol, total protein, and albumin values. The 10 and 20 mg/kg/day doses were associated with an increased incidence of emesis, salivation, and soft/mucoid/liquid feces compared to controls. The NOEL for systemic toxicity was considered to be 10 mg/kg/day.

Sprague-Dawley rats were given in their diet 0, 300, 750, or 1,500 ppm DDAC for at least 104 weeks. These doses corresponded to approximate DDAC intakes of 13, 32, and 64 mg/kg/day for males, and 16, 41, and 83 mg/kg/day for females. Treatment-related

decreases in body weight and food consumption in both males and females were observed in the 1,500 ppm group. In addition, possible treatment-related microscopic changes including hyperplasia of bile ducts in female rats and changes in mesenteric lymph nodes in male and female rats related to blood in the sinuses were observed in the 1,500 ppm group. No treatment-related effects were seen in the type of incidence of clinical signs, survival, palpable masses, clinical pathology, organ weights, gross anatomic pathology, or ophthalmology. The NOEL for toxicity was considered to be 750 ppm (32 and 41 mg/kg/day for males and females, respectively).

CD-1 mice were administered in their diet 0, 100, 500, or 1,000 ppm DDAC for at least 78 weeks. The approximate mean intake levels were 15, 76.3, and 155.5 mg/kg/day for males and 18.6, 93.1, and 193.1 mg/kg/day for females. Treatment-related findings included decreased body weights and body weight gains in both male and females from the 1,000 ppm groups. There were no treatment-related clinical signs of toxicity, increases in palpable masses, changes in food consumption, differences in organ weights or observations at necropsy or differences in histopathological findings. The NOEL for this study was considered to be 500 ppm (76.3 and 93.1 mg/kg/day for males and females, respectively).

Genotoxicity

Several studies evaluating the mutagenicity of DDAC have all given negative results. DDAC was not mutagenic to several strains of *S. typhimurium* in a bacterial reverse mutation assay with or without metabolic activation. DDAC was tested in the CHO/HGPRT forward mutation assay and was not mutagenic in the presence or absence of metabolic activation. DDAC did not induce chromosomal aberrations in CHO cells with or without metabolic activation. In the *in vitro* rat primary hepatocyte unscheduled DNA synthesis (UDS) assay, DDAC did not induce significant increases in UDS. No chromosomal damage was observed in the bone marrow of rats in an *in vivo* cyogenetics assay.

DTAC (24.7% aq. soln.) was not mutagenic to bacteria in a reverse mutation assay with or without metabolic activation. DTAC (24.7% aq. soln.) was not mutagenic in a mouse lymphoma assay with or without metabolic activation. DTAC was inactive in a rat primary hepatocyte UDS assay. DTAC was not genotoxic when given by oral gavage in a rat bone marrow micronucleus assay.

Carcinogenicity

Sprague-Dawley rats received DDAC in their diet at concentrations of 0, 300, 750 or 1,500 ppm for at least 104 weeks. These doses corresponded to approximate mean DDAC intakes of 13, 32, and 64 mg/kg/day for males, and 16, 41, and 83 mg/kg/day for females. DDAC was not considered to be carcinogenic under the conditions of this study.

CD-1 mice were administered in the diet 0, 100, 500, or 1,000 ppm DDAC for at least 78 weeks. The approximate mean intake levels were 15, 76.3, and 155.5 mg/kg/day for males, and 18.6, 93.1, and 193.1 mg/kg/day for females. DDAC was not considered to be carcinogenic under the conditions of this study.

Reproductive Toxicity

A two-generation reproductive toxicity study has been conducted with DDAC. Sprague-Dawley rats were given in their diet 0, 300, 750 or 1,500 ppm for two generations. Results indicate that continuous exposure to DDAC in the diet for two generations resulted in no adverse reproductive effects. Parental toxicity was observed at 1,500 ppm (~112.6 mg/kg/day), limited to body weight reduction, weight gain depression, and decreased food consumption. Postnatal toxicity at 1,500 ppm was indicated by reduced pup body weights. Based on decreased body weight/weight gain and food consumption, the parental Toxicity NOAEL = 750 ppm (56 mg/kg/day); LOAEL = 1500 ppm (113 mg/kg/day). Based on decreased pup body weight/weight gain, the reproductive toxicity NOAEL = 750 ppm (56 mg/kg/day); LOAEL = 1500 ppm (113 mg/kg/day).

Developmental Toxicity

Female NZ rabbits were given by oral gavage 0, 1.0, 3.0 or 10 mg/kg/day of DDAC during GD 6-18. Four of the 16 does in the highest group died prior to GD 13. One doe at 10 mg/kg and 2 does at 1.0 mg/kg delivered early and were removed from the study. Nonlethal indications of maternal toxicity were evident at 3 and 10 mg/kg, as evidenced by reduced weight gain and clinical signs during the treatment period. Developmental toxicity, including increased incidences of fetal mortality and reduced fetal body weight per litter, were observed only at the highest dose. No teratogenicity was observed at any dose level. The NOEL for maternal toxicity is 1 mg/kg/day, and the NOEL for developmental toxicity is 3 mg/kg/day.

Female Sprague-Dawley rats were given by oral gavage 0, 1, 10 or 20 mg/kg DDAC during GD 6-15. No females died, aborted, delivered early, or were removed early from the study. Maternal toxicity was indicated at 10 and 20 mg/kg by characteristic clinical signs of audible respiration. Reductions in body weight and food consumption were also observed at 20 mg/kg during the treatment period. No evidence of developmental toxicity including teratogenicity was observed at any dose level. The NOEL for maternal toxicity was 1 mg/kg/day. The NOEL for developmental toxicity is >20 mg/kg/day.

Key Study/Critical Effect for Screening Criteria

The lowest NOAEL was 10 mg/kg/day for dogs in the one-year chronic toxicity study. The LOAEL of 20 mg/kg/day was based on increased incidence of clinical signs in males and females, and decreased total cholesterol levels in females.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral Reference Dose = 20/100 = 0.2 mg/kg/day

Drinking water guidance value = 0.7 ppm

References

Henderson, N.D. (1992). A Review of the Environmental Impact and Toxic Effects of DDAC. Prepared for: BC Environment, Ministry of Environment, Lands and Parks, Victoria, British Columbia. Found as Appendix B of the Robust Summaries for the Fatty Nitrogen Derived (FND) Cationics Category in the U.S. HPV Chemical Challenge Program.

U.S. EPA (2006). Reregistration Eligibility Decision for Aliphatic Alkyl Quaternaries (DDAC), EPA739-R-06-008, Office of Prevention, Pesticides and Toxic Substances (OPPTS), U.S. Environmental Protection Agency, August 2006 (docket #EPA-HQ-OPP-2006-0338).

U.S. HPVIS (FND Cationics Category): http://www.epa.gov/chemrtk/hpvis/index.html

Santos

APPENDIX F.5 HALLIBURTON ALTERNATIVE FLUID SYSTEM

Toxicity Profile

Acetic acid
(CAS No. 64-19-7)

Acetic acid dissociates in aqueous media to H^+ and the acetate anion ($CH_3CO_2^-$). It is naturally occurring as the acid in apple cider vinegar and other fruit-derived products. It and several of its salts are commonly used as food additives (*e.g.*, as flavor enhancers) and are listed as Generally Recognized as Safe (GRAS) by the U.S. Food and Drug Administration (FDA).

pH: 2.5 at 50 g/L and 20°C
pK_a: 4.76 @ 20°C

Acute Toxicity

The oral LD_{50} in rats is 4,950 mg/kg, and the dermal LD_{50} in rabbits is 1,060 mg/kg. The 4-hour LC_{50} in rats is 11.4 mg/L.

Irritation

In the EU, acetic acid is classified as a skin and eye irritant at concentrations <25%. At ≥25%, it is classified as corrosive to the skin.

Sensitization

No data are available.

Repeated Dose Toxicity

In an 8-month study, rats dosed with 60 mg/kg acetic acid (three times per week) developed hyperplasia in the esophagus and forestomach.

Genotoxicity

Acetic acid was not mutagenic to *Salmonella typhimurium* strains TA 98, TA 100, TA 1535, TA 1537, and TA 1538 in an *in vitro* bacterial mutation assay with or without metabolic activation. Acetic acid (in media adjusted to a pH of 8.5) was also not genotoxic in an *in vitro* chromosomal aberration test using Chinese Hamster Ovary cells with or without metabolic activation.

Carcinogenicity

No adequate carcinogenicity studies have been conducted on acetic acid.

Reproductive Toxicity

No studies could be located.

Developmental Toxicity

There were no effects on implantations or on maternal or fetal survival in mice, rats, or rabbits at doses up to 1,600 mg/kg.

Key Study/Critical Effect for Screening Criteria

There are no repeat dose toxicity studies that were considered adequate for human health risk assessment. The only study reported on the toxicity of acetic acid by oral gavage showed effects of irritation (probably due to the pH of acetic acid) at the site of contact in the gastrointestinal tract. No systemic effects were reported.

The Joint FAO/WHO Expert Committee on Food Additives (JECFA) has maintained a group ADI of "not limited" for acetic acid and its potassium and sodium salts.

The Australian drinking water guidance value for pH may apply to acetic acid.

References

ECHA REACH: http://apps.echa.europa.eu/registered/registered-sub.aspx

JECFA: http://apps.who.int/ipsc/database/evaluations/chemical.aspx?chemID=4785

U.S. EPA HPVIS database: http://www.epa.gov/chemrtk/hpvis/index.html

Toxicity Profile

Alcohols, C6-C12, Ethoxylated Propoxylated
(CAS No. 68937-66-6)

No toxicity information could located on alcohols, C6-C12, ethoxylated propoxylated (CAS No. 68937-66-6). Toxicity information is available on alcohol ethoxylates. Alcohols, C6-C12, ethoxylated propoxylated is produced by the use of propylene oxide (PO) in addition to ethylene oxide (EO) during the alkoxylation of the alcohol(s). the PO is either incorporated randomly by alkoxylation within the epoxide mixture, or in a block by sequencing the addition of EO and PO to the reactor. Because of the similarity in structures, the toxicity data on the alcohol ethoxylates were used to read-across to alcohols, C6-C12, ethoxylated propoxylated.

Alcohol ethoxylates are a class of non-ionic surfactants. The AEs have the basic structure $C_{x-y}AE_n$. The subscript (x-y) following the 'C' indicates the range of carbon chain units. AEs with carbon unit range between C8 to C18 are most commonly used in household detergent products. The hydrocarbon chain can be either linear or branched. AEs also contain an ethylene oxide (E) chain attached to the alcohol. The degree of ethylene oxide polymerization is indicated by the subscript (n) which indicates the average number of ethylene oxide units. In household products the average ethylene oxide chain length commonly ranges between 3 and 12 units.

The toxicity profile has been developed from a risk assessment report on alcohol ethoxylates ranging from C8 to C18 prepared by the household cleaning product and chemical industry (HERA, 2009).

Acute Toxicity

The acute oral LD_{50} of C9-11AE2.5 in rats was calculated to be >4,000 mg/kg and <10,000 mg/kg. The acute oral LD_{50} of C7-9AE6 in rats was determined to be <2,000 mg/kg. The acute oral LD_{50} of C9-11AE8 in fasted rats was found to be 1,200 mg/kg. The oral LD_{50} in rats for C12-13AE6.5 is 2,100 mg/kg. The oral LD_{50} in rats for C12-15AE7 is 1,700 mg/kg. For C14-15AE11, the acute oral LD_{50} values were reported to be 720 mg/kg (neat) and 1,800 mg/kg (given as 50% (m/v) solution in corn oil). The oral LD_{50} in rats for C12-15AE11 is >2,00 mg/kg for males and between 1,000 and 2,000 mg/kg for females. The oral LD_{50} in rats for C14-15AE13 is 1,100 and 1,000 mg/kg in two separate studies.

The dermal LD_{50} of C7-9AE6 was >2,000 mg/kg. The dermal LD_{50} values for AEs with an alkyl chain length of 9 – 11 carbon atoms in three different rat studies were determined to be >2,000 mg/kg and >4,000 mg/kg. An acute dermal LD_{50} value of >2,000 mg/kg was determined for C12-14AE3 and C12-14AE6 in two separate studies. The acute dermal LD_{50} of C12-15AE7 was determined to be >2,000 mg/kg.

The acute rat 4-hour LC_{50} of C9-11AE5 generated as a mist was determined to be >0.22 mg/L. Talmage (1994) reported that alcohol ethoxylates were not acutely toxic to rats at concentrations less than or equal to their saturated vapor concentrations in air. Acute toxic thresholds were reached only when animals were exposed to the undiluted test chemical in the form of a respirable mist or aerosol. Under these conditions, 1- or 4-hour inhalation LC_{50} values ranged from 1.5 to 20.7 mg/L. Some studies reported no mortalities (1-hour LC_{50} -study) occurred at concentrations as high as 52 mg/L.

Irritation

Alcohol ethoxylates with varying alkyl chain lengths and ethoxylation degree were found to be slightly to severely irritating to skin in rabbits and rats. The degree of irritation was dependent on the type of patches used (open application versus full occlusion), the exposure time as well as the concentration of the test material. In humans, AEs are less irritating to skin than in animals. Neat applications of a range AEs in a 4hour human patch test did not warrant these chemicals to be classified as skin irritants under EU legislation, while the same AEs would have been classified for skin irritation on the basis of animal data.

Alcohol ethoxylates range from mildly to severely irritating to rabbit eyes. Rinsing the eyes directly after exposure with water for 20 to 30 seconds greatly reduced the severity of the effects such that these products produced only mildly irritating effects. The degree of irritation is concentration-dependent as dilutions in water cause proportionally lower irritation. Generally, concentration of 0.1% were non-irritating, and concentrations of 1 to 10% ranged from slight to moderately irritating. No relationship could be established between the chemical structures of the tested AEs and their eye irritation responses.

Sensitization

Alcohol ethoxylates should not be considered as skin sensitizers. A substantial amount of skin sensitization studies in guinea pigs following either the Magnusson-Kligman maximization or the Buehler testing protocol are available to evaluate the skin sensitization potential of AEs. Although a mild skin sensitization reaction was observed in a study following the Magnusson-Kligman protocol, the weight of evidence clearly supports the assessment that AEs should not be considered as skin sensitizers. This is further supported by clinical and market data that demonstrate the absence skin sensitization responses to AEs when tested under the conditions of the HRIPT or when used in AE containing consumer products.

Repeated Dose Toxicity

C10AE5 was fed to rats at doses of 0, 125, 250 or 500 mg/kg for 90 days. There were no

treatment-related clinical signs, body weight gain, food consumption or feed efficiency. There was a slight increase in absolute liver weights as well as a trend toward a dose-dependent increase in the liver weight/body weight ratio, with a statistically significant increase in the high dose group. However, the histological evaluation did not reveal any indication of hepatotoxicity and therefore the increase in liver weights was not interpreted to be a toxicological effect. It can be considered to be an adaptive response as a result of extensive metabolism of the test compound by the liver. There were no other gross or histopathological changes that were considered treatment-related. The NOAEL for this study can be considered to be 500 mg/kg/day.

Rats were given in their diet 0, 125, 250, 500, 1,000 or 3,000 ppm C9-11AE6 for 90 days. There were no signs of toxicity at any dose level. The NOAEL is 3,000 ppm (approximately 150 mg/kg/day).

Rats were given in their diet 0, 0.04, 0.2 or 1.0% C9-11AE8 for 90 days. Lower body weight gain and decreased food consumption were noted in the 1% males and females and in the 0.2% females from week 1 through the end of the study. Further statistical analyses revealed a significant decrease in the mean body weight gain noted in the 1% females and the decreases in mean food consumption noted in the 1% males and females. The differences noted in the 0.2% females were not statistically significant. The investigators considered these observations to be the result of poor palatability of the test substance. There were no other treatment-related effects. The NOAEL for this study is 1.0% (about 400 mg/kg/day).

Rats were fed C12-15AE7 in the diet at concentrations of 0%, 0.0313%, 0.0625%, 0.125%, 0.25%, 0.5% or 1.0% for 90 days. Body weight gain was significantly reduced in male and female rats in the $\geq$0.25% groups, and was associated with marked decreases in food and water consumption. Relative liver weights were significantly increased in the 0.5% and 1% male rats fed and in female rats in the $\geq$0.25% groups. There were not treatment-related changes in hematology, urinary and clinical chemistry parameters. Liver cell enlargement was seen in the $\geq$0.125% groups, suggesting increased liver metabolism on the basis of increased alkaline phosphatase activity at the higher dose levels. The NOAEL was established at 0.0625% (102 mg/kg/day).

Rats were fed C12-14AE7 in the diet at concentrations of 0%, 0.0313%, 0.0625%, 0.125%, 0.25%, 0.5% or 1.0% for 90 days. Body weight gain was significantly reduced in male and female rats in the $\geq$0.25% groups, and was associated with marked decreases in food and water consumption. Relative liver weights were significantly increased in the 0.5% and 1% male rats fed and in female rats in the $\geq$0.25% groups. There were no treatment-related changes in hematology, urinary and clinical chemistry parameters. Liver cell enlargement was seen in the $\geq$0.125%, suggesting increased liver metabolism on the basis of increased alkaline phosphatase activity at the higher dose levels. The NOAEL was established at 0.0625% (110 mg/kg/day).

Wistar rats were fed C14-15AE7 in the diet at concentrations of 0, 300, 1,000, 3,000, or 10,000 ppm for 90 days. All animals survived until their scheduled necropsy date.

Significant treatment-related effects on body weight (*i.e.*, reduced mean body weights in males at 10,000 ppm and in females at 3,000 ppm), food intake (*i.e.*, reduced intake in both sexes at 10,000 ppm and at 3,000 ppm for females), organ weights (*i.e.*, increased relative liver weight in both sexes at 3,000 and 10,000 ppm and in females also at 1,000 ppm; increased spleen weight in males at 10,000 ppm; clinical chemistry (*i.e.*, confined to 10,000 ppm dose groups; significantly higher urea, chloride and potassium levels in males; significantly higher urea, chloride and cholesterol levels in females) and hematology (*i.e.*, in both sexes at 10,000 ppm and in males also at 3,000 ppm increased total leukocytes and lymphocytes; females at 10,000 ppm showed depression in numbers of neutrophils, mean cell volume and mean cell hemoglobin) were identified in one or both sexes fed with dietary concentrations of 3,000 and 10,000 ppm. There were no compound-related histopathological effects at any dose level. Minor, but statistically significant changes in liver weight, kidney weights and plasma urea concentration were recorded in female rats in the 1,000 ppm group were not of toxicological significance. The NOAEL for this study is 1,000 ppm (50 mg/kg/day).

Rats were fed C14-15AE7 in the diet at concentrations of 0, 0.1%, 0.5% or 1% for 90 days. There were no treatment-related changes in body weight, food intake, and organ weights including those of the reproductive system, clinical chemistry and hematology at any treatment level. The NOAEL is 1% in the diet, which corresponded to 700 and 785 mg/kg-day for males and females, respectively.

Rats were fed C12-13AE6.5 in their diet at concentrations of 0, 0.1, 0.5 or 1% for two years. There was reduced food consumption in males (1%) and females (0.5 and 1%) which resulted in lower body weight gain compared to controls. At study termination, organ to body weight ratios were increased in the 0.5 and 1% females (liver, kidney and brain), 1% females (heart), and 1% males (liver). A dose-related focal myocarditis was observed in males. The NOAEL was established at 0.1% dietary level based on the relative organ weight increases. This corresponds to 50 mg/kg/day.

Rats were fed C14-15AE7 in their diet at concentrations of 0, 0.1, 0.5 or 1% for two years. There was reduced food consumption in males (1%) and females (0.5 and 1%) which resulted in lower body weight gain compared to controls. At study termination, organ to body weight ratios were increased in the 0.5 and 1% females (liver, kidney and brain), 1% females (heart), and 1% males (liver). A dose-related focal myocarditis was observed in males. The NOAEL was established at 0.1% dietary level based on the relative organ weight increases. This corresponds to 50 mg/kg/day.

Charles River rats were fed C14-15AE7 in the diet at concentrations of 0, 0.1, 0.5 or 1% for two years. There was a dose-related decrease in body weights in the 0.5 and 1% females and in the 1% males, the likely cause being poor palatability of the diet. At study termination, elevated organ-to-body weight ratios were noted for the liver, kidney, heart and thyroid/parathyroid glands in the 1% dietary group. The only significant histopathological finding prevalent in all dose groups was a dose-related increase in incidence of focal myocarditis at 12 months but not at study termination at 2 years. No other treatment-related histopathology was noted. The NOAEL was established at the

0.5% dietary level, which corresponds to about 162 and 190 mg/kg-day for males and females, respectively.

Genotoxicity

In all available *in vitro* and *in vivo* genotoxicity assays, there was no indication of genetic toxicity of broad range of structurally different alcohol ethoxylates.

Carcinogenicity

Alcohol ethoxylates as a class are not carcinogenic by the oral route based of available oral long term toxicity/carcinogenicity studies on AEs.

Charles River rats were given in their diet 0, 0.1, 0.5 or 1% C14-15AE7 for two years. There was no treatment-related changes in general behavior and appearance. The survival rate of the test animals was comparable if not better than the controls. Body weights of 0.5% females and 1% males and females had significantly lower weight gains than the control. There were no treatment-related effects on organ weights and tumor incidence.

Sprague-Dawley rats were fed C14-15AE7 at 0.1, 0.5 or 1% in the diet for two years. A treatment-related body weight depression was observed in females at the two highest treatment levels and in males at the 1% dose level, probably due to the poor palatability of the diet. There was no evidence for any carcinogenic activity.

Sprague-Dawley rats were fed C12-13AE6.5 in the diet at doses up to 1% (500 mg/kg-day). Reduced food consumption was noted at the higher dose levels (*i.e.*, 0.5 and 1% for females and 1% for males), resulting in a lower body weight gain compared to the control group. No treatment-related histopathology was found and no increase in tumor incidence was observed.

Reproductive Toxicity

In a two-generation reproductive toxicity study, Charles River rats were fed C12AE6 in the diet at dose levels of 0, 0.05, 0.1 or 0.5% (about 0, 25, 50 or 250 mg/kg-day).
No treatment related effects in the parents or pups on general behavior, appearance or survival were observed. Fertility of treated groups was comparable with the controls. The only observation was related to a reduced weight gain of parental rats and pups relative to the control at the 0.5% dose level. The NOAEL for reproduction was therefore set at the highest dose level which was 0.5% dietary level (250 mg/kg-day).

In a two-generation developmental and teratogenicity study, CD rats were fed C14-15AE7 in the diet at dose levels of 0, 0.05, 0.1 or 0.5% (about 0, 25, 50 or 250 mg/kg-day). Three of the groups received the compound continuously during the study. In the

other three groups the females received the compound only during the 6th through the 15th day of gestation and the males were untreated. No treatment-related changes in behavior or appearance were observed in the parental rats or pups throughout the study. Female rats from the 0.5% continuous treatment group gained slightly less body weight compared to control females. No other consistent differences in body weight were observed. Food consumption was similar for control and treated rats. No compound related differences were seen between control and treated rats with respect to fertility, gestation or viability indices. The average 21-day body weights for pups at the 0.5% continuous treatment group were significantly lower as compared to the average pup body weights in the controls. No other compound-related changes in body weight were observed. None of the deaths of parental rats during the study was considered to be compound-related. Examination of organ weight values revealed that compound-related effects were limited to increased group mean relative liver weights of male and female F1 from the 0.5% continuous feeding group at the 91-day sacrifice, and increases in group mean relative liver weights of males from the 0.5% continuous feeding group of the F2 generation at the 60-day and caesarean section sacrifices. No compound-related histopathological lesions were observed in any of the tissues examined from rats for the F_0 and F_1 generations. The NOAEL for reproductive toxicity is at least 0.5% in the diet (250 mg/kg/day).

Developmental Toxicity

In a two-generation reproductive toxicity study, Charles River rats were fed C12AE6 in the diet at dose levels of 0, 0.05, 0.1 or 0.5% (about 0, 25, 50 or 250 mg/kg-day). General behavior, appearance and survival were not affected by treatment. At the 0.5% dose level, adults and pups gained less weight than the control rats. In the 0.5% dose group, there was a statistical increase in embryo lethality and soft tissue anomalies and at the 0.1% there was a statistical decrease in mean fetal liver weight. Neither of these effects was considered to be treatment-related by the authors as they showed no dose response characteristics. The NOAEL for maternal toxicity is 50 mg/kg/day. The NOAEL for developmental and teratogenicity is 0.1% (50 mg/kg/day).

Pregnant rabbits were given by oral gavage 0, 50, 100 or 200 mg/kg C12AE6 from GD 2 to16. Nine control rabbits and 31 treated rabbits died during the study. Surviving rabbits at the 200 mg/kg dose level generally showed slight losses of body weight. At 100 and 200 mg/kg, ataxia and a slight decrease in body weight was observed in the pregnant animals. In seven treated and two control rabbits early deliveries were recorded. There were no treatment-related effects on corpora lutea, implantations, number of live fetuses and spontaneous abortions. The NOAEL for maternal toxicity is 50 mg/kg/day; the NOAEL for developmental toxicity is 200 mg/kg/day.

In two-generation developmental and teratogenicity study, CD rats were fed C14-15AE7 in the diet at dose levels of 0, 0.05, 0.1 or 0.5% (about 0, 25, 50 or 250 mg/kg/day). On the 13th day of the gestation period a representative number of female rats from each treatment group of the FC generation (*i.e.*, pups from the 3rd mating of the F_0 and F_1 parental generation) were sacrificed. Laparotomies were performed and the uterus was

examined for uterine abnormalities, normal implantation and resorption sites. Remaining females were sacrificed on the 21st day of gestation. Various maternal and fetal parameters showed occasional values that were significantly different from the corresponding controls. However these were not considered related to the material tested as none occurred at the high feeding level and no dose response for these parameters was apparent. With respect to body weight gains, parental female rats and pups of the high dose group did not gain as much body weight as the control rats. Examination of organ weight values reveal compound related effects were limited to increased group mean liver weighs of male and female P_1 generation from the 0.5% continuous feeding group at the 91 day sacrifice and increase in group mean relative liver weights of males of the 0.5% continuous feeding group of the P_2 generation at the 60 day section sacrifices. The NOAEL for maternal and developmental toxicity was established at the 0.1% in the diet (50 mg/kg/day).

Key Study/Critical Effect for Screening Criteria

AEs of different structures with regard to the length of the alkyl chain and the degree of ethoxylation have been evaluated in a number of 90-day and two-year oral toxicity studies. The lowest NOAEL of AEs for systemic toxicity was established at 50 mg/kg-day in two chronic (two-year) dietary studies on C12-13AE6.5 and C14-15AE7. Effects observed at the LOAEL were related to significantly elevated organ-to-body weight ratios for liver, kidney and heart, although there were no adverse histopathological changes.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD = 50/100 = 0.5 mg/kg/day

Drinking water guidance value = 2 ppm

References

Human and Environmental Risk Assessment (HERA) on Ingredients of Household Cleaning Products: Alcohol Ethoxylates (2009), http://www.heraproject.com

Talmage, S.S. (1994). Environmental and Human Safety of Major Surfactants – Alcohol Ethoxylates and Alkylphenol Ethoxylates. The Soap and Detergent Association. Lewis Publishers, Boca Raton, Florida.

Toxicity Profile

Alcohols, C10-C16, Ethoxylated Propoxylated
(CAS No. 69227-22-1)

No toxicity information could located on alcohols, C10-C16, ethoxylated propoxylated (CAS No. 69227-22-1). Toxicity information is available on alcohol ethoxylates. Alcohols, C10-C16, ethoxylated propoxylated is produced by the use of propylene oxide (PO) in addition to ethylene oxide (EO) during the alkoxylation of the alcohol(s). the PO is either incorporated randomly by alkoxylation within the epoxide mixture, or in a block by sequencing the addition of EO and PO to the reactor. Because of the similarity in structures, the toxicity data on the alcohol ethoxylates were used to read-across to alcohols, C10-16, ethoxylated propoxylated.

Alcohol ethoxylates are a class of non-ionic surfactants. The AEs have the basic structure $C_{x-y}AE_n$. The subscript (x-y) following the 'C' indicates the range of carbon chain units. AEs with carbon unit range between C8 to C18 are most commonly used in household detergent products. The hydrocarbon chain can be either linear or branched. AEs also contain an ethylene oxide (E) chain attached to the alcohol. The degree of ethylene oxide polymerization is indicated by the subscript (n) which indicates the average number of ethylene oxide units. In household products the average ethylene oxide chain length commonly ranges between 3 and 12 units.

Acute Toxicity

The acute oral LD_{50} of C9-11AE2.5 in rats was calculated to be >4,000 mg/kg and <10,000 mg/kg. The acute oral LD_{50} of C7-9AE6 in rats was determined to be <2,000 mg/kg. The acute oral LD_{50} of C9-11AE8 in fasted rats was found to be 1,200 mg/kg. The oral LD_{50} in rats for C12-13AE6.5 is 2,100 mg/kg. The oral LD_{50} in rats for C12-15AE7 is 1,700 mg/kg. For C14-15AE11, the acute oral LD_{50} values were reported to be 720 mg/kg (neat) and 1,800 mg/kg (given as 50% (m/v) solution in corn oil). The oral LD_{50} in rats for C12-15AE11 is >2,00 mg/kg for males and between 1,000 and 2,000 mg/kg for females. The oral LD_{50} in rats for C14-15AE13 is 1,100 and 1,000 mg/kg in two separate studies.

The dermal LD_{50} of C7-9AE6 was >2,000 mg/kg. The dermal LD_{50} values for AEs with an alkyl chain length of 9 – 11 carbon atoms in three different rat studies were determined to be >2,000 mg/kg and >4,000 mg/kg. An acute dermal LD_{50} value of >2,000 mg/kg was determined for C12-14AE3 and C12-14AE6 in two separate studies. The acute dermal LD_{50} of C12-15AE7 was determined to be >2,000 mg/kg.

The acute rat 4-hour LC_{50} of C9-11AE5 generated as a mist was determined to be >0.22 mg/L. Talmage (1994) reported that alcohol ethoxylates were not acutely toxic to rats at concentrations less than or equal to their saturated vapor concentrations in air. Acute

toxic thresholds were reached only when animals were exposed to the undiluted test chemical in the form of a respirable mist or aerosol. Under these conditions, 1- or 4-hour inhalation LC_{50} values ranged from 1.5 to 20.7 mg/L. Some studies reported no mortalities (1-hour LC_{50} -study) occurred at concentrations as high as 52 mg/L.

Irritation

Alcohol ethoxylates with varying alkyl chain lengths and ethoxylation degree were found to be slightly to severely irritating to skin in rabbits and rats. The degree of irritation was dependent on the type of patches used (open application versus full occlusion), the exposure time as well as the concentration of the test material. In humans, AEs are less irritating to skin than in animals. Neat applications of a range AEs in a 4hour human patch test did not warrant these chemicals to be classified as skin irritants under EU legislation, while the same AEs would have been classified for skin irritation on the basis of animal data.

Alcohol ethoxylates range from mildly to severely irritating to rabbit eyes. Rinsing the eyes directly after exposure with water for 20 to 30 seconds greatly reduced the severity of the effects such that these products produced only mildly irritating effects. The degree of irritation is concentration-dependent as dilutions in water cause proportionally lower irritation. Generally, concentration of 0.1% were non-irritating, and concentrations of 1 to 10% ranged from slight to moderately irritating. No relationship could be established between the chemical structures of the tested AEs and their eye irritation responses.

Sensitization

Alcohol ethoxylates should not be considered as skin sensitizers. A substantial amount of skin sensitization studies in guinea pigs following either the Magnusson-Kligman maximization or the Buehler testing protocol are available to evaluate the skin sensitization potential of AEs. Although a mild skin sensitization reaction was observed in a study following the Magnusson-Kligman protocol, the weight of evidence clearly supports the assessment that AEs should not be considered as skin sensitizers. This is further supported by clinical and market data that demonstrate the absence skin sensitization responses to AEs when tested under the conditions of the HRIPT or when used in AE containing consumer products.

Repeated Dose Toxicity

C10AE5 was fed to rats at doses of 0, 125, 250 or 500 mg/kg for 90 days. There were no treatment-related clinical signs, body weight gain, food consumption or feed efficiency. There was a slight increase in absolute liver weights as well as a trend toward a dose-dependent increase in the liver weight/body weight ratio, with a statistically significant increase in the high dose group. However, the histological evaluation did not reveal any

indication of hepatotoxicity and therefore the increase in liver weights was not interpreted to be a toxicological effect. It can be considered to be an adaptive response as a result of extensive metabolism of the test compound by the liver. There were no other gross or histopathological changes that were considered treatment-related. The NOAEL for this study can be considered to be 500 mg/kg/day.

Rats were given in their diet 0, 125, 250, 500, 1,000 or 3,000 ppm C9-11AE6 for 90 days. There were no signs of toxicity at any dose level. The NOAEL is 3,000 ppm (approximately 150 mg/kg/day).

Rats were given in their diet 0, 0.04, 0.2 or 1.0% C9-11AE8 for 90 days. Lower body weight gain and decreased food consumption were noted in the 1% males and females and in the 0.2% females from week 1 through the end of the study. Further statistical analyses revealed a significant decrease in the mean body weight gain noted in the 1% females and the decreases in mean food consumption noted in the 1% males and females. The differences noted in the 0.2% females were not statistically significant. The investigators considered these observations to be the result of poor palatability of the test substance. There were no other treatment-related effects. The NOAEL for this study is 1.0% (about 400 mg/kg/day).

Rats were fed C12-15AE7 in the diet at concentrations of 0%, 0.0313%, 0.0625%, 0.125%, 0.25%, 0.5% or 1.0% for 90 days. Body weight gain was significantly reduced in male and female rats in the $\geq$0.25% groups, and was associated with marked decreases in food and water consumption. Relative liver weights were significantly increased in the 0.5% and 1% male rats fed and in female rats in the $\geq$0.25% groups. There were not treatment-related changes in hematology, urinary and clinical chemistry parameters. Liver cell enlargement was seen in the $\geq$0.125% groups, suggesting increased liver metabolism on the basis of increased alkaline phosphatase activity at the higher dose levels. The NOAEL was established at 0.0625% (102 mg/kg/day).

Rats were fed C12-14AE7 in the diet at concentrations of 0%, 0.0313%, 0.0625%, 0.125%, 0.25%, 0.5% or 1.0% for 90 days. Body weight gain was significantly reduced in male and female rats in the $\geq$0.25% groups, and was associated with marked decreases in food and water consumption. Relative liver weights were significantly increased in the 0.5% and 1% male rats fed and in female rats in the $\geq$0.25% groups. There were no treatment-related changes in hematology, urinary and clinical chemistry parameters. Liver cell enlargement was seen in the $\geq$0.125%, suggesting increased liver metabolism on the basis of increased alkaline phosphatase activity at the higher dose levels. The NOAEL was established at 0.0625% (110 mg/kg/day).

Wistar rats were fed C14-15AE7 in the diet at concentrations of 0, 300, 1,000, 3,000, or 10,000 ppm for 90 days. All animals survived until their scheduled necropsy date. Significant treatment-related effects on body weight (*i.e.*, reduced mean body weights in males at 10,000 ppm and in females at 3,000 ppm), food intake (*i.e.*, reduced intake in both sexes at 10,000 ppm and at 3,000 ppm for females), organ weights (*i.e.*, increased relative liver weight in both sexes at 3,000 and 10,000 ppm and in females also at 1,000

ppm; increased spleen weight in males at 10,000 ppm; clinical chemistry (*i.e*., confined to 10,000 ppm dose groups; significantly higher urea, chloride and potassium levels in males; significantly higher urea, chloride and cholesterol levels in females) and hematology (*i.e*., in both sexes at 10,000 ppm and in males also at 3,000 ppm increased total leukocytes and lymphocytes; females at 10,000 ppm showed depression in numbers of neutrophils, mean cell volume and mean cell hemoglobin) were identified in one or both sexes fed with dietary concentrations of 3,000 and 10,000 ppm. There were no compound-related histopathological effects at any dose level. Minor, but statistically significant changes in liver weight, kidney weights and plasma urea concentration were recorded in female rats in the 1,000 ppm group were not of toxicological significance. The NOAEL for this study is 1,000 ppm (50 mg/kg/day).

Rats were fed C14-15AE7 in the diet at concentrations of 0, 0.1%, 0.5% or 1% for 90 days. There were no treatment-related changes in body weight, food intake, and organ weights including those of the reproductive system, clinical chemistry and hematology at any treatment level. The NOAEL is 1% in the diet, which corresponded to 700 and 785 mg/kg-day for males and females, respectively.

Rats were fed C12-13AE6.5 in their diet at concentrations of 0, 0.1, 0.5 or 1% for two years. There was reduced food consumption in males (1%) and females (0.5 and 1%) which resulted in lower body weight gain compared to controls. At study termination, organ to body weight ratios were increased in the 0.5 and 1% females (liver, kidney and brain), 1% females (heart), and 1% males (liver). A dose-related focal myocarditis was observed in males. The NOAEL was established at 0.1% dietary level based on the relative organ weight increases. This corresponds to 50 mg/kg/day.

Rats were fed C14-15AE7 in their diet at concentrations of 0, 0.1, 0.5 or 1% for two years. There was reduced food consumption in males (1%) and females (0.5 and 1%) which resulted in lower body weight gain compared to controls. At study termination, organ to body weight ratios were increased in the 0.5 and 1% females (liver, kidney and brain), 1% females (heart), and 1% males (liver). A dose-related focal myocarditis was observed in males. The NOAEL was established at 0.1% dietary level based on the relative organ weight increases. This corresponds to 50 mg/kg/day.

Charles River rats were fed C14-15AE7 in the diet at concentrations of 0, 0.1, 0.5 or 1% for two years. There was a dose-related decrease in body weights in the 0.5 and 1% females and in the 1% males, the likely cause being poor palatability of the diet. At study termination, elevated organ-to-body weight ratios were noted for the liver, kidney, heart and thyroid/parathyroid glands in the 1% dietary group. The only significant histopathological finding prevalent in all dose groups was a dose-related increase in incidence of focal myocarditis at 12 months but not at study termination at 2 years. No other treatment-related histopathology was noted. The NOAEL was established at the 0.5% dietary level, which corresponds to about 162 and 190 mg/kg/day for males and females, respectively.

Genotoxicity

In all available *in vitro* and *in vivo* genotoxicity assays, there was no indication of genetic toxicity of broad range of structurally different alcohol ethoxylates.

Carcinogenicity

Alcohol ethoxylates as a class are not carcinogenic by the oral route based of available oral long term toxicity/carcinogenicity studies on AEs.

Charles River rats were given in their diet 0, 0.1, 0.5 or 1% C14-15AE7 for two years. There was no treatment-related changes in general behavior and appearance. The survival rate of the test animals was comparable if not better than the controls. Body weights of 0.5% females and 1% males and females had significantly lower weight gains than the control. There were no treatment-related effects on organ weights and tumor incidence.

Sprague-Dawley rats were fed C14-15AE7 at 0.1, 0.5 or 1% in the diet for two years. A treatment-related body weight depression was observed in females at the two highest treatment levels and in males at the 1% dose level, probably due to the poor palatability of the diet. There was no evidence for any carcinogenic activity.

Sprague-Dawley rats were fed C12-13AE6.5 in the diet at doses up to 1% (500 mg/kg/day). Reduced food consumption was noted at the higher dose levels (*i.e.*, 0.5 and 1% for females and 1% for males), resulting in a lower body weight gain compared to the control group. No treatment-related histopathology was found and no increase in tumor incidence was observed.

Reproductive Toxicity

In a two-generation reproductive toxicity study, Charles River rats were fed C12AE6 in the diet at dose levels of 0, 0.05, 0.1 or 0.5% (about 0, 25, 50 or 250 mg/kg-day). No treatment related effects in the parents or pups on general behavior, appearance or survival were observed. Fertility of treated groups was comparable with the controls. The only observation was related to a reduced weight gain of parental rats and pups relative to the control at the 0.5% dose level. The NOAEL for reproduction was therefore set at the highest dose level which was 0.5% dietary level (250 mg/kg/day).

In a two-generation developmental and teratogenicity study, CD rats were fed C14-15AE7 in the diet at dose levels of 0, 0.05, 0.1 or 0.5% (about 0, 25, 50 or 250 mg/kg/day). Three of the groups received the compound continuously during the study. In the other three groups the females received the compound only during the 6th through the 15th day of gestation and the males were untreated. No treatment-related changes in behavior or appearance were observed in the parental rats or pups throughout the study. Female rats from the 0.5% continuous treatment group gained slightly less body weight

compared to control females. No other consistent differences in body weight were observed. Food consumption was similar for control and treated rats. No compound related differences were seen between control and treated rats with respect to fertility, gestation or viability indices. The average 21-day body weights for pups at the 0.5% continuous treatment group were significantly lower as compared to the average pup body weights in the controls. No other compound-related changes in body weight were observed. None of the deaths of parental rats during the study was considered to be compound-related. Examination of organ weight values revealed that compound-related effects were limited to increased group mean relative liver weights of male and female F_1 from the 0.5% continuous feeding group at the 91-day sacrifice, and increases in group mean relative liver weights of males from the 0.5% continuous feeding group of the F_2 generation at the 60-day and caesarean section sacrifices. No compound-related histopathological lesions were observed in any of the tissues examined from rats for the F_0 and F_1 generations. The NOAEL for reproductive toxicity is at least 0.5% in the diet (250 mg/kg/day).

Developmental Toxicity

In a two-generation reproductive toxicity study, Charles River rats were fed C12AE6 in the diet at dose levels of 0, 0.05, 0.1 or 0.5% (about 0, 25, 50 or 250 mg/kg/day). General behavior, appearance and survival were not affected by treatment. At the 0.5% dose level, adults and pups gained less weight than the control rats. In the 0.5% dose group, there was a statistical increase in embryo lethality and soft tissue anomalies and at the 0.1% there was a statistical decrease in mean fetal liver weight. Neither of these effects was considered to be treatment-related by the authors as they showed no dose response characteristics. The NOAEL for maternal toxicity is 50 mg/kg/day. The NOAEL for developmental and teratogenicity is 0.1% (50 mg/kg/day).

Pregnant rabbits were given by oral gavage 0, 50, 100 or 200 mg/kg C12AE6 from GD 2 to 16. Nine control rabbits and 31 treated rabbits died during the study. Surviving rabbits at the 200 mg/kg dose level generally showed slight losses of body weight. At 100 and 200 mg/kg, ataxia and a slight decrease in body weight was observed in the pregnant animals. In seven treated and two control rabbits early deliveries were recorded. There were no treatment-related effects on corpora lutea, implantations, number of live fetuses and spontaneous abortions. The NOAEL for maternal toxicity is 50 mg/kg/day; the NOAEL for developmental toxicity is 200 mg/kg/day.

In two-generation developmental and teratogenicity study, CD rats were fed C14-15AE7 in the diet at dose levels of 0, 0.05, 0.1 or 0.5% (about 0, 25, 50 or 250 mg/kg/day). On the 13th day of the gestation period a representative number of female rats from each treatment group of the FC generation (*i.e.*, pups from the 3rd mating of the F_0 and F_1 parental generation) were sacrificed. Laparotomies were performed and the uterus was examined for uterine abnormalities, normal implantation and resorption sites. Remaining females were sacrificed on the 21st day of gestation. Various maternal and fetal parameters showed occasional values that were significantly different from the corresponding controls. However these were not considered related to the material tested

as none occurred at the high feeding level and no dose response for these parameters was apparent. With respect to body weight gains, parental female rats and pups of the high dose group did not gain as much body weight as the control rats. Examination of organ weight values reveal compound related effects were limited to increased group mean liver weighs of male and female P_1 generation from the 0.5% continuous feeding group at the 91 day sacrifice and increase in group mean relative liver weights of males of the 0.5% continuous feeding group of the P_2 generation at the 60 day section sacrifices. The NOAEL for maternal and developmental toxicity was established at the 0.1% in the diet (50 mg/kg/day).

Key Study/Critical Effect for Screening Criteria

AEs of different structures with regard to the length of the alkyl chain and the degree of ethoxylation have been evaluated in a number of 90-day and two-year oral toxicity studies. The lowest NOAEL of AEs for systemic toxicity was established at 50 mg/kg/day in two chronic (two-year) dietary studies on C12-13AE6.5 and C14-15AE7. Effects observed at the LOAEL were related to significantly elevated organ-to-body weight ratios for liver, kidney and heart, although there were no adverse histopathological changes.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD = 50/100 = 0.5 mg/kg/day

Drinking water guidance value = 2 ppm

References

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Toxicity Profile

Choline chloride
Cholinium chloride
(CAS No. 67-48-1)

Choline chloride, also known as cholinium chloride, is a quaternary amine salt. It dissociates in water into the corresponding positively charged quaternary hydroxyl alkylammonium ion and the negatively charged chloride ion.

Choline chloride has been reviewed in the OECD-SIDS program (OECD, 2004).

Acute Toxicity

The oral LD_{50} in rats was reported to be between 3,150 and 5,000 mg/kg (BASF AG, 1963a, 1969).

Irritation

Application of a 70% aqueous solution to the skin of rabbits for 20 hours under occlusive conditions resulted in only minor skin irritation (BASF AG, 1963b). Slight eye irritation was seen in the eyes of rabbits after instillation of a 70% aqueous solution of choline chloride; no effects were seen one day after exposure (BASF AG, 1963c).

Sensitization

No data are available in animals. In a Human Repeated Insult Patch Test, there was no evidence of dermal sensitization in two hundred subjects given 0.5% (w/v) aqueous solution of choline chloride during the induction phase and 0.2% (w/v) aqueous solution during the challenge phase (Colgate-Palmolive, 2003).

Repeated Dose Toxicity

A 72-week feeding study was conducted to investigate the impact of choline chloride on the liver tumor promoting activity of phenobarbital and DDT in diethylnitroamine-initiated Fischer 344 rats (Shivapurkar *et al.*, 1986). Animals received approximately 500 mg/kg-day choline chloride. Following the end of the exposure period, the animals were keep on the same untreated diet as the control group until study termination at week 103. Histopathology was limited to the liver and organs that developed gross abnormalities. There were no significant differences between treated and control animals on survival rates, body weights, and relative liver weights. Neither was there any

increased number of neoplastic liver nodules, hepatocellular carcinomas, lung tumors, leukemia nor other tumors between treated and control animals. The NOAEL for choline chloride in this study is 500 mg/kg/day.

In humans, oral administration of 10,000 mg/day choline chloride in a pilot study treating a small number of patients with Alzheimer's disease, resulted in a slight hypotensive effect (Boyd *et al.*, 1977). This dose was regarded as a LOAEL by the Standing Committee on the Scientific Evaluation of Dietary Reference Intake (2000).

Genotoxicity

Choline chloride was not mutagenic to bacteria in reverse mutation assays (Haworth *et al.*, 1984; JETOC, 1997; Litton Bionetics, 1977).

A small, but statistically significant, and dose-related increase in sister chromatid exchanges (SCEs) in Chinese Hamster Ovary (CHO) cells was reported at 50 and 500 μg/ml choline chloride in the absence of S9 only (Bloom *et al.*, 1982). No higher concentrations were examined. These results could not be confirmed in another study using CHO cells at concentrations of choline chloride up to 5,000 μg/ml. (Galloway *et al.*, 1985).

In a gene conversion assay with *Saccharomyces cerevisiae* strain D4, choline chloride was negative in the presence and absence of metabolic activation (Litton Bionetics, 1977).

No *in vivo* genotoxicity studies were available.

Carcinogenicity

No studies were located.

Reproductive Toxicity

No reliable studies have been conducted that address female fertility or reproductive toxicity by a relevant route of exposure.

Developmental Toxicity

Pregnant female mice were given in their feed 1,250 to 20,000 mg/kg choline chloride during gestational days 1 to 18 (BASF AG, 1966). Maternal body weight gain was reduced in all treated groups except for the 1,250 mg/kg group. Determination of maternal weight gain of dams with embryonic/fetal absorptions showed that there was no

almost net weight gain at ≥4,160 mg/kg and net weight loss in the 20,000 mg/kg group. All fetuses were resorbed in the 20,000 mg/kg group. Embryonic/fetal lethality of 35% and 69% were seen in the 4,160 and 10,800 mg/kg groups, respectively. No resorptions occurred in the 1,250 mg/kg group. Developmental toxicity was seen in all but the 1,250 mg/kg group. No statistically significant increases in malformations were observed in any dose group. The NOAELs for maternal and developmental toxicity is 1,250 mg/kg/day.

Key Study/Critical Effect for Screening Criteria

The Standing Committee on the Scientific Evaluation of Dietary Reference Intakes selected hypotension as the critical effect from the study by Boyd *et al.* (1977) when deriving a Tolerable Upper Intake Level. Boyd *et al.* (1977) reported a LOAEL of 10,000 mg/day choline chloride (7,500 mg/day choline). An uncertainty factor of 2 was chosen because of the limited data regarding hypotension and the inter-individual variation in response to cholinergic effects. Thus, the value for the Tolerable Upper Intake Value for repeated exposure of adults to choline is 3,500 mg/day choline.

The oral RfD for choline chloride is derived by using the LOAEL of 10,000 mg/day from the Boyd *et al.* (1977) study, which is divided by an uncertainty factor of 2, to obtain a value of 5,000 mg/day or 71 mg/kg/day for a 70 kg person.

Oral RfD = 71 mg/kg/day

Drinking water guideline value = 248 ppm

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Toxicity Profile

Cocoamidopropyl betaine
(CAS No. 61789-40-0)

Cocoamidopropyl betaine has been reviewed in the OECD-SIDS program (OECD, 2006).

Acute Toxicity

The acute toxicity of cocoamidopropyl betaine (30-35.5% aqueous solution) in rats is low. The oral LD_{50} is $\geq$4,900 mg/kg, and the dermal LD_{50} is >2,000 mg/kg.

Irritation

A 30% aqueous solution of cocoamidopropyl betaine was only very slightly irritating to the skin of rabbits. In human studies, up to 3% solutions were weakly irritating. A 5-10% solution of cocamidopropyl betaine produced mild to moderate irritation to the eyes of rabbits; solutions containing 15% were irritating to highly irritating; and a 30% aqueous solution was irritating with irreversible damage.

Sensitization

The sensitizing potential of cocoamidopropyl betaine in humans is low. Commercial cocoamidopropyl betaine may, however, contain impurities identified as sensitizers (amidoamine and/or 3-dimethylaminopropylamine) which may explain positive results in human patch tests. There is no evidence for a photosensitizing potential.

Repeated Dose Toxicity

Rats were given a 30% aqueous solution of cocoamidopropyl betaine by oral gavage at doses of 0, 250, 500 or 1,000 mg/kg/day (corresponding to about 0, 75, 150, and 300 mg active substance/kg/day, respectively) 5 days/week for 28 days (Henkel KgA, 1991). The only treatment-related findings were forestomach lesions at the highest dose level, probably as a result of the irritant effect of the test substance. The NOAEL for this study is 500 mg/kg/day (150 mg cocoamidopropyl betaine/kg/day).

Rats were given a 30% aqueous solution of cocoamidopropyl betaine by oral gavage at doses of 0, 250, 500 or 1,000 mg/kg/day (corresponding to about 0, 75, 150, and 300 mg active substance/kg/day, respectively) five days/week for 90 days (Th. Goldschmidt AG, 1991). The only treatment-related findings were forestomach lesions at the 500 and 1,000 mg/kg dose levels , probably as a result of the irritant effect of the test substance. The NOAEL for this study is 250 mg/kg day (75 mg cocoamidopropyl betaine/kg/day).

Genotoxicity

There is no evidence for a genotoxic potential of cocoamidopropyl betaine. A 30% aqueous solution of cocoamidopropyl betaine was not genotoxic i*n vitro* in either a bacteria mutation test or in a mouse lymphoma test. A limited intraperitoneal mouse micronucleus test with 27 % active cocamidopropyl betaine was negative.

Carcinogenicity

No valid carcinogenicity studies have been conducted.

Reproductive Toxicity

No reproductive toxicity studies have been conducted on cocoamidopropyl betaine. However, there was no evidence of an adverse effect on the reproductive organs in rats given oral doses of up to 1,000 mg/kg/day of a 30% aqueous solution of cocoamidopropyl betaine (300 mg active substance/kg/day) for 90 days (Th. Goldschmidt AG, 1991).

Developmental Toxicity

A 28.9% aqueous solution of cocoamidopropyl betaine was tested in a rat developmental toxicity at doses of 330, 990, and 3,300 mg/kg/day (corresponding to 95, 286, and 950 mg/kg/day, respectively) (CESIO, 2004). There were dose-related maternal toxic effects (reduced body weights and stomach ulcers) at 990 mg/kg/day and above. Embryotoxic effects (increased numbers of resorptions, decreased number of viable fetuses, decreased fetal body weight) were found only at the maternal toxic dose level of 3,300 mg/kg/day. The NOAEL for maternal toxicity was 330 mg/kg/day (corresponding to 95 mg active substance/kg-day) and the NOAEL for developmental toxicity was 990 mg/kg/day (corresponding to 286 mg active substance/kg/day).

Key Study/Critical Effect for Screening Criteria

The key study is a 90-day rat oral gavage study in which forestomach lesions were seen at dose levels of 500 and 1,000 mg/kg of a 30% aqueous solution of cocoamidopropyl betaine. The NOAEL for this study is 250 mg/kg/day (75 mg active substance/kg/ay).

$NOAEL_{adjusted}$ = 75 * 5/7 = 53.6 mg/kg/day

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (subchronic to chronic)

Oral RfD = 0.05 mg/kg/day

Drinking water guideline: 0.19 ppm

References

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Toxicity Profile

Coffee Beans (Ground and Roasted)

The composition of a medium-roasted coffee (Clarke, 1987; IARC, 1991) is shown in the table below:

Components	Typical avg content (dry basis, %)		% extractable with water, 100ºC[a]
	Arabica	Robusta	
Alkaloids (caffeine)	1.3	2.4	75 - 100
Trigonelline (including roasted by-products)	1.0	0.7	85 - 100
Minerals (as oxide ash)	4.5	4.7	90
Acids			
Residual chlorogenic	2.5	3.8	100
Aquinic	0.8	1.0	100
Aliphatic	1.6	1.6	100
Sugars			
Sucrose	0.0	0.0	-
Reducing	0.3	0.3	100
Polysaccharides (unchanged from green)	33	37	10
Lignin	2.0	2.0	0
Pectins	3.0	3.0	-
Proteinaceous compounds			
Protein	10	10	15 – 20
Free amino acids	0.0	0.0	-
Lipids (coffee oil)	17	11	1
Caramelized or condensation products (*e.g.*, melanoidins) by difference	23	22.5	20-25
Volatile substances other than acids	0.1	0.1	40-80

[a]Maier (1981), for normal household brewing

The focus of this toxicity profile is on caffeine (CAS No. 58-08-2), which is water-soluble alkaloid. Caffeine has well known central nervous system (CNS) stimulatory properties, and the health benefits as well as the potential health concerns of caffeine have been well studied. The chemical names for caffeine are 1,3,7-trimethyl-2,6-dioxopurine; 1,3,7-trimethylxanthine; 2,7-dihydro-1,3,7-trimethyl-1H-purine-2,6-dione; and 7-methyltheophylline.

Caffeine has been widely consumed by most segments of the population worldwide. The U.S. FDA estimates that the average amount of caffeine consumed by the U.S. population between 2003 and 2008 was approximately 300 mg/person/day (FDA, 2012).

Caffeine is probably one of the most studied natural dietary ingredient. In 2004, the Institute of Medicine (IOM) (2004) prepared an extensive review on caffeine, discussing several issues pertaining to safety. Health Canada also released a review of the many studies dealing with caffeine and its health effects (Nawrot *et al.*, 2003).

Pharmacokinetics

Caffeine is rapidly and completely adsorbed in humans, with approximately 99% absorbed within 45 minutes of consumption (Carillo and Benitez, 2000). Plasma caffeine levels may be influenced by the diet or route of exposure, but peak plasma levels occur approximately 15 to 120 minutes after consumption (Mandel, 2002; Beach *et al.*, 1984; Bonati *et al.*, 1984; Collomp *et al.*, 1991). Caffeine is water soluble and is rapidly distributed throughout the body, detected in all bodily fluids, including saliva, breast milk, urine and semen (Beach *et al.*, 1984). Caffeine elimination follows first-order kinetics (Newton *et al.*, 1981), with the plasma half-life of caffeine at approximately 3 to 6 hours in healthy adults and does not accumulate in body fat or other tissues (Kaplan *et al.*, 1997; Nawrot *et al.*, 2003). Caffeine is rapidly metabolized and excreted (1-3 mg/kg/minute) in the urine (Kaplan *et al.*, 1997), and varies between species, with a slightly different metabolic route noted in rats (Nawrot *et al.*, 2003).

Acute toxicity

The LD_{50} of caffeine in rodents ranges from 185 to 400 mg/kg, depending on the species and strain (OECD, 2002a,b). In humans, the fatal acute oral dose is estimated at 10 and 14 g (approximately 160 to 230 mg/kg for a 60 kg person) (Hodgman, 1998). The serum caffeine concentration is the most reliable indicator of potential caffeine toxicity, with a serum caffeine concentration >100 μg/ml considered lethal in humans (Mrvos *et al.*, 1989). Human caffeine consumption at up to 10 g has caused convulsions and vomiting, with recovery in six hours (Dreisbach, 1974). An acute dose of one gram caffeine can cause adverse effects, progressing from restlessness, nervousness, and irritability to delirium, emesis, neuromuscular tremors and convulsions (IOM, 2004). However, caffeine consumption through the day at up to 900 mg has been reported without adverse effects (Nawrot *et al.*, 2003).

Repeated Dose Toxicity

Administration of high levels of caffeine in chronic rodent studies showed decreased weight gain, but in most studies caffeine administration in the diet or in the drinking water did not affect mortality rates of mice and rats, with the exception of two studies that reported a significant reduction in the average life span of rats consuming caffeine (IARC, 1991). Administration of caffeine in chronic toxicity and carcinogenicity studies showed no carcinogenic effects (IARC, 1991). The potential for caffeine to induce genotoxicity has been evaluated in both *in vitro* an *in vivo* studies, with *in vitro* studies indicating both genotoxic and non-genotoxic results; *in vivo* studies have shown that, overall, caffeine is not genotoxic (IARC, 1991; OECD, 2002a,b).

Cardiovascular Effects

Caffeine is a stimulant, and has been studied for its physiological and behavioral effects. Caffeine increases heart rate and blood pressure, increases diuresis, increases locomotion and alertness, and decreases sleepiness. Clinical studies indicate that doses <450 mg do

not increase the risk or severity of cardiac arrhythmia, while acute doses of 150 mg caffeine may decrease heart rate (James, 1991; Green *et al.*, 1996; Myer, 1998). Studies evaluating effects of caffeine on cardiovascular health or serum cholesterol levels have not provided a consistent adverse effect with caffeine consumption (Nawrot *et al.*, 2003).

Reproductive and Developmental Toxicity

Studies that evaluated the potential teratogenicity of caffeine have been discussed in a review (Christian and Brent, 2001). In animal studies, caffeine administration to pregnant animals has been found to induce teratogenicity and toxic effects on the development of the fetuses only at doses that also caused toxic effects in the dams (Christian and Brent, 2001). Christian and Brent (2001) concluded that studies reporting positive teratogenic effects were administering large doses of caffeine that were far greater than human consumption and were providing the caffeine via gavage, which results in much higher peak serum caffeine levels and therefore overstates toxicity potential. Neither rodents or humans could attain such peak exposures by consuming solutions of caffeine over several hours, the usual mode of human caffeine consumption.

There have been questions raised on whether high intake of coffee or caffeine may increase the risk of miscarriage. Caffeine crosses the placenta and increases maternal catecholamine levels (Goldstein and Warren, 1962). The American College of Obstetricians and Gynecologists (2010) have concluded the following: "Moderate caffeine consumption (less than 200 mg per day) does not appear to be a major contributing factor in miscarriage or preterm birth. The relationship of caffeine to growth restriction remains undetermined. A final conclusion cannot be made at this time as to whether there is a correlation between high caffeine intake and miscarriage."

Conclusions

Based on animal and clinical studies, the long history of caffeine use, moderate daily consumption of caffeine does not appear to cause an irreversible adverse effect on human health.

Drinking Water Guidance Value

Nawrot *et al.* (2003) concluded in their review of the effects of caffeine on human health that "for the healthy adult population, moderate daily caffeine intake at a dose level up to 400 mg/day (equivalent to 6 mg/kg body weight/day in a 65-kg person) is not associated with adverse effects such as general toxicity, cardiovascular effects, effects on bone status and calcium balance (with consumption of adequate calcium), changes in adult behavior, increased incidence of cancer and effects on male fertility." It was indicated that habitual daily use of caffeine at greater than 500-600 mg/day (8.3 - 10 mg/kg) (4-7 cups of coffee or 7-9 cups of tea) could be considered a health risk. For women, caffeine intake greater than 400 mg/day (6.7 mg/kg) "may increase the risk of detrusor instability (unstable bladder) development in women" (Nawrot *et al.*, 2003).

More recently, the American College of Obstetricians and Gynecologists (2010) have concluded that moderate caffeine consumption (<200 mg/day) does not appear to be a major contributing factor in miscarriage or preterm birth.

Thus, the acceptable daily intake of caffeine will be set at 200 mg/person/day for the derivation of a drinking water guidance value. Assuming that humans consume 2 liters of water a day, the drinking water guidance value for caffeine is determined to be 100 mg/L.

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Toxicity Profile

Crystalline Silica, Cristobalite
(CAS No 14464-46-1)

Crystalline Silica, Quartz
(CAS No. 14808-60-7)

Silica is an off-white granule that occurs naturally in various crystalline and amorphous or other non-crystalline forms. Crystalline silica is characterized by silicon dioxide (SiO_2) molecules oriented in fixed, periodic patterns to form stable crystals. The primary crystalline form of silica is quartz. Other crystalline forms of silica include cristobalite, tripoli and tridymite. Particle size is a key determinate of silica toxicity, since toxicity is restricted to particles that are small enough to be deposited into the target regions of the respiratory tract.

Oral Exposure

No oral studies were located; however, crystalline silica is not expected to exhibit toxicity by the oral route. Although absorption studies were not found for crystalline silica, kinetic studies on amorphous silica show no absorption from the gastrointestinal tract.

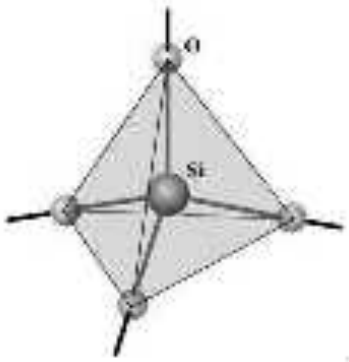
Dermal Exposure

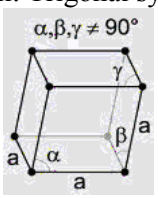
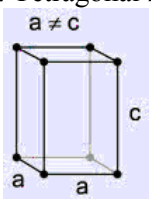
No dermal studies were located; however, crystalline silica is not expected to exhibit toxicity by the dermal route.

Inhalation Exposure

See attached OECD-SIDS Initial Targeted Assessment Profile on Quartz and Cristobalite, SIAM 32, 19-21 April 2011.

INITIAL TARGETED ASSESSMENT PROFILE (Human Health)

CAS No.	Quartz: CAS RN 14808-60-7 Cristobalite: CAS RN 14464-46-1
Chemical Name	Quartz and Cristobalite
Structural Formula	Molecular Formula: SiO_2 

Unit Cell: Trigonal symmetry	Unit Cell: Tetragonal symmetry
	
Quartz: CAS RN 14808-60-7	Cristobalite: CAS RN 14464-46-1

SUMMARY CONCLUSIONS OF THE TARGETED ASSESSMENT

NOTE: The present assessment is targeted to address the following human health endpoints: repeated dose toxicity and carcinogenicity via the inhalation route of exposure, and genotoxicity. It cannot be considered as a full SIDS Initial Assessment. Summary information on exposure is also reported here. Other endpoints for human health and the environment included in the Canadian screening assessment but have not been presented to OECD member countries, and thus are not included in this profile.

The final screening assessment will be published under the responsibility of the Government of Canada.

Rationale for Targeting the Assessment

The Government of Canada "categorized" or prioritized all 23,000 chemical substances on its Domestic Substances List (DSL) from 1999 to September 2006, as required by its *Canadian Environmental Protection Act, 1999* (CEPA 1999). Additional details may be found at http://www.chemicalsubstanceschimiques.gc.ca/about-apropos/categor/index-eng.php. Using information from Canadian industry, academic research and other countries, Government of Canada scientists applied a set of rigorous tools to the 23,000 chemical substances on the DSL. They were categorized to identify those that were: **inherently toxic** to humans or to the environment and that might be **persistent** and/or **bioaccumulative**; and substances to which people might have **greatest potential for exposure**. During this priority-setting exercise, distinct approaches were taken for identifying substances of likely concern for human health and the environment, and subsequent assessment activities may have focused on either human health or ecological endpoints. Through categorization, the Government of Canada has identified approximately 4,000 of the 23,000

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chemical substances on the DSL as priorities for further assessment, research and/or measures to control their use or release. Quartz and cristobalite were identified at that time, applying the categorization criteria, as high priorities for human health risk because they were considered to pose greatest potential for exposure and their respirable forms are classified by the International Agency for Research on Cancer as carcinogenic to humans (quartz and cristobalite) and by the National Toxicology Program as known human carcinogens (crystalline silica). These substances did not meet the ecological categorization criteria for bioaccumulation potential or inherent toxicity to aquatic organisms.

Under the Canadian legislation a determination of whether one or more of the criteria of the CANADIAN ENVIRONMENTAL PROTECTION ACT (CEPA) 1999, section 64 are met is based upon an assessment of potential risks to the environment and/or to human health associated with exposures in the general environment. For humans, this includes, but is not limited to, exposures from ambient and indoor air, drinking water, foodstuffs, and the use of consumer products. A conclusion under CEPA 1999 on the substances in the Chemicals Management Plan (CMP) Challenge is not relevant to, nor does it preclude, an assessment against the hazard criteria specified in the Controlled Products Regulations, which is part of the regulatory framework for the Workplace Hazardous Materials Information System [WHMIS] for products intended for workplace use.

Physical-chemical properties

The silicon dioxide group represents a polymorphic category containing a large number of forms identical in composition but with different atomic arrangements which afford different chemical properties. There are two sub-categories within this group: crystalline silica, to which the present substances quartz and cristobalite belong, and non-crystalline or amorphous silica. The key distinction between these sub-categories is that in crystalline substances, the building blocks are arranged in regular, repeating 3-dimensional pattern having long range order, whereas amorphous materials do not display long range order. In all forms of silica, (crystalline and non-crystalline), the silicon atom is tetrahedral and bound to four neighbouring oxygen atoms.

Quartz and cristobalite are solid at room temperature, existing normally as colourless or white crystals. The melting points for quartz and cristobalite are 1400-2000 ^{o}C and 1713-1728 ^{o}C, respectively and for both compounds, the boiling point is 2230^{o}C. Even though no experimental data were available, their vapour pressure and Henry's Law constant are likely negligible. Log K_{ow} (octanol-water partition coefficient) and log K_{oc} (organic carbon-water partition coefficient) are not applicable to these substances. The densities range from 2500-2700 kg/m^3 for quartz and 2300-2380 kg/m^3 for cristobalite.

The very similar physico-chemical properties of quartz and cristobalite reflect their closely related crystal forms. The solubility of crystalline silicates decreases as a function of silica tetrahedral packing density and long-range crystal order. For example, cristobalite has a more open framework structure than quartz and its density is lower, therefore, its solubility is higher. The water solubility of these minerals is also function of temperature, pH, particle size, and the presence of a disrupted surface layer. This may explain the variability of solubility values reported by many authors. The most probable solubility value for quartz is approximately 3.8 mg Si/L, or 6.4 mg/L expressed as the SiO_2 species, while the solubility of cristobalite is approximately 8.7 mg Si/L, or 18 mg SiO_2/L. The kinetics of dissolution of these substances is slow due to the high activation energy required to hydrolyse the Si-O-Si bond.

Human Health Targeted Endpoints

The majority of the studies described here have been reviewed by the International Agency for Research on Cancer (IARC 1997). However, additional data relevant to the screening assessment were identified up to August 2010.

Repeated dose toxicity/non-neoplastic effects (development of silicosis).

Studies on animals

Significant short-term and subchronic studies have demonstrated adverse effects in the lungs, while one of the 6 studies showed effects on the spleen in mice. Rats were exposed to 0, 10 or 100 mg/m^3 of cristobalite via inhalation for 6 hours/day during 3 days. Animals were observed 3 months after exposure. Elevated levels of granulocytes and elevated markers of cytotoxicity from the lung lavage fluid were noted in all exposed groups. Another study of similar duration (9 days) conducted in mice also identified a LOAEC of 10 mg/m^3. Effects observed included minimal interstitial thickening, accumulations of mononuclear cells and slight lymphoid tissue hypertrophy in the lungs.

In a 4-week inhalation study, female rats were exposed to 0, 0.1, 1 or 10 mg/m^3 of quartz 6 hours/day, 5 days/week. Bronchoalveolar lavage fluid was evaluated at 1, 8, and 24 weeks after exposure. Elevated levels of

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granulocytes and significant elevation of markers of cytotoxicity (Lactate dehydrogenase [LDH] and β-glucuronidase [β-glu]) were observed at 1 mg/m^3 and higher. The increased levels of LDH and β-glu were only significant at 24 weeks after exposure. A LOAEC of 1 mg/m^3 was identified at 24 weeks.

Male rats (4 animals per dose) were exposed to 0 or 3 mg/m^3 of cristobalite via inhalation for 6 hours/day, 5 days/week during 13 weeks. Pulmonary inflammation and fibrosis were observed in the exposed group at the end of treatment. When mice were similarly exposed to 5 mg/m^3 of quartz for 6 hours/day, 5 days/week for 15 or 27 weeks, the authors observed increased spleen weight and formation of plaque in the spleen.

In two separate studies, in which rats or hamsters were exposed to quartz via inhalation for at least 6 months, LOAECs of 2 and 3 mg/m^3 were identified, respectively. All the effects observed were related to inflammation and fibrosis of the lung tissue.

Several chronic studies investigated exposure of the respirable forms (i.e. accumulated via inhalation in the lung tissues) of quartz and cristobalite to rats, mice and hamsters. The following is a description of the study in which the lowest non-neoplastic LOAEC was determined. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz, containing 74% of respirable quartz, through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. The mean mass of particle at the end of the exposure period was 0.91 mg/lung. The LOAEC identified was 0.74 mg/m^3 (adjusted for 74% respirable quartz) based on lipoproteinosis, multifocal, inflammatory cell infiltrate and alveolar hyperplasia.

Human epidemiology data

In humans, the lowest observed adverse effect level was identified in a U.S. cohort study. The study was conducted on 3330 gold miners (all are males), who had an average of 9 years underground exposure during the period 1940 to 1965. The cohort was followed up through 1990. Silicosis[1] was identified through death certificates or chest X-rays. A job-exposure matrix together with work history was used to estimate individual exposure. The total silica content in the respirable dust in the mine was estimated at 13% and the median crystalline silica exposure was 0.05 mg/m^3. In this sub population of miners, 170 cases of silicosis were identified. The best predictor for risk of silicosis was cumulative exposure, which varied from less than 1% for a 0.5 mg/m^3-year exposure to 68-84% when exposed to more than 4 mg/m^3-year (based on the average daily dust exposure during the workday each year and summed over time for each miner). The main limitations identified by the authors include the limited number of radiographic surveys, the potential bias from death certificates

[1] Silicosis: Lung disease caused by inhalation of crystalline silica dust, and resulting in inflammation and scarring in forms of nodular lesions in the upper lobes of the lungs. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics). It does not follow that a history of exposure to silica necessarily results in silicosis (Nonsilicotics). The typical "Silicotic" lung nodule is shown in Figure 1.

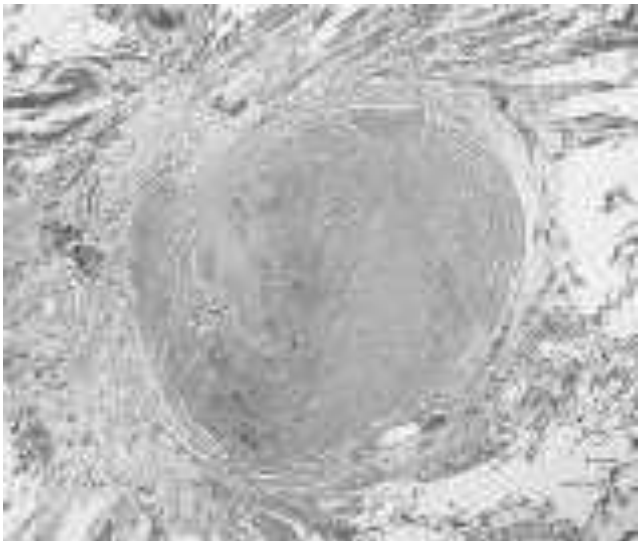


Figure 1. Silicotic nodule characterised by a central zone of hyalinised collagen with a whorled appearance and peripheral dust-containing macrophages (Rees and Murray, 2007).

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(relying on death certificates instead of relying on repeated x-rays, which were lacking for each miner, may have underestimated the number of cases) and the fact that the conversion of dust counts to

gravimetric measurements may not be accurate based on the estimation of 13% silica content in the respirable dust (although based on a relatively large number of samples (n = 82) collected in two different surveys, there was broad range of content in these samples (1% to 48%, SD = 9), and the percentage of respirable quartz may have differed in earlier years, but data were lacking for these years).

Two other human studies have identified similar LOAECs based on the critical endpoint of radiographic confirmed silicosis. A LOAEC of 0.053 mg/m^3 (mean exposure) was identified in a cross sectional study of South African gold miners and a LOAEC of 0.064 mg/m^3 (mean exposure) was derived in a mining community population-based random sample survey in Colorado.

Carcinogenicity studies

Studies on animals

Experimental studies conducted in rats have shown clear and consistent increases in lung tumours after chronic inhalation exposure. In the nine rat studies identified, five were inhalation studies and four were intratracheal instillation studies. All studies except one inhalation study showed increased incidence of lung tumours. For the inhalation studies with treatment related tumours, concentrations ranged from 1 to 50 mg/m^3 (1, 6, and 30 mg/m^3 of DQ-12 quartz; 12 and 50 mg/m^3 of Min-U-Sil 5 quartz) and duration of exposure ranged from 29 days to 2 years. In the inhalation study with no treatment-related tumours, exposure was 60 mg/m^3 of Sikron F300 quartz for 13 weeks. The following is a description of the neoplastic results in the study also identified as the critical study for non-neoplastic results. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. In the exposed group, 18 animals developed tumours (12 in females, 5 in males), as opposed to 3 and 2 for the control and positive control groups respectively. The majority (10/18) of the tumours observed were adenocarcinomas. The mean mass of particles in the lungs at the end of the exposure period was 0.91 mg/lung.

For the intratracheal instillation studies, doses ranged from 4 to 57 mg/kg-bw (based on 7, 12 or 20 mg/animal of Min-U-Sil (5) quartz or 20 mg/animal of novaculite quartz). Exposure regimes were diverse and included single instillation with observation for up to two years, to weekly instillation for 10 weeks. It is noteworthy that the single intratracheal administration of a 95% pure quartz particles (<5 μm) resulted in an increased incidence of silicotic granulomas after 3 weeks and lung tumours after 11 months. The most common tumours reported across the long term rat studies were adenocarcinomas, however other tumours such as squamous-cell carcinoma, alveolar carcinoma and bronchiole-alveolar adenoma were also reported, and all animals that developed tumours also showed some degree of fibrosis.

Of particular interest is the intratracheal instillation study, investigating the sequence of pathological events leading to lung tumors. An unspecified number of rats/sex/dose received a single intratracheal instillation of various crystalline silica dusts or ferric oxide, allowing direct administration into the bronchial tree. The doses were 12 or 20 mg of Min-U-Sil 5 quartz (MQZ), 12 mg of hydrofluoric-acid-etched Min-U-Sil 5 quartz (HFMQZ), 12 mg of cristobalite, 12 mg of tridymite and 12 mg of ferric oxide suspended in saline. All groups were observed until six months post exposure, except for both MQZ groups, the HFMQZ and the ferric oxide group which were observed up until 17 months post-exposure. Interim sacrifices were conducted at 6, 11 and 17 months. The rat lungs showed a clear progression of effects. The sequence of pathological events were, an initial inflammatory response leading to a marked hyperplasia and hypertrophy of alveolar cells after one month, and at six months hyperplasia was evident but no lung tumours were observed. In this study, lung tumours were observed starting at the 11 month sacrifice with a 17% and 42% incidence in males and females (based on 3/18 males and 8/19 females), respectively, and at 17 months incidences were 32% and 59% (based on 6/19 males and 10/17 females, respectively). No lung tumours were found in ferric oxide treated rats. Similar studies have also been conducted in hamsters and mice. Although treated mice and hamsters showed treatment related signs (inflammation or fibrosis), no tumours were observed in hamsters. No increase in the incidence of lung tumours was seen in mice treated with quartz; however silicotic granulomas and lymphoid cuffing around airways but no fibrosis were seen in the lungs of quartz-treated mice.

Human epidemiology data

There is an extensive dataset of human studies investigating the link between crystalline silica exposure and cancer. IARC (1997) identified over 50 epidemiological studies based on occupational exposure to dust containing respirable crystalline silica. Main industry sectors from which the human data is derived include gold mines, foundries, granite/stone industry, pottery workers and refractory brick workers. From the least confounded studies, it was noted that lung cancer tended to increase with the following parameters: cumulative

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exposure; duration of exposure; peak intensity of exposure; presence of radiographically defined silicosis; and length of follow-up time from date of silicosis diagnostic. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics).

Since the 1997 IARC report, a large number of epidemiological studies have been published, with the more recent studies being updates from supplementary follow-up of results from previously assessed case-control studies cohorts, new results based on refined exposure assessments or adjustment for confounders or meta-analyses of the pooled data from these epidemiology studies

In a meta-analysis of the data from 10 cohort studies of gold, tin and tungsten miners, granite workers, industrial sand, diatomaceous earth and pottery workers with quantitative exposure estimates for crystalline silica were pooled in order to analyse the risk related to lung cancer. The pooled cohort standardized mortality ratio (SMR, against national rates) [See Appendix 1 for definition] was 1.2 (Confidence Interval [CI] 1.1-1.3). The results from the case-control analyses show a statistically significant trend with duration of exposure (odds ratios (ORs) [See Appendix 1] by quintile of cumulative exposure increased from 1.0 to 1.6 [CIs of 0.85 to 2.1] and by quintile of average concentration increased from 1.0 to 1.7 [CIs of 1.1 to 2.3]), supporting the importance of the increasing lung burden of silica in the occurrence of cancer. Overall, the authors concluded that the results support the carcinogenicity conclusion presented by IARC (1997).

To investigate the link between crystalline silica, silicosis and lung cancer, epidemiological data published between 1966 and 2001 were gathered. Over 50 studies were selected and pooled according to type of study and the parameter being linked to lung cancer (i.e. silica exposure, presence of silicosis in subjects). The quality of study, adjustment for confounding factors, co-exposure to other carcinogens and availability of a more recent analysis of a same cohort were taken into consideration in the final selection of the studies. Analysis of the relationship between exposure to silica and lung cancer included 17 cohort and 13 case-control studies. For the analysis of lung cancer versus silicosis, 11 cohort and 5 case-control studies were selected. The third analysis included 6 cohort and 2 case-control studies to evaluate the risk of lung cancer in non-silicotics. A random effect model was used to conduct each meta-analysis. Pooled cancer risk ratios (RRs) were 1.32 (CI 1.23-1.41) for crystalline silica exposure, 2.37 (CI 1.98-2.84) for individuals exposed to silica with confirmed silicosis (Silicotics) and 0.96 (CI 0.81-1.15) for individuals with no evidence of silicosis (non-silicotics) with confirmed exposure to silica, supporting the general observation that silicosis has a stronger temporal relationship with crystalline silica exposure and furthermore support the view that a human silicotic response could be a preliminary stage in the development of cancer.

A more recent meta-analysis included 28 cohort, 15 case-control and two proportionate mortality ratio (PMR) [See Appendix 1] studies from a variety of occupational settings conducted between 1996 and 2005. Risk ratios (RRs) were calculated based on type of study and silicosis status using fixed and random effect models (results presented here are from the random model). RRs for all cohort studies was 1.34 (CI 1.25-1.45), and were 1.69 (CI 1.32-2.16) for silicotics, 1.25 (CI 1.18-1.33) for those with undefined silicosis status and 1.19 (CI 0.87-1.57) for non-silicotics. In the case-control studies, the general RR was 1.41 (CI1.18-1.67), and the same sub-groups as mentioned above resulted in RRs of 3.27 (CI 1.32-8.2), 1.41 (CI1.18-1.70) and 0.97 (CI 0.68-1.38), respectively. The proportionate mortality ratio for the last two studies was 1.24 (CI 1.05-1.47). The authors noted that the association between lung cancer and exposure to crystalline silica was more consistent for silicotics, i.e., those diagnosed with silicosis and RR values split into type of occupational settings in which participants worked.

Based upon the above three meta-analysis studies and the epidemiology studies discussed in IARC (1997), the following can be concluded. Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis. Cancer risk is often more significant in workers exposed to crystalline silica over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours. Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles.

There have been reports of tumours outside of the lungs in persons with high silica exposure; however, these reports are sparse and the data inconsistent and have not been unequivocally linked to exposure to either one of the crystalline forms (quartz or cristobalite). Some of the reported locations are: oesophagus, stomach, liver, skin and bone. Sufficient epidemiological or toxicological data do not currently exist for quantitative assessment of the exposure-response relationship on these other tissues or organs.

Genotoxicity

Potential genotoxicity has been assessed in multiple *in vitro* and *in vivo* assays. Table 1 below gives a brief summary of the positive results observed in each type of assay.

Table 1. Summary of positive results over total number of results for each assay and each category (all studies

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conducted with crystalline silica: quartz, except where indicated).

Assay	Animal data		Human data		Positives/Total	
	In vitro	In vivo	In vitro	In vivo[d]	In vitro	In vivo
Rec Assay	0/1				0/1	
DNA strand break	1/1	2/2	5/5[b]	1/1	6/6	3/3
Sister chromatid exchange	0/1		0/1[c]	1/1	0/2	1/1
Micronucleus	2/3	0/1	2/2[b]	1/1	4/5	1/2
Chromosome aberration	0/1			1/1	0/1	1/1
Aneuploidy/polyploidy	0/3				0/3	
Cell transformation	4/4				4/4	
Hprt mutation	1/2	2/2[a]	1/1[b]		2/3	2/2
Oxidative DNA damage		4/5	2/2		2/2	4/5
DNA binding		1/1				1/1
p53 activation		0/1				0/1

a. one assay conducted with crystalline silica: cristobalite
b. one assay conducted with "ultrafine crystalline silicon dioxide".
c. crystalline silica: tridymite
d. crystalline silica dust (subtypes not provided).

All the *in vivo* human genotoxicity studies are based on three independent studies that used blood samples from workers from diverse occupational settings with confirmed exposures to crystalline silica dust; however, quantification of exposure was not provided. After stratification by smoking status, sister chromatid exchange remained statistically significant in both smokers and non-smokers although the frequency was higher in smokers. For the chromosome aberration assay conducted as part of the same study (blood samples from workers in the stone crusher industry), the increased frequency was no longer significant after stratification. In the DNA damage study of foundry and pottery workers and the micronucleus assay of workers involved in sandblasting and related jobs, results were positive when compared to controls. However, in both studies, smoking status influenced the results, contributing to the increased DNA damage observed since results were greater in smokers versus non-smokers, and the frequency of micronuclei in nasal epithelial cells was higher in smokers (p=0.002) but when using peripheral blood lymphocytes did not differ statistically between smokers and non-smokers who were similarly exposed to silica dust,

The role of *in situ* generation of reactive oxygen species (ROS) and reactive nitrogen species (RNS) has been well established in the following types of DNA damage: small scale insertions, DNA base pair deletion, base modification, chromosomal change/loss, microsatellite instability, DNA strand break, 8-hydroxydeoxyguanosine (8-OHdG) mutation and point mutations. ROS and RNS generation is postulated to be (a part of) the DNA damage mechanism for crystalline silica. Studies are described below to support this hypothesis.

DNA was exposed *in vitro* to various crystalline silica dusts, to H_2O_2, or to both. Results show that DNA damage was limited when dust or H_2O_2 were administered alone but increased with the co-exposure. When the reactive oxygen scavenger, dimethylsulfoxide, was added to the test system, DNA strand break was inhibited, data supporting the viewpoint that it is the presence of radicals generated in response to quartz and cristobalite that causes the DNA damage and not quartz or cristobalite themselves.

Hprt mutation assays in rat alveolar epithelial cells, both *in vitro* and *in vivo,* were positive in response to quartz. The positive results *in vivo* were seen only in the presence of significant inflammatory responses in the treated animals. Also, in a parallel *in vitro* experiment, rat alveolar epithelial cells were incubated with the bronchoalveolar lavage fluid from the rats exposed to quartz. Both macrophage and neutrophil enriched lavage cells induced mutation in the exposed alveolar epithelial cells. Addition of catalase (an enzyme which inactivates H_2O_2) before incubation inhibited the increase in *hprt* mutation.

Rats were exposed to either crystalline or amorphous silica in a manner to induce the same level of

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inflammation in the lungs. The inflammatory response was assessed by measuring the proportion of neutrophils in the bronchiolar lavage fluid. The actual concentrations were 3 and 50 mg/m^3 for crystalline and amorphous silica respectively. The animals were exposed for 13 weeks. *Hprt* mutation frequency was measured in the alveolar epithelial cells at the end of the exposure period. Mutation frequency was greatly increased only in the crystalline silica treated rats; no treatment related increase was found in the rats treated with the amorphous form.

In an 8-OHdG assay conducted to monitor DNA damage by reactive oxygen species, female rats were exposed to 0, 0.3, 1.5 and 7.5 mg/animal of quartz via intratracheal instillation. Effects were observed 90 days post-exposure. A clear dose-response relationship was identified between quartz exposure and various inflammation markers (differential cell count, protein, lung surfactant lipids and tumour necrosis factor alpha). Inflammation was present starting at the lowest dose. However, 8-OHdG showed a statistically significant increase starting at 1.5 mg/animal only. Similarly, in another study, 8-OHdG and DNA strand breaks were observed at concentrations of or above 10 ug/m^3 in rat lung epithelial cells.

In the aim of investigating the role of ROS in lung carcinogenesis, rat lung epithelial cells were incubated with polymorphonuclear (PMN) leukocytes (involved in the inflammatory process and responsible for the release of certain ROS) or hydrogen peroxide. Statistically significant increases in 8-OHdG were observed in the presence of PMN or hydrogen peroxide in a dose-response manner.

In a series of experiments which used *in vitro* stimulation of macrophages with crystalline silica and *in vivo* intranasal instillation of crystalline silica in mice, it was demonstrated that that the chronic fibrosis seen in a murine model of silicosis *in vivo* is dependent on the presence of adaptor molecule ASC and Nalp3 inflammazome. These data support a potential mode of action whereby silica triggers cellular responses that in turn activate alveolar macrophages, resulting in an inflammatory response and silicosis. In mice deficient in Nalp3 inflammazome, the development of inflammation and collagen deposition was significantly reduced compared with normal mice 3 months after the initial intranasal instillation of silica.

Analysis of Lung Tumour Data

The weight of evidence for both rats and humans indicates that fibrotic and silicotic lesions in the lung result from inhalation exposure to crystalline silica and that lung cancer is secondary to those lesions in the lung. Although the mechanism of induction for the lung tumours has not been fully elucidated, there is sufficient supportive mode of action evidence from the data presented to demonstrate that a threshold approach to risk assessment is appropriate based on an understanding of the key events in the pathogenesis of crystalline silica induced lung tumours. The body of evidence include the following:

- In experimental studies, all rats that developed tumours also showed fibrosis.
- Adenocarcinomas, the most common type of tumour identified in rats, are commonly associated with fibrosis and deeply scarred lung tissue.
- Experimental rat studies showed a clear progression of the effects from initially mild inflammation, followed by fibrosis over-time, leading eventually to lung tumours.
- Tumours are not present in all treated species dosed in the same way.
- The tumours, both in rats and humans, are concentrated in the lungs only, although other organs are indirectly exposed.
- In human studies, cancer risk is often more significant in workers exposed over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours.
- Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles
- Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis.
- For genotoxicity, in vitro results were mostly mixed and in vivo results were mostly positive. However, the vast majority of the positive genotoxicity assay results can be explained by the generation of reactive oxygen species, as demonstrated experimentally, where ROS scavenging prevents the genotoxicity.
- *In vivo*, macrophage deficient mice (macrophages produce ROS in response to crystalline silica) do not develop silicosis nor do they develop tumours and the Nalp3 inflammazome, a key player in the macrophage initiated inflammatory response, is required for the development of pulmonary fibrosis after

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inhalation of silica.

- Though inhalation exposure to crystalline silica in multiple occupational settings is clear, the increase in risk, based on the several recent meta-analyses of the multiple human epidemiological studies, remains low.

It is worth noting that where aggressive engineering controls have been made to reduce silica dust levels in the workplace (Sweden), silicosis has been eliminated. By corollary, existing exposures outside of the workplace in such areas do not pose a risk for silicosis to the general population.

The respirable forms of quartz and cristobalite possess properties indicating a hazard for human health (repeated dose toxicity, carcinogenicity and genotoxicity). The mode of action in the lungs involves irritation, inflammation and reactive species formation, leading to silicosis, and eventually to tumour formation.

Exposure

Uses

Consistent with oxygen and silicon being the two most abundant elements in the Earth's crust, silicon-oxide minerals, including quartz are ubiquitous in the natural environment. In particular, as a component of sand, quartz may find use in a diverse array of applications. Several high volume uses include, but are not limited to, the use of sand as a filling material for the construction of roads and in general building activities, the use of sand and gravel aggregates as abrasives on roads in winter and the use of fly-ash, which may contain 4-14% quartz and 0.5-1% cristobalite, as a cement additive. These abrasives when used on winter roads are usually mixed with road salts and may be sand only, stone dust, sand and gravel aggregates, or pre-treated sand. They are used mainly by rural municipalities or in areas where cold temperatures diminish the efficiency of salts for de-icing. Quantities of abrasives used in Canada were 5.73×10^9 kg, 4.59×10^9 kg, and 4.93×10^9 kg for 2007, 2008 and 2009, respectively.

Industrial sand, high purity silica sand products with closely controlled sizing are expected to contain quartz and cristobalite, include lump silica (2-3mm up to 15 cm or more), silica sand (75µm to 2-3mm) and silica flour (less than 75µm). Lump silica may be used in the production of silicon alloys, silica bricks, and the linings of certain types of pulverizers (eg. ball mills and tube mills).

Silica sand may be used in the manufacture of glass and glass fibres, silicate chemicals and silicon carbide, the hydraulic fracturing of wells, foundry moulding, and for sandblasting. Silica flour may find use in the ceramics and cement industries, as a filler and extender in rubber and coatings, and as an abrasive in soaps.

Natural clays, such as bentonite and fuller's earth, are used in cat litters for their high water absorbance capacities. Quartz is a natural component of these clays, and consequently, it may be present in cat litter products. High purity α-quartz is a piezoelectric material, which means that application of a voltage induces a distortion in the crystal shape and vice versa. This ability to interconvert electrical and mechanical energy has led to the use of quartz crystals in electronic devices requiring precise timing control, for example telephones, radios, watches and computers.

According to a survey conducted in Canada, quartz and cristobalite are also used in abrasives, adsorbents, filter products (diatomaceous earth), grout and cement. These substances reportedly also find use as fillers, which add bulk and improve wear resistance, in paints and coatings, adhesives, sealants, polymer films, caulking, epoxy resins and silicones. Also, quartz is listed as an ingredient in 60 cosmetic products in Canada. The types of products include anti-wrinkle preparation, eye and face makeup, lipstick, hair dyes, shampoos and grooming products, as well as skin cleansers, moisturizers and tanning preparations.

Natural Sources

In Canada, quartz naturally occurs in many types of rock formations. Those with high silicon dioxide content (95% SiO_2 or more) include vein and massive intrusion bodies, quartz pebbles, silica sand, sandstone and quartzite. Sandstone is a sedimentary rock mostly composed of quartz grains cemented by a bonding material such as clay, calcite or iron oxide. Quartzite is a hard, compact, metamorphosed sandstone made of grains of quartz firmly bonded with a siliceous cement. Mineral aggregates (e.g., sand and gravel) have variable silicon dioxide content. Quartz is also found as crystals, aggregates or discrete particles in certain igneous rocks (e.g., granites and pegmatites), soils, sediments, air and surface water. This omnipresence is consistent with the fact that silicon is the second most abundant chemical element on Earth.

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Cristobalite is naturally produced in the ashes of volcanic eruptions, and by combustion metamorphism which is a local phenomenon of spontaneous combustion of naturally occurring substances such as bituminous rocks, coal or oil. It may be found in cavities in volcanic rocks and in thermally metamorphosed sandstones and may also be a transient stage in the diagenesis of diatomaceous shale with the result that soils made of these geologic formations may be rich in cristobalite. Unlike quartz, the natural occurrence of cristobalite is limited to specific geographic regions and mineral types.

Anthropogenic Sources

Natural quartz is isolated from ore via beneficiation, which involves milling or grinding the material into particles that are separated into desired mineral and waste. The materials obtained are either used directly or further purified. In Canada, in 2006, 2.146×10^{9} kg of pure quartz were mined, and 2.385×10^{11} kg of sand and gravel aggregates were produced. The proportion of quartz in silica sand deposits and gravel aggregates will vary from one site to another.

Cristobalite can form from silica melts during the preparation of silica glass; quartz is not obtained from melts but is manufactured at elevated temperature and pressure via a hydrothermal process. Cristobalite also forms during the calcination[2] of diatomaceous earth.

Human Exposure Estimate

Ambient air

The exposure assessment is focussed on respirable quartz and cristobalite, which in ambient air comprises a component of total particulate matter (PM). In Canada, data on the concentrations of silicon in PM was available and used as a surrogate for quartz and cristobalite. This approach is conservative because the measured silicon includes all silicon-containing substances and therefore represents the upper limit for quartz and cristobalite in ambient air.

The National Air Pollution Surveillance (NAPS) Program measured concentrations in $\mu g/m^3$ of silicon in PM with aerodynamic radii less than 2.5 µm ($PM_{2.5}$ (dichot)), and from 2.5 to 10 µm (PM_{10} (dichot)) (the total particulate matter with aerodynamic radii less than 10 µm (PM_{10}) is obtained by adding these values) in Canada. In 2009, as part of the NAPS Program, silicon concentrations were determined on over 1600 samples of $PM_{2.5}$(dichot) and over 1500 samples of PM_{10}(dichot) at 24 urban locations across Canada. An estimate of exposure to quartz and cristobalite can be obtained by assuming that all the silicon in the PM is represented stoichiometrically as SiO_2, and multiplying the reported concentration of silicon by 2.14 to obtain a value for silica.

The intake of respirable quartz and cristobalite by the general population of Canada is estimated using a range covering the lowest 50^{th} percentile SiO_2 concentration in PM_{10}, measured in Pt. Petre, ON, (0.12 $\mu g/m^3$) to the highest 50^{th} percentile concentration in PM_{10} measured in Calgary, AB (2.1 $\mu g/m^3$). The 50^{th} percentile SiO_2 concentrations ranged from 0.1 to 2.1 $\mu g/m^3$ across the survey sites; the top of this range is quite close to the average of the maximum values for the 24 sites (3.7 $\mu g/m^3$). The outdoor data were used to represent the indoor levels, because information on indoor silicon concentrations was not available, and the range of PM_{10} measured indoors is generally lower than the outdoor range. Thus, this approach conservatively overestimates indoor exposure in homes.

The highest exposure group based on these calculations is children ages 0.5 to 4 years with an estimated daily intake ranging from 0.07 to 5.26 µg/kg-bw per day; the estimated daily intake decreases with age due to changes in the ratio of inhalation rates to body weights; the daily intake of adults, 20-59 years old, is estimated to range from 0.03 to 2.00 µg/kg-bw per day.

Consumer Products

Exposure to respirable quartz from the use of cosmetic products, which contained quartz as an ingredient, was considered low because they are not formulated for spray application, the loose powders were reported to contain less than 0.1% quartz, and in these products the substance is not expected to be associated with other components of the formulation and not available in a free form.

For consumer Do It Yourself (DIY) activities around the home, the highest mean breathing zone concentration of particles from sanding dry wall (median cut-point of 10µm) of 6.31 mg/m^3, was used to derive an upper-

[2] Calcinations: Heat treating a substance, but without fusion, to bring about change in its physical or chemical constitution.

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bound exposure estimate ranging from 2 to10 µg/kg-bw per event.

Quartz is used to formulate a large number of paints and coatings. To estimate potential inhalation exposure to quartz from these products, the spray painting of wall paints with an airless spray gun was considered appropriate as a conservative scenario. Exposure to respirable paint particles was estimated using data from controlled a laboratory study in which walls of poorly ventilated test rooms were painted by professional painters using an airless sprayer to apply interior latex paint. The maximum concentration of 13% quartz in paint in Canada was used to estimate exposure. The upper-bound estimate of exposure to quartz, based on the maximum concentration of 13% quartz in paint in the Canadian market and the maximum concentration of respirable paint particles measured in these controlled studies when recommended personal protective equipment is used, is 0.954 µg/kg-bw per event.

Inhalation of ambient air containing quartz and cristobalite is the dominant pathway of chronic exposure (excluding that from DIY activities) for the general population. Because SiO_2 makes up only approximately 5% of PM_{10}, silicon concentrations (expressed as SiO_2) measured in the Canadian NAPS survey of 24 urban locations were considered most relevant to the estimation of exposure by the general population. Quartz and cristobalite comprise only a portion of the total SiO_2 in PM_{10}, therefore, the use of the total silicon concentration to represent the upper bound crystalline silica concentrations results in an overestimation of exposure.

Appendix 1: Definitions of Epidemiological Terms in the ITAP

SMR (Standardized Mortality Ratio): The ratio (x 100) of observed to expected deaths in a study population. Expected deaths are calculated by applying a set of standard age-specific mortality rates to the age distribution of the study population. Standardized ratios are only useful for comparisons. They have no intrinsic meaning.

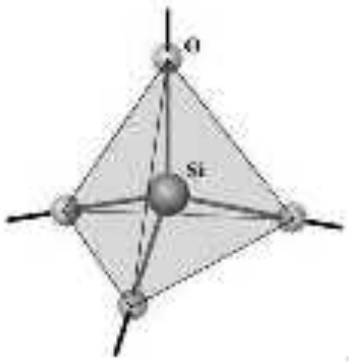
OR (Odds Ratio): In epidemiological case-control studies, a relative measure of disease occurrence. The odds in favour of a particular disease occurring in an exposed group are divided by the odds in favour of its occurring in an unexposed group. If the condition being studied is rare, the odds ratio is a close approximation to the relative risk.

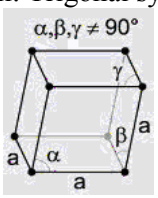
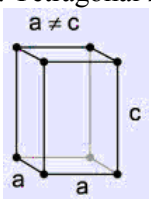
RR (Risk Ratio): The probability of the occurrence of a disease in a group that has been exposed to some environmental, medicinal, microbial, or toxic influence, relative to its probability in a randomly selected population.

PMR (Proportionate Mortality Ratio): Proportionate mortality is the proportion of deaths in a specified population over a period of time attributable to different causes. Each cause is expressed as a percentage of all deaths, and the sum of the causes must add to 100%. These proportions are not mortality rates, since the denominator is all deaths, not the population in which the deaths occurred. Thus, proportionate mortality ratio is a measure of the frequency of occurrence of the proportionate mortality in a defined population during a specified interval of time.

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INITIAL TARGETED ASSESSMENT PROFILE (Human Health)

CAS No.	Quartz: CAS RN 14808-60-7 Cristobalite: CAS RN 14464-46-1
Chemical Name	Quartz and Cristobalite
Structural Formula	Molecular Formula: SiO_2 

Unit Cell: Trigonal symmetry	Unit Cell: Tetragonal symmetry
	
Quartz: CAS RN 14808-60-7	Cristobalite: CAS RN 14464-46-1

SUMMARY CONCLUSIONS OF THE TARGETED ASSESSMENT

NOTE: The present assessment is targeted to address the following human health endpoints: repeated dose toxicity and carcinogenicity via the inhalation route of exposure, and genotoxicity. It cannot be considered as a full SIDS Initial Assessment. Summary information on exposure is also reported here. Other endpoints for human health and the environment included in the Canadian screening assessment but have not been presented to OECD member countries, and thus are not included in this profile.

The final screening assessment will be published under the responsibility of the Government of Canada.

Rationale for Targeting the Assessment

The Government of Canada "categorized" or prioritized all 23,000 chemical substances on its Domestic Substances List (DSL) from 1999 to September 2006, as required by its *Canadian Environmental Protection Act, 1999* (CEPA 1999). Additional details may be found at http://www.chemicalsubstanceschimiques.gc.ca/about-apropos/categor/index-eng.php. Using information from Canadian industry, academic research and other countries, Government of Canada scientists applied a set of rigorous tools to the 23,000 chemical substances on the DSL. They were categorized to identify those that were: **inherently toxic** to humans or to the environment and that might be **persistent** and/or **bioaccumulative**; and substances to which people might have **greatest potential for exposure**. During this priority-setting exercise, distinct approaches were taken for identifying substances of likely concern for human health and the environment, and subsequent assessment activities may have focused on either human health or ecological endpoints. Through categorization, the Government of Canada has identified approximately 4,000 of the 23,000

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chemical substances on the DSL as priorities for further assessment, research and/or measures to control their use or release. Quartz and cristobalite were identified at that time, applying the categorization criteria, as high priorities for human health risk because they were considered to pose greatest potential for exposure and their respirable forms are classified by the International Agency for Research on Cancer as carcinogenic to humans (quartz and cristobalite) and by the National Toxicology Program as known human carcinogens (crystalline silica). These substances did not meet the ecological categorization criteria for bioaccumulation potential or inherent toxicity to aquatic organisms.

Under the Canadian legislation a determination of whether one or more of the criteria of the CANADIAN ENVIRONMENTAL PROTECTION ACT (CEPA) 1999, section 64 are met is based upon an assessment of potential risks to the environment and/or to human health associated with exposures in the general environment. For humans, this includes, but is not limited to, exposures from ambient and indoor air, drinking water, foodstuffs, and the use of consumer products. A conclusion under CEPA 1999 on the substances in the Chemicals Management Plan (CMP) Challenge is not relevant to, nor does it preclude, an assessment against the hazard criteria specified in the Controlled Products Regulations, which is part of the regulatory framework for the Workplace Hazardous Materials Information System [WHMIS] for products intended for workplace use.

Physical-chemical properties

The silicon dioxide group represents a polymorphic category containing a large number of forms identical in composition but with different atomic arrangements which afford different chemical properties. There are two sub-categories within this group: crystalline silica, to which the present substances quartz and cristobalite belong, and non-crystalline or amorphous silica. The key distinction between these sub-categories is that in crystalline substances, the building blocks are arranged in regular, repeating 3-dimensional pattern having long range order, whereas amorphous materials do not display long range order. In all forms of silica, (crystalline and non-crystalline), the silicon atom is tetrahedral and bound to four neighbouring oxygen atoms.

Quartz and cristobalite are solid at room temperature, existing normally as colourless or white crystals. The melting points for quartz and cristobalite are 1400-2000 ^{o}C and 1713-1728 ^{o}C, respectively and for both compounds, the boiling point is 2230^{o}C. Even though no experimental data were available, their vapour pressure and Henry's Law constant are likely negligible. Log K_{ow} (octanol-water partition coefficient) and log K_{oc} (organic carbon-water partition coefficient) are not applicable to these substances. The densities range from 2500-2700 kg/m^3 for quartz and 2300-2380 kg/m^3 for cristobalite.

The very similar physico-chemical properties of quartz and cristobalite reflect their closely related crystal forms. The solubility of crystalline silicates decreases as a function of silica tetrahedral packing density and long-range crystal order. For example, cristobalite has a more open framework structure than quartz and its density is lower, therefore, its solubility is higher. The water solubility of these minerals is also function of temperature, pH, particle size, and the presence of a disrupted surface layer. This may explain the variability of solubility values reported by many authors. The most probable solubility value for quartz is approximately 3.8 mg Si/L, or 6.4 mg/L expressed as the SiO_2 species, while the solubility of cristobalite is approximately 8.7 mg Si/L, or 18 mg SiO_2/L. The kinetics of dissolution of these substances is slow due to the high activation energy required to hydrolyse the Si-O-Si bond.

Human Health Targeted Endpoints

The majority of the studies described here have been reviewed by the International Agency for Research on Cancer (IARC 1997). However, additional data relevant to the screening assessment were identified up to August 2010.

Repeated dose toxicity/non-neoplastic effects (development of silicosis).

Studies on animals

Significant short-term and subchronic studies have demonstrated adverse effects in the lungs, while one of the 6 studies showed effects on the spleen in mice. Rats were exposed to 0, 10 or 100 mg/m^3 of cristobalite via inhalation for 6 hours/day during 3 days. Animals were observed 3 months after exposure. Elevated levels of granulocytes and elevated markers of cytotoxicity from the lung lavage fluid were noted in all exposed groups. Another study of similar duration (9 days) conducted in mice also identified a LOAEC of 10 mg/m^3. Effects observed included minimal interstitial thickening, accumulations of mononuclear cells and slight lymphoid tissue hypertrophy in the lungs.

In a 4-week inhalation study, female rats were exposed to 0, 0.1, 1 or 10 mg/m^3 of quartz 6 hours/day, 5 days/week. Bronchoalveolar lavage fluid was evaluated at 1, 8, and 24 weeks after exposure. Elevated levels of

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granulocytes and significant elevation of markers of cytotoxicity (Lactate dehydrogenase [LDH] and β-glucuronidase [β-glu]) were observed at 1 mg/m^3 and higher. The increased levels of LDH and β-glu were only significant at 24 weeks after exposure. A LOAEC of 1 mg/m^3 was identified at 24 weeks.

Male rats (4 animals per dose) were exposed to 0 or 3 mg/m^3 of cristobalite via inhalation for 6 hours/day, 5 days/week during 13 weeks. Pulmonary inflammation and fibrosis were observed in the exposed group at the end of treatment. When mice were similarly exposed to 5 mg/m^3 of quartz for 6 hours/day, 5 days/week for 15 or 27 weeks, the authors observed increased spleen weight and formation of plaque in the spleen.

In two separate studies, in which rats or hamsters were exposed to quartz via inhalation for at least 6 months, LOAECs of 2 and 3 mg/m^3 were identified, respectively. All the effects observed were related to inflammation and fibrosis of the lung tissue.

Several chronic studies investigated exposure of the respirable forms (i.e. accumulated via inhalation in the lung tissues) of quartz and cristobalite to rats, mice and hamsters. The following is a description of the study in which the lowest non-neoplastic LOAEC was determined. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz, containing 74% of respirable quartz, through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. The mean mass of particle at the end of the exposure period was 0.91 mg/lung. The LOAEC identified was 0.74 mg/m^3 (adjusted for 74% respirable quartz) based on lipoproteinosis, multifocal, inflammatory cell infiltrate and alveolar hyperplasia.

Human epidemiology data

In humans, the lowest observed adverse effect level was identified in a U.S. cohort study. The study was conducted on 3330 gold miners (all are males), who had an average of 9 years underground exposure during the period 1940 to 1965. The cohort was followed up through 1990. Silicosis[1] was identified through death certificates or chest X-rays. A job-exposure matrix together with work history was used to estimate individual exposure. The total silica content in the respirable dust in the mine was estimated at 13% and the median crystalline silica exposure was 0.05 mg/m^3. In this sub population of miners, 170 cases of silicosis were identified. The best predictor for risk of silicosis was cumulative exposure, which varied from less than 1% for a 0.5 mg/m^3-year exposure to 68-84% when exposed to more than 4 mg/m^3-year (based on the average daily dust exposure during the workday each year and summed over time for each miner). The main limitations identified by the authors include the limited number of radiographic surveys, the potential bias from death certificates

[1] Silicosis: Lung disease caused by inhalation of crystalline silica dust, and resulting in inflammation and scarring in forms of nodular lesions in the upper lobes of the lungs. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics). It does not follow that a history of exposure to silica necessarily results in silicosis (Nonsilicotics). The typical "Silicotic" lung nodule is shown in Figure 1.

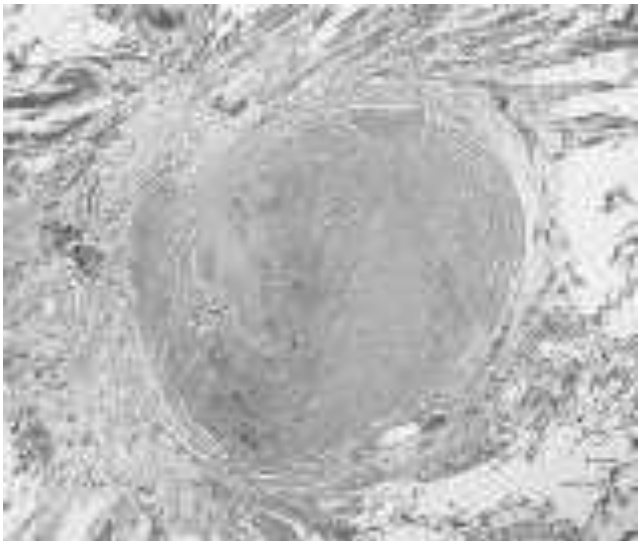


Figure 1. Silicotic nodule characterised by a central zone of hyalinised collagen with a whorled appearance and peripheral dust-containing macrophages (Rees and Murray, 2007).

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(relying on death certificates instead of relying on repeated x-rays, which were lacking for each miner, may have underestimated the number of cases) and the fact that the conversion of dust counts to

gravimetric measurements may not be accurate based on the estimation of 13% silica content in the respirable dust (although based on a relatively large number of samples (n = 82) collected in two different surveys, there was broad range of content in these samples (1% to 48%, SD = 9), and the percentage of respirable quartz may have differed in earlier years, but data were lacking for these years).

Two other human studies have identified similar LOAECs based on the critical endpoint of radiographic confirmed silicosis. A LOAEC of 0.053 mg/m^3 (mean exposure) was identified in a cross sectional study of South African gold miners and a LOAEC of 0.064 mg/m^3 (mean exposure) was derived in a mining community population-based random sample survey in Colorado.

Carcinogenicity studies

Studies on animals

Experimental studies conducted in rats have shown clear and consistent increases in lung tumours after chronic inhalation exposure. In the nine rat studies identified, five were inhalation studies and four were intratracheal instillation studies. All studies except one inhalation study showed increased incidence of lung tumours. For the inhalation studies with treatment related tumours, concentrations ranged from 1 to 50 mg/m^3 (1, 6, and 30 mg/m^3 of DQ-12 quartz; 12 and 50 mg/m^3 of Min-U-Sil 5 quartz) and duration of exposure ranged from 29 days to 2 years. In the inhalation study with no treatment-related tumours, exposure was 60 mg/m^3 of Sikron F300 quartz for 13 weeks. The following is a description of the neoplastic results in the study also identified as the critical study for non-neoplastic results. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. In the exposed group, 18 animals developed tumours (12 in females, 5 in males), as opposed to 3 and 2 for the control and positive control groups respectively. The majority (10/18) of the tumours observed were adenocarcinomas. The mean mass of particles in the lungs at the end of the exposure period was 0.91 mg/lung.

For the intratracheal instillation studies, doses ranged from 4 to 57 mg/kg-bw (based on 7, 12 or 20 mg/animal of Min-U-Sil (5) quartz or 20 mg/animal of novaculite quartz). Exposure regimes were diverse and included single instillation with observation for up to two years, to weekly instillation for 10 weeks. It is noteworthy that the single intratracheal administration of a 95% pure quartz particles (<5 μm) resulted in an increased incidence of silicotic granulomas after 3 weeks and lung tumours after 11 months. The most common tumours reported across the long term rat studies were adenocarcinomas, however other tumours such as squamous-cell carcinoma, alveolar carcinoma and bronchiole-alveolar adenoma were also reported, and all animals that developed tumours also showed some degree of fibrosis.

Of particular interest is the intratracheal instillation study, investigating the sequence of pathological events leading to lung tumors. An unspecified number of rats/sex/dose received a single intratracheal instillation of various crystalline silica dusts or ferric oxide, allowing direct administration into the bronchial tree. The doses were 12 or 20 mg of Min-U-Sil 5 quartz (MQZ), 12 mg of hydrofluoric-acid-etched Min-U-Sil 5 quartz (HFMQZ), 12 mg of cristobalite, 12 mg of tridymite and 12 mg of ferric oxide suspended in saline. All groups were observed until six months post exposure, except for both MQZ groups, the HFMQZ and the ferric oxide group which were observed up until 17 months post-exposure. Interim sacrifices were conducted at 6, 11 and 17 months. The rat lungs showed a clear progression of effects. The sequence of pathological events were, an initial inflammatory response leading to a marked hyperplasia and hypertrophy of alveolar cells after one month, and at six months hyperplasia was evident but no lung tumours were observed. In this study, lung tumours were observed starting at the 11 month sacrifice with a 17% and 42% incidence in males and females (based on 3/18 males and 8/19 females), respectively, and at 17 months incidences were 32% and 59% (based on 6/19 males and 10/17 females, respectively). No lung tumours were found in ferric oxide treated rats. Similar studies have also been conducted in hamsters and mice. Although treated mice and hamsters showed treatment related signs (inflammation or fibrosis), no tumours were observed in hamsters. No increase in the incidence of lung tumours was seen in mice treated with quartz; however silicotic granulomas and lymphoid cuffing around airways but no fibrosis were seen in the lungs of quartz-treated mice.

Human epidemiology data

There is an extensive dataset of human studies investigating the link between crystalline silica exposure and cancer. IARC (1997) identified over 50 epidemiological studies based on occupational exposure to dust containing respirable crystalline silica. Main industry sectors from which the human data is derived include gold mines, foundries, granite/stone industry, pottery workers and refractory brick workers. From the least confounded studies, it was noted that lung cancer tended to increase with the following parameters: cumulative

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exposure; duration of exposure; peak intensity of exposure; presence of radiographically defined silicosis; and length of follow-up time from date of silicosis diagnostic. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics).

Since the 1997 IARC report, a large number of epidemiological studies have been published, with the more recent studies being updates from supplementary follow-up of results from previously assessed case-control studies cohorts, new results based on refined exposure assessments or adjustment for confounders or meta-analyses of the pooled data from these epidemiology studies

In a meta-analysis of the data from 10 cohort studies of gold, tin and tungsten miners, granite workers, industrial sand, diatomaceous earth and pottery workers with quantitative exposure estimates for crystalline silica were pooled in order to analyse the risk related to lung cancer. The pooled cohort standardized mortality ratio (SMR, against national rates) [See Appendix 1 for definition] was 1.2 (Confidence Interval [CI] 1.1-1.3). The results from the case-control analyses show a statistically significant trend with duration of exposure (odds ratios (ORs) [See Appendix 1] by quintile of cumulative exposure increased from 1.0 to 1.6 [CIs of 0.85 to 2.1] and by quintile of average concentration increased from 1.0 to 1.7 [CIs of 1.1 to 2.3]), supporting the importance of the increasing lung burden of silica in the occurrence of cancer. Overall, the authors concluded that the results support the carcinogenicity conclusion presented by IARC (1997).

To investigate the link between crystalline silica, silicosis and lung cancer, epidemiological data published between 1966 and 2001 were gathered. Over 50 studies were selected and pooled according to type of study and the parameter being linked to lung cancer (i.e. silica exposure, presence of silicosis in subjects). The quality of study, adjustment for confounding factors, co-exposure to other carcinogens and availability of a more recent analysis of a same cohort were taken into consideration in the final selection of the studies. Analysis of the relationship between exposure to silica and lung cancer included 17 cohort and 13 case-control studies. For the analysis of lung cancer versus silicosis, 11 cohort and 5 case-control studies were selected. The third analysis included 6 cohort and 2 case-control studies to evaluate the risk of lung cancer in non-silicotics. A random effect model was used to conduct each meta-analysis. Pooled cancer risk ratios (RRs) were 1.32 (CI 1.23-1.41) for crystalline silica exposure, 2.37 (CI 1.98-2.84) for individuals exposed to silica with confirmed silicosis (Silicotics) and 0.96 (CI 0.81-1.15) for individuals with no evidence of silicosis (non-silicotics) with confirmed exposure to silica, supporting the general observation that silicosis has a stronger temporal relationship with crystalline silica exposure and furthermore support the view that a human silicotic response could be a preliminary stage in the development of cancer.

A more recent meta-analysis included 28 cohort, 15 case-control and two proportionate mortality ratio (PMR) [See Appendix 1] studies from a variety of occupational settings conducted between 1996 and 2005. Risk ratios (RRs) were calculated based on type of study and silicosis status using fixed and random effect models (results presented here are from the random model). RRs for all cohort studies was 1.34 (CI 1.25-1.45), and were 1.69 (CI 1.32-2.16) for silicotics, 1.25 (CI 1.18-1.33) for those with undefined silicosis status and 1.19 (CI 0.87-1.57) for non-silicotics. In the case-control studies, the general RR was 1.41 (CI1.18-1.67), and the same sub-groups as mentioned above resulted in RRs of 3.27 (CI 1.32-8.2), 1.41 (CI1.18-1.70) and 0.97 (CI 0.68-1.38), respectively. The proportionate mortality ratio for the last two studies was 1.24 (CI 1.05-1.47). The authors noted that the association between lung cancer and exposure to crystalline silica was more consistent for silicotics, i.e., those diagnosed with silicosis and RR values split into type of occupational settings in which participants worked.

Based upon the above three meta-analysis studies and the epidemiology studies discussed in IARC (1997), the following can be concluded. Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis. Cancer risk is often more significant in workers exposed to crystalline silica over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours. Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles.

There have been reports of tumours outside of the lungs in persons with high silica exposure; however, these reports are sparse and the data inconsistent and have not been unequivocally linked to exposure to either one of the crystalline forms (quartz or cristobalite). Some of the reported locations are: oesophagus, stomach, liver, skin and bone. Sufficient epidemiological or toxicological data do not currently exist for quantitative assessment of the exposure-response relationship on these other tissues or organs.

Genotoxicity

Potential genotoxicity has been assessed in multiple *in vitro* and *in vivo* assays. Table 1 below gives a brief summary of the positive results observed in each type of assay.

Table 1. Summary of positive results over total number of results for each assay and each category (all studies

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conducted with crystalline silica: quartz, except where indicated).

Assay	Animal data		Human data		Positives/Total	
	In vitro	In vivo	In vitro	In vivo[d]	In vitro	In vivo
Rec Assay	0/1				0/1	
DNA strand break	1/1	2/2	5/5[b]	1/1	6/6	3/3
Sister chromatid exchange	0/1		0/1[c]	1/1	0/2	1/1
Micronucleus	2/3	0/1	2/2[b]	1/1	4/5	1/2
Chromosome aberration	0/1			1/1	0/1	1/1
Aneuploidy/polyploidy	0/3				0/3	
Cell transformation	4/4				4/4	
Hprt mutation	1/2	2/2[a]	1/1[b]		2/3	2/2
Oxidative DNA damage		4/5	2/2		2/2	4/5
DNA binding		1/1				1/1
p53 activation		0/1				0/1

a. one assay conducted with crystalline silica: cristobalite
b. one assay conducted with "ultrafine crystalline silicon dioxide".
c. crystalline silica: tridymite
d. crystalline silica dust (subtypes not provided).

All the *in vivo* human genotoxicity studies are based on three independent studies that used blood samples from workers from diverse occupational settings with confirmed exposures to crystalline silica dust; however, quantification of exposure was not provided. After stratification by smoking status, sister chromatid exchange remained statistically significant in both smokers and non-smokers although the frequency was higher in smokers. For the chromosome aberration assay conducted as part of the same study (blood samples from workers in the stone crusher industry), the increased frequency was no longer significant after stratification. In the DNA damage study of foundry and pottery workers and the micronucleus assay of workers involved in sandblasting and related jobs, results were positive when compared to controls. However, in both studies, smoking status influenced the results, contributing to the increased DNA damage observed since results were greater in smokers versus non-smokers, and the frequency of micronuclei in nasal epithelial cells was higher in smokers (p=0.002) but when using peripheral blood lymphocytes did not differ statistically between smokers and non-smokers who were similarly exposed to silica dust,

The role of *in situ* generation of reactive oxygen species (ROS) and reactive nitrogen species (RNS) has been well established in the following types of DNA damage: small scale insertions, DNA base pair deletion, base modification, chromosomal change/loss, microsatellite instability, DNA strand break, 8-hydroxydeoxyguanosine (8-OHdG) mutation and point mutations. ROS and RNS generation is postulated to be (a part of) the DNA damage mechanism for crystalline silica. Studies are described below to support this hypothesis.

DNA was exposed *in vitro* to various crystalline silica dusts, to H_2O_2, or to both. Results show that DNA damage was limited when dust or H_2O_2 were administered alone but increased with the co-exposure. When the reactive oxygen scavenger, dimethylsulfoxide, was added to the test system, DNA strand break was inhibited, data supporting the viewpoint that it is the presence of radicals generated in response to quartz and cristobalite that causes the DNA damage and not quartz or cristobalite themselves.

Hprt mutation assays in rat alveolar epithelial cells, both *in vitro* and *in vivo,* were positive in response to quartz. The positive results *in vivo* were seen only in the presence of significant inflammatory responses in the treated animals. Also, in a parallel *in vitro* experiment, rat alveolar epithelial cells were incubated with the bronchoalveolar lavage fluid from the rats exposed to quartz. Both macrophage and neutrophil enriched lavage cells induced mutation in the exposed alveolar epithelial cells. Addition of catalase (an enzyme which inactivates H_2O_2) before incubation inhibited the increase in *hprt* mutation.

Rats were exposed to either crystalline or amorphous silica in a manner to induce the same level of

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inflammation in the lungs. The inflammatory response was assessed by measuring the proportion of neutrophils in the bronchiolar lavage fluid. The actual concentrations were 3 and 50 mg/m^3 for crystalline and amorphous silica respectively. The animals were exposed for 13 weeks. *Hprt* mutation frequency was measured in the alveolar epithelial cells at the end of the exposure period. Mutation frequency was greatly increased only in the crystalline silica treated rats; no treatment related increase was found in the rats treated with the amorphous form.

In an 8-OHdG assay conducted to monitor DNA damage by reactive oxygen species, female rats were exposed to 0, 0.3, 1.5 and 7.5 mg/animal of quartz via intratracheal instillation. Effects were observed 90 days post-exposure. A clear dose-response relationship was identified between quartz exposure and various inflammation markers (differential cell count, protein, lung surfactant lipids and tumour necrosis factor alpha). Inflammation was present starting at the lowest dose. However, 8-OHdG showed a statistically significant increase starting at 1.5 mg/animal only. Similarly, in another study, 8-OHdG and DNA strand breaks were observed at concentrations of or above 10 ug/m^3 in rat lung epithelial cells.

In the aim of investigating the role of ROS in lung carcinogenesis, rat lung epithelial cells were incubated with polymorphonuclear (PMN) leukocytes (involved in the inflammatory process and responsible for the release of certain ROS) or hydrogen peroxide. Statistically significant increases in 8-OHdG were observed in the presence of PMN or hydrogen peroxide in a dose-response manner.

In a series of experiments which used *in vitro* stimulation of macrophages with crystalline silica and *in vivo* intranasal instillation of crystalline silica in mice, it was demonstrated that that the chronic fibrosis seen in a murine model of silicosis *in vivo* is dependent on the presence of adaptor molecule ASC and Nalp3 inflammazome. These data support a potential mode of action whereby silica triggers cellular responses that in turn activate alveolar macrophages, resulting in an inflammatory response and silicosis. In mice deficient in Nalp3 inflammazome, the development of inflammation and collagen deposition was significantly reduced compared with normal mice 3 months after the initial intranasal instillation of silica.

Analysis of Lung Tumour Data

The weight of evidence for both rats and humans indicates that fibrotic and silicotic lesions in the lung result from inhalation exposure to crystalline silica and that lung cancer is secondary to those lesions in the lung. Although the mechanism of induction for the lung tumours has not been fully elucidated, there is sufficient supportive mode of action evidence from the data presented to demonstrate that a threshold approach to risk assessment is appropriate based on an understanding of the key events in the pathogenesis of crystalline silica induced lung tumours. The body of evidence include the following:

- In experimental studies, all rats that developed tumours also showed fibrosis.
- Adenocarcinomas, the most common type of tumour identified in rats, are commonly associated with fibrosis and deeply scarred lung tissue.
- Experimental rat studies showed a clear progression of the effects from initially mild inflammation, followed by fibrosis over-time, leading eventually to lung tumours.
- Tumours are not present in all treated species dosed in the same way.
- The tumours, both in rats and humans, are concentrated in the lungs only, although other organs are indirectly exposed.
- In human studies, cancer risk is often more significant in workers exposed over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours.
- Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles
- Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis.
- For genotoxicity, in vitro results were mostly mixed and in vivo results were mostly positive. However, the vast majority of the positive genotoxicity assay results can be explained by the generation of reactive oxygen species, as demonstrated experimentally, where ROS scavenging prevents the genotoxicity.
- *In vivo*, macrophage deficient mice (macrophages produce ROS in response to crystalline silica) do not develop silicosis nor do they develop tumours and the Nalp3 inflammazome, a key player in the macrophage initiated inflammatory response, is required for the development of pulmonary fibrosis after

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inhalation of silica.

- Though inhalation exposure to crystalline silica in multiple occupational settings is clear, the increase in risk, based on the several recent meta-analyses of the multiple human epidemiological studies, remains low.

It is worth noting that where aggressive engineering controls have been made to reduce silica dust levels in the workplace (Sweden), silicosis has been eliminated. By corollary, existing exposures outside of the workplace in such areas do not pose a risk for silicosis to the general population.

The respirable forms of quartz and cristobalite possess properties indicating a hazard for human health (repeated dose toxicity, carcinogenicity and genotoxicity). The mode of action in the lungs involves irritation, inflammation and reactive species formation, leading to silicosis, and eventually to tumour formation.

Exposure

Uses

Consistent with oxygen and silicon being the two most abundant elements in the Earth's crust, silicon-oxide minerals, including quartz are ubiquitous in the natural environment. In particular, as a component of sand, quartz may find use in a diverse array of applications. Several high volume uses include, but are not limited to, the use of sand as a filling material for the construction of roads and in general building activities, the use of sand and gravel aggregates as abrasives on roads in winter and the use of fly-ash, which may contain 4-14% quartz and 0.5-1% cristobalite, as a cement additive. These abrasives when used on winter roads are usually mixed with road salts and may be sand only, stone dust, sand and gravel aggregates, or pre-treated sand. They are used mainly by rural municipalities or in areas where cold temperatures diminish the efficiency of salts for de-icing. Quantities of abrasives used in Canada were 5.73×10^9 kg, 4.59×10^9 kg, and 4.93×10^9 kg for 2007, 2008 and 2009, respectively.

Industrial sand, high purity silica sand products with closely controlled sizing are expected to contain quartz and cristobalite, include lump silica (2-3mm up to 15 cm or more), silica sand (75µm to 2-3mm) and silica flour (less than 75µm). Lump silica may be used in the production of silicon alloys, silica bricks, and the linings of certain types of pulverizers (eg. ball mills and tube mills).

Silica sand may be used in the manufacture of glass and glass fibres, silicate chemicals and silicon carbide, the hydraulic fracturing of wells, foundry moulding, and for sandblasting. Silica flour may find use in the ceramics and cement industries, as a filler and extender in rubber and coatings, and as an abrasive in soaps.

Natural clays, such as bentonite and fuller's earth, are used in cat litters for their high water absorbance capacities. Quartz is a natural component of these clays, and consequently, it may be present in cat litter products. High purity α-quartz is a piezoelectric material, which means that application of a voltage induces a distortion in the crystal shape and vice versa. This ability to interconvert electrical and mechanical energy has led to the use of quartz crystals in electronic devices requiring precise timing control, for example telephones, radios, watches and computers.

According to a survey conducted in Canada, quartz and cristobalite are also used in abrasives, adsorbents, filter products (diatomaceous earth), grout and cement. These substances reportedly also find use as fillers, which add bulk and improve wear resistance, in paints and coatings, adhesives, sealants, polymer films, caulking, epoxy resins and silicones. Also, quartz is listed as an ingredient in 60 cosmetic products in Canada. The types of products include anti-wrinkle preparation, eye and face makeup, lipstick, hair dyes, shampoos and grooming products, as well as skin cleansers, moisturizers and tanning preparations.

Natural Sources

In Canada, quartz naturally occurs in many types of rock formations. Those with high silicon dioxide content (95% SiO_2 or more) include vein and massive intrusion bodies, quartz pebbles, silica sand, sandstone and quartzite. Sandstone is a sedimentary rock mostly composed of quartz grains cemented by a bonding material such as clay, calcite or iron oxide. Quartzite is a hard, compact, metamorphosed sandstone made of grains of quartz firmly bonded with a siliceous cement. Mineral aggregates (e.g., sand and gravel) have variable silicon dioxide content. Quartz is also found as crystals, aggregates or discrete particles in certain igneous rocks (e.g., granites and pegmatites), soils, sediments, air and surface water. This omnipresence is consistent with the fact that silicon is the second most abundant chemical element on Earth.

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Cristobalite is naturally produced in the ashes of volcanic eruptions, and by combustion metamorphism which is a local phenomenon of spontaneous combustion of naturally occurring substances such as bituminous rocks, coal or oil. It may be found in cavities in volcanic rocks and in thermally metamorphosed sandstones and may also be a transient stage in the diagenesis of diatomaceous shale with the result that soils made of these geologic formations may be rich in cristobalite. Unlike quartz, the natural occurrence of cristobalite is limited to specific geographic regions and mineral types.

Anthropogenic Sources

Natural quartz is isolated from ore via beneficiation, which involves milling or grinding the material into particles that are separated into desired mineral and waste. The materials obtained are either used directly or further purified. In Canada, in 2006, 2.146×10^{9} kg of pure quartz were mined, and 2.385×10^{11} kg of sand and gravel aggregates were produced. The proportion of quartz in silica sand deposits and gravel aggregates will vary from one site to another.

Cristobalite can form from silica melts during the preparation of silica glass; quartz is not obtained from melts but is manufactured at elevated temperature and pressure via a hydrothermal process. Cristobalite also forms during the calcination[2] of diatomaceous earth.

Human Exposure Estimate

Ambient air

The exposure assessment is focussed on respirable quartz and cristobalite, which in ambient air comprises a component of total particulate matter (PM). In Canada, data on the concentrations of silicon in PM was available and used as a surrogate for quartz and cristobalite. This approach is conservative because the measured silicon includes all silicon-containing substances and therefore represents the upper limit for quartz and cristobalite in ambient air.

The National Air Pollution Surveillance (NAPS) Program measured concentrations in $\mu g/m^3$ of silicon in PM with aerodynamic radii less than 2.5 µm ($PM_{2.5}$ (dichot)), and from 2.5 to 10 µm (PM_{10} (dichot)) (the total particulate matter with aerodynamic radii less than 10 µm (PM_{10}) is obtained by adding these values) in Canada. In 2009, as part of the NAPS Program, silicon concentrations were determined on over 1600 samples of $PM_{2.5}$(dichot) and over 1500 samples of PM_{10}(dichot) at 24 urban locations across Canada. An estimate of exposure to quartz and cristobalite can be obtained by assuming that all the silicon in the PM is represented stoichiometrically as SiO_2, and multiplying the reported concentration of silicon by 2.14 to obtain a value for silica.

The intake of respirable quartz and cristobalite by the general population of Canada is estimated using a range covering the lowest 50^{th} percentile SiO_2 concentration in PM_{10}, measured in Pt. Petre, ON, (0.12 $\mu g/m^3$) to the highest 50^{th} percentile concentration in PM_{10} measured in Calgary, AB (2.1 $\mu g/m^3$). The 50^{th} percentile SiO_2 concentrations ranged from 0.1 to 2.1 $\mu g/m^3$ across the survey sites; the top of this range is quite close to the average of the maximum values for the 24 sites (3.7 $\mu g/m^3$). The outdoor data were used to represent the indoor levels, because information on indoor silicon concentrations was not available, and the range of PM_{10} measured indoors is generally lower than the outdoor range. Thus, this approach conservatively overestimates indoor exposure in homes.

The highest exposure group based on these calculations is children ages 0.5 to 4 years with an estimated daily intake ranging from 0.07 to 5.26 µg/kg-bw per day; the estimated daily intake decreases with age due to changes in the ratio of inhalation rates to body weights; the daily intake of adults, 20-59 years old, is estimated to range from 0.03 to 2.00 µg/kg-bw per day.

Consumer Products

Exposure to respirable quartz from the use of cosmetic products, which contained quartz as an ingredient, was considered low because they are not formulated for spray application, the loose powders were reported to contain less than 0.1% quartz, and in these products the substance is not expected to be associated with other components of the formulation and not available in a free form.

For consumer Do It Yourself (DIY) activities around the home, the highest mean breathing zone concentration of particles from sanding dry wall (median cut-point of 10µm) of 6.31 mg/m^3, was used to derive an upper-

[2] Calcinations: Heat treating a substance, but without fusion, to bring about change in its physical or chemical constitution.

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bound exposure estimate ranging from 2 to10 µg/kg-bw per event.

Quartz is used to formulate a large number of paints and coatings. To estimate potential inhalation exposure to quartz from these products, the spray painting of wall paints with an airless spray gun was considered appropriate as a conservative scenario. Exposure to respirable paint particles was estimated using data from controlled a laboratory study in which walls of poorly ventilated test rooms were painted by professional painters using an airless sprayer to apply interior latex paint. The maximum concentration of 13% quartz in paint in Canada was used to estimate exposure. The upper-bound estimate of exposure to quartz, based on the maximum concentration of 13% quartz in paint in the Canadian market and the maximum concentration of respirable paint particles measured in these controlled studies when recommended personal protective equipment is used, is 0.954 µg/kg-bw per event.

Inhalation of ambient air containing quartz and cristobalite is the dominant pathway of chronic exposure (excluding that from DIY activities) for the general population. Because SiO_2 makes up only approximately 5% of PM_{10}, silicon concentrations (expressed as SiO_2) measured in the Canadian NAPS survey of 24 urban locations were considered most relevant to the estimation of exposure by the general population. Quartz and cristobalite comprise only a portion of the total SiO_2 in PM_{10}, therefore, the use of the total silicon concentration to represent the upper bound crystalline silica concentrations results in an overestimation of exposure.

Appendix 1: Definitions of Epidemiological Terms in the ITAP

SMR (Standardized Mortality Ratio): The ratio (x 100) of observed to expected deaths in a study population. Expected deaths are calculated by applying a set of standard age-specific mortality rates to the age distribution of the study population. Standardized ratios are only useful for comparisons. They have no intrinsic meaning.

OR (Odds Ratio): In epidemiological case-control studies, a relative measure of disease occurrence. The odds in favour of a particular disease occurring in an exposed group are divided by the odds in favour of its occurring in an unexposed group. If the condition being studied is rare, the odds ratio is a close approximation to the relative risk.

RR (Risk Ratio): The probability of the occurrence of a disease in a group that has been exposed to some environmental, medicinal, microbial, or toxic influence, relative to its probability in a randomly selected population.

PMR (Proportionate Mortality Ratio): Proportionate mortality is the proportion of deaths in a specified population over a period of time attributable to different causes. Each cause is expressed as a percentage of all deaths, and the sum of the causes must add to 100%. These proportions are not mortality rates, since the denominator is all deaths, not the population in which the deaths occurred. Thus, proportionate mortality ratio is a measure of the frequency of occurrence of the proportionate mortality in a defined population during a specified interval of time.

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Toxicity Profile

Ethylene glycol
(CAS No. 107-21-1)

Ethylene glycol has been reviewed in the OECD-SIDS program (OECD, 2004a,b).

Toxicokinetics/Metabolism

Ethylene glycol is almost completely absorbed by laboratory animals via oral routes as would be expected from their total miscibility with water. In *in vivo* rodent dermal absorption studies, 1-51% of ethylene glycol was absorbed. Since ethylene glycol is completely soluble in water, it is expected to be well distributed throughout the aqueous tissues of the body with lower concentrations in adipose tissue. Uniform distribution has been demonstrated to a limited extent for ethylene glycol. The main metabolic pathway for metabolism of ethylene glycol is oxidation via alcohol dehydrogenases and aldehyde dehydrogenases. The main metabolites of ethylene glycol are carbon dioxide, oxalic acid and glycolic acid. Ethylene glycol may be directly eliminated by urinary excretion. Acid metabolites of ethylene glycol are also eliminated in urine and may also be metabolized to carbon dioxide and eliminated in exhaled breath.

Acute Toxicity

The oral LD_{50} values range from 589 to 13,400 mg/kg for rats (OECD, 2004b), 800 to 15,280 mg/kg for mice (OECD, 2004b), 661 to 11,000 mg/kg for guinea pigs (OECD, 2004b), and 5,000 mg/kg for rabbits (OECD, 2004b).

Irritation

Ethylene glycol was not irritating to rabbit skin (Guillot *et al.*, 1982), but there was some indication of irritation in a human primary irritation patch test (OECD, 2004b). It was not an eye irritant to rabbits (Guillot *et al.*, 1982).

Sensitization

Ethylene glycol was not a skin sensitizer to guinea pigs (Kurihara *et al.*, 1996).

Repeated Dose Toxicity (Oral Studies only)

Male and female Fischer 344 rats were given in their feed 0, 40, 200 or 1,000 mg/kg ethylene glycol for 24 months. At 1,000 mg/kg, the following effects were seen in males:

increased neutrophils, blood urea nitrogen, serum creatinine, urine volume, urine calcium oxalate crystals, water consumption rates, kidney weight (absolute and relative), mortality, mineralization of the heart, lungs, stomach, vas deferens and urinary system pathologic changes; decreased red blood cells, hematocrit, hemoglobin, serum glutamic pyruvic transaminase, mean corpuscular volume, urine specific gravity, urine pH, liver weight (absolute and relative), body weight gain, and life span. At the highest dose, the following effects were seen in females: increased mean corpuscular volume, urine specific gravity, urine calcium oxalate crystals, urine uric acid crystals, and kidney weight (absolute and relative); and decreased mean corpuscular hemoglobin concentration, urine pH, and urine volume. The NOAEL for this study is 200 mg/kg/day (DePass *et al.*, 1986a).

Male Wistar rats were given in their feed 0, 50, 150, 300 or 400 mg/kg ethylene glycol for one year. At the higher dose levels (300 and 400 mg/kg), the histopathological observations included basophilic foci of crystaluria-related nephropathy, renal tube dilation, bifringent crystals morphologically representative of calcium oxalate, dilation of the renal pelvis, and transitional cell hyperplasia in the renal pelvis or bladder. To determine renal effects, the severity of nephropathy in the kidney sections was graded on a scale of 0 to 5, with 0 representing no crystal nephropathy and 5 representing end-stage nephropathy indicative of impending renal failure. Ethylene glycol related nephropathy was not present in the kidney sections from the control group or the lower doses (50 and 150 mg/kg). In the 300 mg/kg group, severity grades ranged from 1 to 4 with the mode of occurring at 1 (minimal). In the 400 mg/kg group, severity grades ranged from 3 (moderate) to 5 (end-stage) with the mode at 4 (marked). The NOAEL for this study is 150 mg/kg/day (Wilson *et al.*, 2005).

Male Fischer 344 and Wistar rats were given in their feed 0, 150, 500 or 1,000 mg/kg ethylene glycol for 16 weeks. At 1000 mg/kg, the following effects were seen: mortality in Wistar strain (2/10) with prior clinical observations of emaciation and dermal atonia and macroscopic findings of changes in kidneys (pale, calculi) and small seminal vesicles in these animals; mean body weight losses, lower mean body weights and mean cumulative body weight changes in Wistar strain (weeks 2 – 16); lower mean food consumption in Wistar strain; higher mean water consumption in both F344 and Wistar strains; lower mean specific gravity and higher mean total urine volume in both F344 and Wistar strains; macroscopic findings of pale kidneys, presence of calculi, rough surface and dilated pelvis; higher mean absolute and relative kidney weights in both F344 and Wistar strains; renal macroscopic findings of crystal nephropathy in Wistar and F-344 rats, with more severe nephropathy in Wistar strain than in the F344 strain. At 500 mg/kg, the following effects were seen: lower mean body weights (study weeks 3, 6-8, and 10-12) and mean cumulative body weight changes in the Wistar strain throughout the study with slightly lower mean food consumption throughout the study; higher mean water consumption in the Wistar strain; lower mean urine specific gravity and higher mean total urine volume in the Wistar strain; macroscopic findings in the Wistar strain consisting of predominantly pale kidneys, presence of calculi, rough surface, and dilated pelvis; higher mean absolute and relative kidney weight in the Wistar strain; renal macroscopic findings of crystal nephropathy in Wistar and F-344 strains, with more

severe nephropathy in the Wistar strain than in the F344 strain. The NOAEL in both the F344 and Wistar rats is 150 mg/kg/day (Cruzan *et al.*, 2004).

Male and female Fischer 344 rats were given in their feed 0, 0.32, 0.63, 1.25, 2.5, or 5% ethylene glycol for 13 weeks. Mortality was seen in the 5% animals in males, but not in females. Mean weight gain was significantly decreased in the 2.5 and 5% males, while there was no significant differences in female rats. There was no apparent difference in feed consumption between both male and female rats and the control group. There was no significant change in right kidney weight (both sexes), but a significant increase was seen in the left kidney weight in the 2.5 and 5% dose groups (both sexes). Mean thymus ratio to terminal body weight was significantly decreased in the 5% males. Serum urea nitrogen levels were significantly increased in the 2.5 and 5% males, and significantly increased in the $\geq$0.32% females. For both sexes, creatinine levels were decreased in the 0.32% group and significantly increased in the 2.5 and 5% groups. Kidneys from the 2.5 and 5% male rats had rough, granular and/or pitted appearances. Nephrosis was seen only in the 5% females. Brains from the 5% male rats contained clusters of crystals. The NOAEL for this study is 1.25%, which was estimated to be 600 to 1,000 mg/kg/day (Melnick, 1984).

Male and female Sprague Dawley rats were given in their drinking water ethylene glycol for 90 days. The concentrations for females were 0, 0.5, 1.0, 2.0 or 4.0% (0, 597, 1,145, 3,087 or 5,744 mg/kg-day). The concentrations for males were 0, 0.25, 0.5, 1.0 or 2.0% (0, 205, 407, 947 or 3,134 mg/kg-day). Mortality was seen only at the highest dose level for both males and females. Decreased body weights were seen in the highest dosed males. Only males showed any significant changes in organ weights. Kidney weights were significantly increased in the 1% and 2% males, which heart, liver, and lung were significantly decreased in the 2% males. There was also a significant increase in the ratio to body weight for the brain and gonads of the males in the highest dose group. Leukocyte levels were significantly decreased in the 0.5, 2 and 4% females, but not in males. LDH, creatinine, ALT, calcium and glucose were significantly different in the 1% males, and phosphorus, BUN, and creatinine in the 2% males. There were significant increases in phosphorus in the 1% females and glucose in the 0.5 and 4% females. Kidney lesions were seen in the $\geq$2% females and in the $\geq$1% males. Lesions were more prominent in males than in females. Renal changes consisted of tubular dilation, tubular degeneration, acute inflammation, birefringent crystals in tubules and pelvic epithelium. The NOAEL for this study is 407 mg/kg-day for males. The LOAEL for females is 597 mg/kg/day; a NOAEL was not established (Robinson *et al.*, 1990).

Male and female Sprague-Dawley rats were given in their feed 0, 0.1, 0.2, 0.5, 1.0 or 4.0% ethylene glycol for two years. There was significant reduction in growth in the 4% males after week 16, and in the 1% males after week 70. The 4% females did not gain any weight past the first year of the study. Water consumption was double that of the controls in the 4% males that initiated soon after the start of the study. The 1% males had significant increases in water consumption after 6 months and some increase was observed in the 0.5% males. Females only showed increased water consumption in the 4% group. There was 100% mortality in the 1 and 4% males, while mortality of

additional dose levels were below that of the controls. There was 100% mortality in the 4% females, while the 1% females were similar to the controls; the 0.1, 0.2 and 0.5% females were increased compared to the controls. Since the 1 and 4% males and the 4% females all died before the study termination date, there are no data for these groups on terminal organ weight. For males, the terminal organ weights were decreased in all dose levels compared to the controls. For females, the organ weights were similar to the controls. The 1 and 4% males and females had kidneys with stones and crystals. The NOAEL for this study is 0.2% (data was insufficient to calculate the dose) (Blood, 1965).

Male and female B6C3F_1 mice were given in their feed 0, 0.32, 0.63, 1.25, 2.5, or 5.0% ethylene glycol for 13 weeks. There was no mortality for either male or female mice at any dose level. No clear dose-related effect was seen in mean weight gain, and there was no clear evidence of decreased feed consumption. There was no significant change in organ/body weight ratio for either sex for any dose level. Serum urea nitrogen and creatinine levels were unaffected. Kidney lesions were observed in half of the male mice in the 5% dose level and one mouse in the 2.5% dose level. Lesions were tubular dilation, cytoplasmic vacuolization, and regenerative hyperplasia. There was no evidence of crystal formation in the tubules. No kidney effects were seen in the female mice. Degenerative change was present in the livers of all male mice in the 2.5 and 5% dose levels. The NOAEL for this study is 1.25%, which was estimated to be 600 to 1,000 mg/kg/day (Melnick, 1984).

Male and female B6C3F_1 mice were given in their feed 0, 6,250 ppm (males only), 12,500 and 25,000 ppm (males and females) or 50,000 ppm (females only) for 103 weeks. These concentrations are approximately equivalent to 0, 1,500, 3,000, 6,000 or 12,000 mg/kg-day. There was no statistically significant difference in survival between dosed and control groups. Mean body weight and food consumption of mice administered ethylene glycol were generally similar to those of controls throughout the study. No chemical-related clinical findings were observed. Liver lesions (in male mice) and arterial hyperplasia (in females) were observed at 12,500 ppm, but no adverse effects were observed at 6250 ppm. The NOAEL for this study is 1,500 mg/kg/day (NTP, 1993).

Genotoxicity

Mutagenicity studies in bacteria and *in vitro* mutagenicity studies in mammalian cells have been uniformly negative (OECD, 2004a,b). The results of *in vitro assays* of ethylene glycol for chromosomal aberrations (CHO chromosomal aberration and sister chromatid exchange assays) have also been uniformly negative (OECD, 2004a,b).

Ethylene glycol was equivocal when tested in an *in vivo* mouse bone marrow micronucleus study (Conan *et al*., 1979). There were some findings of statistically significant increases in micronuclei, but no dose-related trends and potential confounding due to toxicity (lethality) at high doses. Ethylene glycol did not increase the incidence of chromosomal aberrations in mice *in vivo* (Conan *et al*., 1979). An *in vivo* rodent

dominant lethal mutagenesis assay conducted at doses up to 1,000 mg/kg in Fischer 344 rats was negative (DePass *et al*., 1986b).

Carcinogenicity

Male and female B6C3F_1 mice were given in their feed 0, 6,250 ppm (males only), 12,500 and 25,000 ppm (males and females) or 50,000 ppm (females only). These concentrations were approximately equivalent to 0, 1,500, 3,000, 6,000 or 12,000 mg/kg-day. Body weights, survival, and incidence of tumors were similar between treated and control mice (NTP, 1993).

Reproductive Toxicity

Ethylene glycol has been assessed by the Reproductive Assessment by Continuous Breeding (RACB) protocol in which parental mice received chemical via drinking water during pre-mating exposure, cohabitation, pregnancy, and lactation. The F_1 generation received prenatal exposure via maternal exposure during gestation, with the exposure continuing during lactation, weaning, and mating of F_1 animals and production of an F_2 litter. The doses were 0, 0.25, 0.5 or 1% ethylene glycol, which corresponded to approximately 0, 410, 840 or 1,640 mg/kg/day. No adverse effects were noted in the parental animals at doses up to 1%. There was a small, but statistically significant, effects on the numbers of litters per fertile pair, the number of live pups per litter, and live pup weight in the 1% dose group. Neither the 0.25 nor 0.5% dose groups were significantly affected. The number of live pups per litter was lower in the treated group, but differences were not statistically significant. Unusual facial features (*i.e.*, shorter snout and wide-set eye) and skeletal defects (shortened frontal, nasal, and parietal bones; fused ribs abnormally shaped or missing sternebrae, abnormally shaped vertebrae; and twisting of the spine at 1%) were noted on some of the offspring of the treated mice, but not in the controls. The parental NOAEL is 1% (approximately 1,640 mg/kg/day), and the NOAEL for reproductive toxicity is 0.5% (approximately 840 mg/kg/day (Lamb *et al*., 1985).

In a three-generation reproductive toxicity study, Fischer 344 rats were given in their diet 0, 40, 200 or 1,000 mg/kg/day ethylene glycol. There were no treatment-related effects on clinical signs of toxicity or survival in the parental animals. There were no significant effects on fertility index, gestation index, gestation survival for all three generations. Mean pup weights in the all three generations were similar between treated and control animals. The NOAELs for parental and reproductive toxicity are 1,000 mg/kg/day (DePass *et al.*, 1986b).

Developmental Toxicity (Oral and Dermal Studies only)

Pregnant Sprague-Dawley rats were dosed by oral gavage with 0, 50, 150, 500, 1,000 or 2,500 mg/kg ethylene glycol during gestational days (GD) 6-15. Maternal toxicity was

observed in the 2,500 mg/kg group and consisted of significantly decreased body weights, increased water consumption, decreased uterine weights, increased kidney weights, and increased relative liver weights. At 500 mg/kg, there were developmental effects, which included reduced fetal body weights, extra or missing ribs, missing arches, and poor ossification in thoracic and lumbar centra. In the 2500 mg/kg group, in addition to skeletal malformations, there was gastroschisis, hydrocephaly, lateral ventricle dilated (tissue depressed), umbilical hernia, and atelectasis. The NOAELs for maternal and developmental toxicity are 1,000 and 500 mg/kg/day, respectively (Neeper-Bradley *et al.*, 1995).

Pregnant CD rats were dosed by oral gavage with 0, 1,250 2,500 or 5,000 mg/kg ethylene glycol during GD 6-15. In the $\geq$2,500 mg/kg groups, the dams had increased relative kidney weights, decreased gravid uterine weight, and increased water consumption. Maternal body weight gain was significantly decreased in the 1,250 mg/kg group. Live litter size was significantly decreased in the 5,000 mg/kg group, and fetal body weights were decreased in the 1,250 and 5,000 mg/kg groups. Litters with malformed fetuses were observed in the $\geq$1,250 mg/kg groups. The LOAELs for maternal and developmental toxicity are 1,250 mg/kg/day; NOAELs were not established (Price *et al.*, 1985).

Pregnant Fischer 344 rats were given by oral gavage 0, 40, 200 or 1,000 mg/kg ethylene glycol during GD 6-15. No maternal toxicity was observed at any dose level. There were no significant effects on preimplantation loss, fetal length, fetal weight, total implantations or litter size. There was an increased incidence of skeletal alterations in the 1,000 mg/kg group, which consisted of poorly ossified and unossified vertebral centra. No significant increases in the incidence of major malformations were observed. The NOAELs for maternal and developmental toxicity are 1,000 and 400 mg/kg/day (Maronpot *et al.*, 1983).

Pregnant CD-1 mice were dosed by oral gavage with 0, 50, 150, 500 or 1,500 mg/kg ethylene glycol during gestational days (GD) 6 to 15. There was no maternal toxicity. At 1,500 mg/kg, there were reduced fetal body weights, fused ribs and arches, poor ossification in thoracic and lumbar centra, and increased occurrence of an extra 14^{th} rib. At 500 mg/kg, there was slight reductions in fetal body weight and increased incidences of extra ribs. The NOAELs for maternal and developmental toxicity were 1,500 and 150 mg/kg/day, respectively (Neeper-Bradley et al., 1995).

Pregnant CD-1 mice were dosed by oral gavage with 0, 750, 1,500 or 3,000 mg/kg ethylene glycol during GD 6 to 15. There was a significant decrease in maternal gain, gravid uterine weights, and liver weights in the 1,500 mg/kg group. A decreased number of implantation sites per litter was observed in the 1,500 mg/kg group. Significant decrease in liver litter size was observed in the 3,000 mg/kg group and decreased fetal body weights were seen at $\geq$750 mg/kg. Litters with a significant increase in malformed fetuses were observed in the $\geq$750 mg/kg groups. There was a significant dose-related increase in postimplantation loss per litter, though there were no significant pairwise comparisons. The NOAEL for maternal toxicity is 750 mg/kg/day;. The LOAEL for

developmental toxicity is 750 mg/kg/day; the NOAEL was not established (Price *et al.*, 1985).

In a short-term reproductive and developmental toxicity screen test, male and female Swiss Crl:CD-1 mice were allowed to mate over a three-day period. The males were dosed by oral gavage from study day 3 to study day 20. The Group A females were exposed throughout the 21-day test period; the Group B females were exposed during GD 8-14. The doses were 0, 250, 700 or 2,500 mg/kg ethylene glycol. The Group A females were sacrificed after 19 days of treatment, and the Group B females were allowed to litter and rear to postnatal day (PND) 4. There was no maternal or paternal toxicity. The 2,500 mg/kg females in Group A had significantly fewer liver implants and more dead implants. The 2,500 mg/kg in Group B had significantly lower total litter weights on PND 1 and 4. The NOAELs for parental and developmental toxicity are 2,500 and 700 mg/kg/day (Harris *et al.*, 1992).

In a Chernoff/Kavlock assay, pregnant CD-1 mice were dosed by oral gavage with 0 or 11,090 mg/kg ethylene glycol during GD 7-14. The females were allowed to litter and rear to PND 3. Ten percent of the maternal animals died. The number of surviving pups per litter (40% survived), birth weight and pup weight gain were reduced. The LOAELs for maternal and developmental toxicity are 11,090 mg/kg; NOAELs were not established (Schuler *et al.*, 1984; Hardin *et al.*, 1987).

Pregnant CD-1 mice were administered by dermal application 0, 400, 1,677 or 3,549 mg/kg ethylene glycol during GD 6-15. There was minimal, if any, treatment-related maternal toxicity. Copora lutea, total implants, percentage of live fetuses per litter, fetal body weights, and incidence of external or visceral malformations were unaffected by treatment. There was, however, a significant increase in two skeletal variations in the 3,549 mg/kg group. The NOAELs for maternal and developmental toxicity were considered to be 3,549 mg/kg/day (Tyl *et al.*, 1995).

Key Study/Critical Effect for Screening Criteria

The available data show that repeated oral exposures to ethylene glycol causes primarily kidney toxicity; is also a reproductive and developmental toxicant in rodents when administered at high doses by oral gavage. Rats develop kidney toxicity at substantially lower doses than mice. Among rats, there are differences in the susceptibility of strains towards developing kidney toxicity from ethylene glycol exposure. The renal toxicity of dietary ethylene glycol to rats was clearly related to oxalic acid levels in the kidney, which explained strain differences (Corley *et al.*, 2002). In animals chronically exposed to ethylene glycol histopathologically-detectable kidney damage is believed to be related to oxalate crystals (crystal nephropathy). No adverse chronic renal effects from ethylene glycol dosing were seen in animals exposed below 150 mg/kg/day. The oral RfD for ethylene glycol is thus based on the NOAEL of 150 mg/kg/day from the one-year rat feeding study by Wilson *et al.* (2005).

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD = 150/100 = 1.5 mg/kg/day

Drinking water guideline value = 5.3 ppm

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Toxicity Profile

Guar Gum
(CAS No. 9000-30-0)

Guar gum (CAS No. 9000-30-0) is the milled endosperm of the leguminous plant *Cyanopsis tetragonolobus*. Structurally, it is a galactomannan consisting of a main chain of D-mannose with a side chain of D-galactose at approximately every second mannose unit. The mannose units are β-(l-4) linked, and the single D-galactose units are joined to the main chain by α-(1-6) linkages. The estimated molecular weight of guar gum cranges from 200,000 to 300,000 daltons (Glickman, 1969).

Guar gum is approved for use as a food additive by the U.S. Food and Drug Administration and is on the list of substances "generally recognized as safe" (CFR 1974).

Acute Toxicity

The oral LD_{50} is 8,100 mg/kg for mice and 9,400 mg/kg for rats (Bailey and Morgareidge, 1948).

Irritation

No data were found.

Sensitization

There are reports of respiratory sensitization in workers exposed occupationally to guar gum dusts (Maio, 1986).

Repeat Dose Toxicity Studies

F344 rats and B6C3F_1 mice were given diets containing 0, 6,300, 12,500, 25,000, 50,000 or 100,000 ppm guar gum for 13 weeks (NTP, 1982). Mean body weights were decreased in male rats (100,000 ppm group) and in female mice (50,000 and 100,000 ppm). A dose-related decrease in feed consumption was observed for male and female rats; male and female mice were comparable or higher than that of controls. There were no compound-related clinical signs or histopathological effects.

F344 rats and B6C3F_1 mice were given diets containing 0, 25,000 ppm or 50,000 ppm guar gum for 103 weeks (NTP, 1982). Mean body weights of the high-dose females were

lower than those of the controls after week 20 for mice and week 40 for rats. No compound-related clinical signs or adverse effects on survival were observed. Feed consumption by dosed rats and mice of either sex was lower than that of controls. There were no non-neoplastic histopathological effects in either rats or mice that were treatment-related.

Genotoxicity

Guar gum was not mutagenic to *Salmonella typhimurium* TA 1530 or G-46 when tested without metabolic activation; however, it was mutagenic to *Saccharomyces cerevisiae* D-3 (Green, 1977). Guar gum also was reported to cause chromosomal aberrations in human embryonic lung cells WI-38 (Green, 1977). No *in vivo* genotoxicity studies have been conducted on guar gum.

Carcinogenicity

F344 rats and B6C3F_1 mice were given diets containing 0, 25,000 ppm or 50,000 ppm guar gum for 103 weeks (NTP, 1982). There were increased incidences of adenomas of the pituitary in male rats and pheochromocytomas of the adrenal in female rats that were statistically significant, but these differences were considered to be unrelated to guar gum administration. When pituitary adenomas or carcinomas and when pheochromocytomas or malignant pheochromocytomas are combined, the statistical differences disappear. Hepatocellular carcinomas occurred in treated male mice at incidences that were significantly lower than that in controls. The combined incidence of male mice with either hepatocellular adenomas or carcinomas was also significantly lower in the high-dose group. It was concluded that under conditions of this bioassay, guar gum was not carcinogenic for F344 rats or B6C3F_1 mice.

Reproductive Toxicity

No data were found.

Developmental Toxicity

Female rabbits were given daily (6 hours/day) dermal administration of 0, 2, 10 and 50 mg/kg guar gum during gestational days 6 through 18 (IRDC, 1988). Mortalities included 2 deaths at 50 mg/kg and 1 death at 10 mg/kg. A single animal was killed in extremis. A dose-related increase in dermal irritation (including erythema, edema, and desquamation) was observed in animals receiving 10 and 50 mg/kg. The number of early resorptions was significantly increased and the number of viable fetuses was correspondingly decreased at 50 mg/kg/day ($p<0.05$). The frequency of fetal malformations and variations in the treated groups was comparable to that of the control

group at all dose levels. The NOEL for this study is 2 mg/kg/day.

Key Study/Critical Effect for Screening Criteria

The key studies for the determination of a drinking water guidance value is the NTP two-year chronic bioassays. The LOAELs are based on decreased mean body weights in female mice and rats fed 50,000 ppm guar gum in diet for 103 weeks. The NOAELs for these studies are 25,000 ppm guar gum.

Rat: NOAEL (mg/kg/day) = 25,000 ppm * 0.05 = 1,250 mg/kg/day

Mouse: NOAEL (mg/kg/day) = 25,000 ppm * 0.13 = 3,250 mg/kg/day

Where 0.05 and 0.13 are the fraction of body weight that rats and mice, respectively, consume per day as food (U.S. EPA).

The lowest NOAEL of 1,250 mg/kg/day for the rat will be used to derive a drinking water guidance value.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD = 1,250/100 = 12.5 mg/kg/day

Drinking water guideline = 44 ppm

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Toxicity Profile

Hemicellulase
(CAS No. 9025-56-3)

Hemicellulases are a group of enzymes that break down hemicellulose, which are polysaccharides that are present in cell walls of all terrestrial plants. These polysaccharides have a β-(1→4)-linked backbone and are composed of pentoses (xylose, arabinoses), hexoses (mannose, glucose, galactose), and sugar acids. Unlike cellulose which are polysaccharides consisting of linear chains of several hundred to over ten thousand β-(1→4) linked D-glucoses, hemicelluloses are not chemically homogeneous. The best characterized hemicellulases are the 1,4- β -D-xylanases and, in particular, those derived from fungal sources presumably because their substrates, xylans, constitute the largest proportion of hemicelluloses in pasture plants.

No toxicity information could be located on hemicellulases; however, mammalian toxicity information were found on the cellulase enzymes (HERA, 2005). Cellulases cleave the ß-1,4-glycosidic bonds in cellulose, and are used in the pulp and paper industry, the textile industry, and in detergents to remove deposits and stains.

Enzymes are catalytic proteins or polypeptides and consist of amino acid residues coupled via peptide bonds. They are primarily characterized by their biocatalytic or enzymatic activity. There is a broad range of detergent cellulases used both from fungal as well as from bacterial origin; all are characterized by ß-1,4-endoglucanase activity. For the purposes of risk assessment, the structure of hemicellulases would be expected to be similar to that of cellulases, given that hemicellulases and cellulases are both enzyme families that hydrolyze polysaccharides, although differing in their substrates. Thus, the toxicity data on cellulases will be used as read-across to hemicellulases.

Acute Toxicity

The oral LD_{50} of a cellulase enzyme was calculated to be 8,000 mg/kg for mice and >10,000 mg/kg for rats (HERA, 2005). The inhalation LC_{50} of the same cellulase enzyme in rats was >3.48 mg/L. The mass mean diameter was 7.8 μm with a geometric standard deviation of 2.1 μm (HERA, 2005).

Irritation

Cellulase enzymes are mild to non-irritating to the skin and eyes of rabbits (HERA, 2005). However, the irritation potential is dependent on the amount of protease contamination in the enzyme test preparation, particularly with regards to eye irritation.

Sensitization

A cellulase enzyme was not a skin sensitizer to guinea pigs (HERA, 2005).

Repeated Dose Toxicity

Male and female rats were dosed by oral gavage with 0, 300, 1,000 or 3,000 mg/kg of a cellulase enzyme for 4 weeks. There were no treatment-related clinical signs, but a slight dose-related increase in body weight gain (approx. 7%) was seen in the males. No treatment-related changes were noted in the hematology or clinical chemistry. There were no gross or histopathologic changes that were considered treatment-related (HERA, 2005).

Male and female rats were given in their feed concentrations of 0, 120, 600 or 3,000 mg/kg of a cellulase enzyme for 13 weeks. There were no treatment-related clinical signs. A reduction in body weight gain was seen in both sexes at the 3,000 mg/kg level (10% in males and 20% in females). A slight reduction in food consumption was also noted for the 3,000 mg/kg rats. Alkaline phosphatase was increased in the 600 and 3,000 mg/kg females in a dose-dependent manner. There were no gross or histopathologic changes that were considered treatment-related. The NOAEL for this study is 600 mg/kg/day (HERA, 2005).

Genotoxicity

In an *in vitro* bacterial mutation assay, a cellulase enzyme was not mutagenic to *Salmonella typhimurium* strains TA 1535, TA 100, TA 1537 and TA98 in the presence or absence of metabolic activation. In an *in vivo* bone marrow micronucleus assay, a cellulase enzyme was not genotoxic when given to rats by oral gavage (HERA, 2005).

Carcinogenicity

No data were found.

Reproductive Toxicity

No data were found.

Developmental Toxicity

No data were found.

Key Study/Critical Effect for Screening Criteria

In a 13-week dietary study, there was reduced body weight gain in rats given 3,000 mg/kg of a cellulase enzyme. No other adverse effects were observed. The NOAEL for this study is 600 mg/kg-day.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (subchronic to chronic)

Oral RfD = 600/1000 = 0.6 mg/kg-day

Drinking water guideline = 2 ppm

Reference

Human and Environmental Risk Assessment (HERA) on Ingredients of Household Cleaning Products: α-amylase, CAS No. 9000-90-2; Cellulase (β-(1,4)-glucanase), CAS No. 9012-54-8; Lipase, 9001-62-1, 2005. http://www.heraproject.com

Toxicity Profile

Maltodextrin
(CAS No. 9050-36-6)

Maltodextrin is a nonsweet nutritive saccharide polymer that consists of D-glucose unites linked primarily by $\alpha,1\rightarrow4$ bonds and that has a dextrose equivalent (D.E.) of <20. Typical commercial maltodextrins contain as few as three and as many as nineteen linked dextrose units. It is prepared as a white powder or concentrated solution by partial hydrolysis of corn starch, potato starch, or rice starch with safe and suitable acids and enzymes.

Maltodextrin is considered to be a biopolymer that is broken down in the gastrointestinal tract to its monomeric units and absorbed. The corresponding monomers are found naturally in the body. Thus, maltodextrin is expected to be safe to human health.

The U.S. FDA lists maltodextrin as GRAS (Generally Recognized as Safe).

No toxicity data could be found on maltodextrin and therefore no oral reference dose or drinking water standard was determined.

References

http://www.sugar.org/other-sweeteners/other-caloric-sweeteners.html#maltodextrin

Toxicity Profile

Polyethylene Glycol
(CAS No. 25322-68-3)

Polyethylene glycols (PEGs) are water-soluble linear polymers formed by the addition reaction of ethylene oxide to an ethylene glycol equivalent. The general formula for polyethylene glycol is: $H-(OCH_2CH_2)_n-OH$ where "n" is the average number of repeating oxyethylene groups. PEGs are available in average molecular weights ranging from 200 to 8000.

Toxicity data are available on PEG 200. PEG 200 is a mixture consisting of ethylene glycols with an average molecular weight of approximately 200; there is an average of 4 oxyethylene units, but the range is from 2 to 8 oxyethylene units. The approximate composition of PEG 200 is as follows: 3% diethylene glycol, 17% triethylene glycol, 29% tetraethylene glycol, 25% pentaethylene glycol, 16% hexaethylene glycol, 8% heptaethylene glycol, and 2% octaethylene glycol (Bailey and Koleske, 1966).

Toxicity data on the two primary constituents of PEG 200, tetraethylene glycol (tetraEG) and pentaethylene glycol (pentaEG), have also been included in this toxicity profile.

Acute Toxicity

The oral LD_{50} in rats was reported to range from 25,700 to 32,500 mg/kg (OECD, 2004) and 28,130 mg/kg (OECD, 2004). The dermal LD_{50} in rabbits ranges from 14,000 to 20,000 (OECD, 2004). No deaths were reported in rats exposed to an aerosol of 2,516 mg/m^3 PEG 200 for 6 hours (OECD, 2004).

Irritation

TetraEG was minimally irritating to human skin (OECD, 2004). PentaEG produced minor transient irritation to rabbit skin (OECD, 2004). Both tetraEG and pentaEG produced minimal transient irritation to the eyes of rabbits (OECD, 2004).

Sensitization

TetraEG was not a skin sensitizer to guinea pigs or to humans (OECD, 2004).

Repeated Dose Toxicity

No toxicity was seen in rats given 1,880 mg/kg/day PEG 200 in feed, the highest dose tested, for two years (OECD, 2004).

Genotoxicity

PEG 200 produced chromosomal aberrations *in vitro* (Biondi *et al.*, 2002). *In vivo*, the mixture was associated with significant elevations producing a dose-dependent trend for chromosome aberrations, but only in males at a single time point (12 hour harvest) in an otherwise negative two-sex, multi-time point rat bone marrow assay (OECD, 2004).

PEG 200 also contains diethylene glycol DEG), triethylene glycol (TEG), tetraEG and pentaEG; all have been tested for genotoxicity. PEG 200 also contains several glycols of higher molecular weights, which have not been assessed for mutagenicity.

Mutagenicity studies in bacteria and *in vitro* mutagenicity studies in mammalian cells have been conducted for DEG and TEG and the results have been uniformly negative (OECD, 2004). The results of *in vitro assays* of EG and DEG for chromosomal aberrations (CHO chromosomal aberration and sister chromatid exchange assays) have also been uniformly negative (OECD, 2004). DEG and TEG have not been tested *in vivo* for genotoxicity.

TetraEG has been found to cause chromosome aberrations *in vitro* (OECD, 2004); however, three assays for chromosome levels effects *in vivo* have been either negative or equivocal. These *in vivo* studies include a negative rat dominant lethal test; a negative rat bone marrow chromosome aberration test; and an equivocal mouse peripheral blood micronucleus assay (OECD, 2004). A more recent statistical reanalysis of the rat chromosome aberration study (White and Douglas, 2003; OECD, 2004) judged the overall result to be equivocal because of a marginal association and dose related trends for either sex but at different harvest times, and a significant effect of treatment limited to the lowest doses in females at the 24 hour harvest and males at the 12 hour harvest. However, inspection of the overall data from this assay show these two values to be isolated to the lowest exposure animals and the dose effect trends to be inverse, i.e. decreasing with increasing doses without evidence of cytotoxicity from treatments. The reason for the equivocal designation for the tetraEG mouse micronucleus test was a weak statistically significant increase in MN-PCE in males only at a single time point and without a dose-response.

PentaEG was not mutagenic in the Ames test or in mammalian cells *in vitro* in the CHO/HGPRT assay (OECD, 2004). A mouse bone marrow micronucleus test of crude pentaEG (70% pentaEG, 19% tetraEG) was assessed as negative by the original investigators but deemed to be equivocal after statistical reanalysis (White and Douglas, 2003; OECD, 2004) using non-parametric contingency table analyses and trend tests. However, inspection of the primary data reveals that this reanalysis was influenced by a single uncharacteristically low MN control value in one sex (females) at a single time point, indicating that the test result is biologically negative.

Carcinogenicity

There was no evidence of carcinogenicity when rats were given 1,880 mg/kg/day PEG 200 in feed for two years (OECD, 2004).

Reproductive Toxicity

Repeat dosing with tetraEG at doses up to 6,386 mg/kg-day for 14 days or 2,000 mg/kg/day for 4 weeks produced no notable changes in the histopathology of the testes and epididymides of rats (OECD, 2004).

Developmental Toxicity

No developmental effects were seen in rats dosed orally up to 10,000 mg/kg/day PEG 200 (OECD, 2004).

Key Study/Critical Effect for Screening Criteria

No toxicity was seen in rats given 1,880 mg/kg-day PEG 200 in feed, the highest dose tested, for two years (OECD, 2004). The NOAEL for this study is 1,880 mg/kg/day.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD: 1880/100 = 19 mg/kg/day

Drinking water guideline value = 66 ppm

References

Bailey, F.E., Jr., and Koleske, J.V. (1966). Chapter 23. Configuration and hydrodynamic properties of the polyoxyethylene chain in solution. In: Nonionic Surfactants. Edited by M.J. Schick, Marcel Dekker, Inc., New York.

Biondi, O., Motta, S., and Mosesso, P. (2002). Low molecular weight polyethylene glycol induced chromosome aberrations in Chinese hamster cells cultured *in vitro*. Mutagenesis 17: 261-264.

OECD (2004). SIDS Initial Assessment Report on the Ethylene Glycol Category: Ethylene Glycol (CAS No. 107-21-1), Diethylene Glycol (CAS No. 111-46-6), Triethylene Glycol (CAS No. 112-27-6), Tetraethylene Glycol (CAS No. 112-60-7), Pentaethylene glycol (CAS No. 4792-15-8).

Toxicity Profile

Sodium hydroxide
(CAS No. 1310-73-2)

Sodium hydroxide (NaOH) has been reviewed in the OECD-SIDS program (OECD, 2002a,b).

Sodium hydroxide (NaOH) is present in the environment as sodium (Na^+) and hydroxyl ions (OH^-). Sodium is a normal constituent of the blood and an excess is excreted in the urine. A significant amount of sodium is taken up via the food because the normal uptake of sodium via food is 3.1-6.0 g per day according to Fodor *et al.* (1999). Exposure to NaOH could potentially increase the pH of the blood. However, the pH of the blood is regulated between narrow ranges to maintain homeostasis (pH of 7.4 to 7.5) by urinary excretion of bicarbonate and via exhalation of carbon dioxide.

Acute Toxicity

An oral LD_{50} of a 1-10% solution of NaOH in rabbits was reported to be 325 mg/kg (expressed as 100% NaOH). Mortality was also observed when 1% NaOH was dosed, but in this case, the applied volume was relatively high (24 mL per kg body weight).

Irritation

A NaOH solution of 8% can be considered corrosive based on animal data. Human data indicate that concentrations of 0.5 to 4% were irritating. In two different studies a concentration of 0.5% was irritating for only 55 and 61% of the volunteers, respectively. Thus, it is assumed that a concentration, which is slightly lower than 0.5%, is the non-irritating concentration.

The available animal data on eye irritation showed that the non-irritant level was 0.2-1.0 %, while the corrosive concentration was 1.2 % or >2%.

Sensitization

Male volunteers were exposed on the back to sodium hydroxide concentrations of 0.063 – 1.0% (induction). After 7 days the volunteers were challenged to a concentration of 0.125%. The irritant response correlated well with the concentration of NaOH, but an increased response was not observed when the previously patch tested sites were re-challenged. Based on this study sodium hydroxide has no skin sensitization potential.

Repeated Dose Toxicity

No animal data are available on repeated dose toxicity studies by oral, dermal, inhalation or by other routes for NaOH. It is not useful to study the repeated dose toxicity of hydroxide via an oral study because at high concentrations the substance is corrosive or irritating, while at low concentrations the hydroxide will be neutralized in the stomach by gastric juice, which has a very low pH.

Genotoxicity

Both the *in vitro* and the *in vivo* genotoxicity tests are negative.

Carcinogenicity

No carcinogenicity studies on sodium hydroxide were identified.

Reproductive Toxicity

No valid studies were identified regarding toxicity to reproduction in animals after oral, dermal or inhalation exposure to NaOH. It is not useful to study the reproduction/developmental toxicity of hydroxide via an oral study because at high concentrations the substance is corrosive or irritating, while at low concentrations the hydroxide will be neutralized in the stomach by gastric juice, which has a very low pH.

Developmental Toxicity

No valid studies were identified regarding developmental toxicity in animals after oral, dermal or inhalation exposure to NaOH. It is not useful to study the reproduction/developmental toxicity of hydroxide via an oral study because at high concentrations the substance is corrosive or irritating, while at low concentrations the hydroxide will be neutralized in the stomach by gastric juice, which has a very low pH.

Key Study/Critical Effect for Screening Criteria

The Australian drinking water guideline value for pH may apply to sodium hydroxide.

Reference

OECD (2002). IUCLID Data Set for Sodium hydroxide (CAS No. 1310-73-2), UNEP Publications.

OECD (2002). Screening Information Dataset (SIDS) Initial Assessment Report for Sodium hydroxide (CAS No. 1310-73-2), UNEP Publications.

Toxicity Profile

Tetrakis(hydroxymethyl)phosphonium sulfate
(CAS No. 55566-30-8)

Toxicity information is provided on tetrakis(hydroxymethyl)phosphonium sulfate (THPS) and its structural analog tetrakis(hydroxymethyl)phosphonium chloride (THPC)

Metabolism

A metabolism study on rats has been conducted using ^{14}C-radiolabelled THPS. THPS was not found in rat urine. However, three metabolites were present, identified as trihydroxymethyl phosphine oxide, bishydroxymethylphosphonic acid and possibly a formaldehyde adduct of the trihydroxy compound (IPCS, 2000).

Acute Toxicity

No female mice died when given an oral dose of 200 mg/kg THPS (IPCS, 2000). The oral LD_{50} value of THPC (as a 75% solution) was reported to be 282 mg/kg in male rats; 575 mg/kg in male and female rats combined; 185 mg/kg in male rats; and 161 mg/kg in female rats (IPCS, 2000).

No deaths occurred when rats were treated with THPS at 2,000 mg/kg (IPCS, 2000).

The 4-hour LC_{50} in rats was 5.5 mg/L when exposed nose-only to a respirable aerosol (IPCS, 2000).

Irritation

THPS was not irritating to the skin of rabbits; however, repeated application resulted in severe skin irritation (IPCS, 2000). THPS is a severe eye irritant in rabbits (IPCS, 2000).

Sensitization

THPS is a skin sensitizer to guinea-pigs (IPCS, 2000).

Repeat Dose Toxicity

In a 13-week NTP oral gavage study, male and female F344/N rats were given 0, 5, 10, 20, 40 or 60 mg/kg THPS five days/week. Death occurred in the 60 mg/kg male rats (3/10) prior to the end of the study; all other rats survived to the end of the studies. Final mean body weights were 5%, 15%, and 22% lower than those of the vehicle controls for

males that received 20,40,or 60 mg/kg, and from 7% to 19% lower for all groups of dosed female rats. Diarrhea occurred in all groups of dosed rats during weeks 3 and 4. Vacuolar degeneration of the hepatocytes occurred in all males receiving $\geq$10 mg/kg, in all females receiving 40 or 60 mg/kg, and in 5/10 females receiving 20 mg/kg. The severity of this lesion was greatest in the 60 mg/kg group. In other groups, the severity was generally minimal to mild. Lymphoid depletion in the spleen or thymus was observed in the three males in the 60 mg/kg group which died before the end of the studies. Bone marrow hypoplasia was diagnosed in 3/10 male and 4/10 female rats in the 60 mg/kg groups.

In a 13-week NTP oral gavage study, male and female B6C3F$_1$ mice were given 0, 5, 10, 20, 40 or 60 mg/kg THPS 5 days/week. Females (1/10) that received 60 mg/kg and 2/10 males and 1/10 females that received 40 mg/kg died before the end of the studies. Final mean body weights of mice that received 20, 40, or 60 mg/kg were 4%, 7%, and 11% lower than those of the vehicle controls for males and 3%, *5%*, and 11% lower for females. Periportal vacuolar degeneration occurred in all mice that received 60 mg/kg (minimal to moderate severity), 10/l0 male and 9/10 female mice that received 40 mg/kg, and 8/10 male mice that received 20 mg/kg (minimal to mild severity).

In the 2-yr NTP study, male and female F344/N rats were given by oral gavage 0, 5, or 10 mg/kg THPS, 5 days/week for 103 to 104 weeks. Survival of male rats was reduced for the low dose (after week 102) and the high dose (after week 67) groups given THPS compared with that of the vehicle controls; survival at terminal kill was as follows: vehicle control, 28/50; low dose, 13/50; high dose, 16/50. Mean body weights of rats dosed with THPS were comparable to those of the vehicle controls. There was an increase in the incidence of hepatocellular lesions, primarily cytoplasmic vacuolization, which was dose-related. The incidence of these lesions were: in males, 2/50, 4/50, 9/49, at 0, 5, 10 mg/kg; in females, 1/49, 3/50, 8/49 at 0, 5, and 10 mg/kg. The incidences of mononuclear cell leukemia in 5 mg/kg male rats was somewhat greater than those in the vehicle controls (THPS: 30/50; 36/50; 20/50). This marginal increase in the incidences of hematopoietic system tumors was not considered related to chemical exposure, since they were significant only by the life table tests and were not dose related. The incidence of cystic degeneration of the liver was also increased in male rats (7/50, 15/50, and 14/49 at 0, 5, and 10 mg/kg). The LOAEL for this study is 5 mg/kg with no NOAEL.

In the 2-yr NTP study, male and female B6C3F$_1$ mice were given by oral gavage 0, 5, or 10 mg/kg THPS, 5 days/week for 103 to 104 weeks. There was no difference in survival or mean body weights between the vehicle controls and mice dosed with THPS. There was an increase in the incidence of hepatocellular lesions, primarily cytoplasmic vacuolization in female mice only, but it was not dose-related. The incidences of this lesion were: in males, 0/48, 1/49, 0/50 at 0, 5, and 10 mg/kg; in females, 6/50, 13/50, and 7/49 at 0, 5, and 10 mg/kg. The LOAEL for this study was 5 mg/kg, with no NOAEL.

There was also focal hyperplasia of the adrenal medulla in the 10 mg/kg male mice. The 5 mg/kg male mice had an increased incidence of malignant lymphomas when compared with vehicle controls (2/50; 9/50; 0/50). This marginal increase in the incidences of

hematopoietic system tumors was not considered related to chemical exposure, since they were significant only by the life table tests and were not dose related.

Genotoxicity

Salmonella microsomal assays in the presence or absence of metabolic activation have shown uniformly negative results for THPS (IPCS, 2000). THPS induced forward mutations in mouse lymphoma L5178Y cells without metabolic activation; it was not tested in the presence of S9 (NTP, 1987). Another mouse lymphoma assay showed mutations both in the presence and absence of metabolic activation (IPCS, 2000).

Increased chromosomal aberrations were detected at metaphase in CHO cells treated with THPS in the presence or absence of S9 from liver of Aroclor-treated rats (IPCS, 2000). Anaphase analysis of THPS-treated CHO cells also showed that chromosomal aberrations were produced along with abnormal spindles (IPCS, 2000).

The results of an *in vitro* assay for unscheduled DNA synthesis in a primary culture of rat hepatocytes were negative (IPCS, 2000).

THPS was administered to mice by gavage or dermal application or by mixing treated cloth with the animals' feed. The urine of these dosed mice was analyzed for mutagenicity in the Salmonella microsome assay, and frequencies of micronuclei and chromosomal aberrations were evaluated in bone marrow cells. None of these investigations demonstrated mutagenic activity for THPS (NTP, 1987; IPCS, 2000).

THPS was negative in rats and mice in dominant lethal assays (IPCS, 2000).

Carcinogenicity

Two-year NTP studies have been conducted in F344/N rats and $B6C3F_1$ mice by administering 0, 5, or 10 mg/kg THPS by oral gavage, 5 days per week for 103 or 104 weeks (NTP, 1987). The incidences of mononuclear cell leukemia in the low dose male rats administered THPS was somewhat greater than those in the vehicle controls. Low dose male mice administered THPS had an increased incidence of malignant lymphomas when compared with vehicle controls (2/50; 9/50; 0/50). These marginal increases in the incidences of hematopoietic system tumors were not considered related to chemical exposure, since they were significant only by the life table tests and were not dose-related.

Reproductive/Developmental Toxicity

Pregnant CD rats were given by oral gavage 0, 15, 30 or 60 mg/kg THPS (as a 75% solution) during gestational days 6 to 15. Maternal body weight gain was significantly lower from gestational day 12 until the end of the study in the 60 mg/kg group. There

were minor signs of maternal toxicity in the 30 mg/kg group. The incidence of fetuses showing extra thoraco-lumbar ribs was significantly higher in the 60 mg/kg group compared to controls. The maternal and developmental NOAELs for this study were 30 mg/kg-day (IPCS, 2000).

Pregnant New Zealand rabbits were given by oral gavage 0, 6, 18 or 60 mg/kg THPS (as a 75% solution) during gestational days 7 to 19. Maternal body weight gain was significantly lower in the 60 mg/kg group compared to the controls. There was increased incidence (42/120) of fetuses with eye malformation and some with additional hydrocephaly or limb/phalangeal reduction defects in the 60 mg/kg group. An increased incidence of specific skeleton variation was also observed. No adverse effects were noticed in the 6 or 18 mg/kg groups. The maternal and developmental NOAELs for this study is 18 mg/kg-day (IPCS, 2000).

Key Study/Critical Effect for Screening Criteria

The critical effect for a drinking water guideline value is liver effects in male and female rats and female mice at 5 mg/kg/day in the two-year study. To adjust for continuous exposure, the LOAEL is adjusted by converting 5 days/week to 7 days/week.

$LOAEL_{adjusted}$ = 5 * 5/7 = 3.6 mg/kg/day

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (LOAEL to NOAEL)

Oral RfD = 4/1,000 = 0.004 mg/kg/day

Drinking water guideline: 0.01 ppm

References

IPCS (2000). Flame Retardants: Tris(2-butoxyethyl)phosphate, Tris (2-ethylhexyl) phosphate and tetrakis (hydroxymethyl)phosphonium Salts, Environmental Health Criteria 218, International Programme on Chemical Safety, United Nations Environment Programme, International Labour Organisation, World Health Organization.

NTP (1987) NTP Technical Report on the Toxicology and Carcinogenesis Studies of Tetrakis(hydroxymethyl)phosphonium sulfate (THPS) (CAS No. 55566-30-8) and Tetrakis(hydroxymethyl)phosphonium chloride (THPSC) (CAS No. 124-64-1) in F344/N Rats and B6C3F1 mice (Gavage Studies), NTP TR 296, NIH Publication No. 87-2552, National Toxicology Program, U.S. Department of Health and Human Services, Public Health Service, National Institutes of Health.

Santos

APPENDIX F.6 SCHLUMBERGER YF120FLEX WITH J318 SYSTEM

Toxicity Profile

Reaction mass of 5-chloro-2-methyl-4-isothiazolin-3-one and 2-methyl-2H-isothiazolin-3-one [3:1]
(CAS No. 55965-84-9)

5-Chloro-2-methyl-4-isothiazol-3-one (CMI) and 2-methyl-2H-isothiazolin-3-one (MI) combined formulations are marketed under several trade names, such as Kathon CG, Kathon 886, Kathon WT, Kathon 886, Acticide LG, Acticide 14 L, Acticide 14P, Microcare IT, Microcare ITL etc.

Acute Toxicity

The oral LD_{50} of Kathon WT (1.5% a.i.) is >5,000 mg/kg (>75 mg a.i./kg) in male rats and >3,310 mg/kg (~49.6 mg a.i./kg) in female rats. The oral LD_{50} of Acticide 14 (14% a.i.) is 472-490 mg/kg (~66 to 69 mg a.i./kg) in rats (combined sexes); and 465 mg/kg (69 mg a.i./kg) in male rats and 393 mg/kg (59 mg a.i./kg) in female rats.

The dermal LD_{50} of Kathon CG is >5,000 mg/kg (>75 mg a.i./kg) in female rabbits. The dermal LD_{50} of Acticide 14 (14% a.i.) is 1,008 mg/kg (141 mg a.i./kg) in rats (combined sexes).

The inhalation LC_{50} of Kathon 886F (13.9% a.i.) in male and female rats is 2.36 mg/L (0.33 mg a.i./L).

Irritation

Undiluted Kathon MW (1.5% a.i.) and Acticide 14 (14% a.i.) were corrosive to rabbit skin. Undiluted Kathon CG was severely irritating to the eyes of rabbits. Kathon RH 886T at 100 ppm (0.01% a.i.) was non-irritating to the eyes of rabbits.

Sensitization

CMI/MI has been tested in the guinea pig Buehler and Magnusson-Kligman tests and has been shown to be a strong skin sensitizer. It is also a strong contact allergen in humans.

Repeat Dose Toxicity

Rats were exposed to CMI/MI in a powdered commercial diet. CMI/MI concentrations were increased over the 13-week period (initial concentration up to week 2, intermediate concentration week 3-4, final concentration week 5 to 13). Concentrations in the control and CMI/MI groups were: 0/0/0, 40/57/80, 132/187/260, 400/570/800 ppm. There were no mortalities and no effects on body weight or food consumption. In each group, some animals showed slight alopecia or reddened raw or

scabbed areas on the skin. There were no other differences in general behavior or appearance. There were no treatment-related changes in hematological, biochemical, urinary parameters nor any pathology. No systemic toxicity was observed up to and including the highest dose of either CMI/MI (800 ppm, equivalent 29.1 mg a.i./kg-day). The NOAEL in this study is 800 ppm (29.1 mg a.i. /kg-day).

Rats were exposed to CMI/MI via their drinking water at concentrations of 25, 75 or 225 ppm a.i. for three months (equivalent to an average intake of 2.38, 6.28 and 16.3 mg/kg/day in males and 4.06, 10.8, and 24.7 mg/kg-day in females). Two additional groups of rats were given tap water or tap water containing the inorganic ions present in the CMI/MI solution, at a concentration equal to that in the high dose group (225 ppm). This solution is referred to as the ion control solution. There were no mortalities in either sex at any dose level. There were no treatment-related effects on body weight up to the mid dose. A significant decrease in body weight was seen in males at the high dose during the first two weeks of the study. Food consumption was significantly decreased in males at all dose levels and in females mid and high dose groups during the first few weeks of dosing. Water consumption was significantly decreased at all concentrations. No overt clinical signs or ophthalmic were seen in any group throughout the 13 week toxicity or the reproductive phase. No adverse effects were seen in the examinations. No hematological treatment-related changes were seen in either sex at any dose level. There was a significant decrease in globulin and an increase in the albumin/globulin (A/G) ratio in males in both the high concentration and in the ion control groups, after 13 weeks of treatment. A significant decrease in total protein was also seen high concentration group, but was not seen in the ion control group. Females in the high concentration group showed a modest (40%) increase in SGOT (AST, aspartate aminotransferase) levels after 13 weeks of dosing. No changes were observed at any dose in mixed-function oxidase activities of the liver. At the end of 13 weeks of treatment, there was a significant increase in relative liver weight in males and in relative kidney weight in females at the high concentration but without any correlative changes in organ pathology. Histology revealed a local irritation of the glandular mucosa of the stomach in 7 of 15 males and 5 of 15 females at the high concentration. These subtle low level changes did not occur at the low or mid concentration nor were they present in either control group. No other compound related changes were seen. Reproductive organs at all doses were comparable to the control. The NOEL in this study was considered to be 75 ppm a.i. (equivalent to 6.28 and 10.8 mg/kg-day in males and females, respectively), based primarily on irritation of the glandular stomach at the high dose. The No Observed Adverse Effect Level (NOAEL) is 225 ppm a.i. (equivalent to 16.3 and 24.7 mg/kg-day in males and females, respectively), the highest dose tested, since no adverse effects were observed on the histopathology of any tissues or organs distant from the site of dosing.

Genotoxicity

The results of the *in vitro* mutagenicity tests were equivocal. In bacterial reverse mutation tests, CMI/MI was positive in *Salmonella* strain TA100 but was predominantly negative in other strains commonly tested strains. CMI/MI was

mutagenic in the mouse lymphoma assay with and without metabolic activation. Effects at the Tk locus was seen both with and without S-9, but were enhanced with S9 mix. CMI/MI was not genotoxic in the *in vitro* unscheduled DNA synthesis (UDS) assay with primary rat hepatocytes or in an *in vitro* chromosomal aberration test with Chinese hamster lung cells.

The *in vivo* studies indicated that CMI/MI does not have relevant mutagenic potential *in vivo*. The positive mutagenic effect of CMI/MI found in *in vitro* gene mutation assays was not confirmed in the sex-linked recessive lethal test in *Drosophila melanogaster* nor in two unscheduled DNA synthesis (UDS) studies in the rat. CMI/MI also did not show any increase in cells with micronuclei in mice nor did it induce chromosomal aberrations in rat bone marrow cells.

Carcinogenicity

In a two-year rat drinking water study, Kathon 886 is given as 14.2% active ingredient with a pH between 2-3. In the document with compiled batch information for Kathon, the active ingredient is 13.2, [10.13 % CMI/ 3.85% MI] with 15.4% magnesium nitrate and 9.0% magnesium chloride. The dose levels were 0, 30, 100 and 300 ppm (equivalent to: 0, 2.0, 6.6, 17.2 mg a.i./kg-day in males and 0, 3.1, 9.8, 25.7 mg a.i./kg-day in females. There were no deaths. There were no treatment-related effects on body weight or body weight gain at doses or food consumption up to and including the mid dose group. A treatment-related and concentration-dependent decrease in water consumption was seen in both sexes in all treated groups throughout the study. These decreases ranged from 0-22% at low dose 3-30% at mid dose and 15-40% at high dose. These decreases appear to be due to the unpalatability of the CMI/MI and not its inorganic stabilizer salts since the water consumption in the salt control was comparable to the tap water control throughout the study. Based on the average daily water consumption, the high dose was judged to be a maximum tolerated dose. The decreases in body weight and body weight gain were seen in high dose animals throughout the study and may be secondary to decreased water consumption. No treatment-related clinical effects were recorded. No treatment-related ophthalmic, hematological. biochemical or urinary changes were noted. Organ weights were comparable to the control. No effects on type or incidence of neoplasms were seen at up to and including the high dose (males: 17.2 a.i.; females 25.7 mg a.i./kg/day). Slight to moderate forestomach hyperplasia was seen at both mid and high dose groups. Gastric irritation was the primary effect observed. No adverse effects on the histopathology of any other tissues/organs were observed away from the site of dosing. No systemic effects were observed. The NOEL in this study was considered to be 30 ppm a.i. (2.0 to 3.1 mg a.i./kg-day), based primarily on gastric irritation of the stomach at 100 and 300 ppm a.i.. The NOAEL was considered to be 300 ppm a.i. (17.2 to 25.7 mg/a.i./kg-day), since no evidence of systemic toxicity was observed at any dose and there was no adverse effects on the histopathology of any tissues/organs distant from the site of dosing at any dose.

Reproductive/Developmental Toxicity

A one-generation reproductive toxicity study was combined with the 13-week

drinking water study reported above in the repeated dose toxicity section. Reproductive capability was similar in all groups. Litter size and survival at birth was also similar in all groups. One dam at the high concentration lost the entire litter by day 4 due to a lactation problem. This is not uncommon and was not considered treatment related. Pups of the other high concentration group dams, except one, survived and thrived to day 21. Thus, no adverse effects were observed on reproductive capability of male and female rats and no effects were observed on fetal health or pup survival (to day 21) up to and including the high dose (equivalent to 16.3 and 24.7 mg/kg-day in males and females, respectively].

In a two-generation reproductive toxicity study, rats were dosed with CMI/MI (Kathon 886F: 11.1% CMI, 3.7% MI a.i.) at concentrations of 0 (control), 0 (magnesium salt control), 30, 100 or 300 ppm a.i. For the P_1 generation, this was equivalent to 0, 2.8-4.4; 8.5-11.8, and 22.7-28.0 mg a.i./kg-day; and in the P_2 generation 0, 4.3-5.5, 13.4-16.0, and 35.7-39.1 mg a.i./kg-day. There were no treatment related effects on survival, food consumption or overt signs of toxicity. A decrease in bodyweight gain was noted initially in the P_1 generation. This was thought to be linked to reduced water consumption since significant dose-related reduction in water consumption was seen at all concentrations in both the P_1 and P_2 generations, during the premating, gestation and lactation stages. Treatment-related histopathological changes were seen in the stomach in the P_1 and P_2 generation. These included erosions of the glandular mucosa, edema and inflammation in the submucosa of the glandular and nonglandular stomach, with hyperplasia and hyperkeratosis of the nonglandular stomach at the 100 and 300 ppm a.i. Other histopathological changes were seen but were not dose dependent.The estrus cycle in P_1 or P_2 females at any treatment level was comparable with the controls, as was the sperm motility, morphology, testicular sperm count or caudal epididymal reserves of P_1 or P_2 males. All other endpoints (gestation index, gestation length, number of pups per litter or treatment-related gross findings in F_1 or F_2 pups) were similar to those in the controls in either generation. The study authors considered that rats exposed to CMI/MI in the drinking water through two generations had a NOAEL of 30 ppm a.i. (2.8-4.4 mg/kg-day in the P_1 animals; 4.3-5.5 mg/kg-day in the P_2 animals) for parental animal toxicity, based on the gastric irritation of stomach at higher doses. The NOEL for reproductive toxicity is 300 ppm a.i. (22.7-28.0 mg/kg-day in the P_1 animals; 35.7-39.1 mg/kg-day in the P_2 animals), the highest dose tested. There were no effects on fertility or fetal development at any dose level.

In a rat oral gavage developmental toxicity study on Kathon 886 (13.9% a.i.), the developmental NOEL for CMI/MI is >15 mg a.i./kg-day during organogenesis (highest dose tested). In a rat oral gavage developmental toxicity study on Acticide 14 (10.2% CMi/ 4% MI), the NOAEL for maternal toxicity is <3.95 mg a.i./kg-day; the NOAEL for teratogenicity is >19.6 mg a.i./kg-day; and the NOAEL for embryotoxicity is >19.6 mg a.i./kg-day. In a rabbit oral gavage developmental toxicity study on Acticide 14 (10.2% CMI/ 4% MI), the developmental NOAEL is >5.49 mg a.i./kg-day; the NOAELs for maternal toxicity and fetal toxicity are 1.41 mg a.i./kg-day. In a rabbit oral gavage developmental toxicity study on Kathon MW (13.9% a.i.), the NOEL for maternal toxicity is 2 mg a.i./kg-day; the developmental NOEL is 8 mg a.i./kg-day, the highest dose based on severe maternal toxicity at 20 mg a.i./kg.

Key Study/Critical Effect for Screening Criteria

A two-year drinking water study was conducted in rats with CMI/MI (13.2% active ingredient). No systemic effects were observed. There was, however, gastric irritation of the stomach at 100 and 300 ppm. The NOEL for this study is 30 ppm (equivalent to 2.0 and 3.1 mg a.i./kg-day for males and females, respectively). The NOEL of 2.0 mg/kg-day will be used to derive an oral RfD and a drinking water guidance value.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral Reference Dose = 2/100 = 0.02 mg/kg-day

Drinking water guidance value = 0.07 ppm

Reference

EU SCCS (2009). Opinion on the mixture of 5-chloro-2-methyl-4-isothiazolin-3-one and 2-methyl-2H-isothiazol-3-one [3:1], Colipa Nº P56, Scientific Committee on Consumer Safety, SCCS/1238/09.

Toxicity Profile

Amorphous/Non-crystalline Silica
(CAS No. 7631-86-9[1])

Silica Gel
(CAS No. 112926-00-8)

Amorphous silica and silica gel have been reviewed in the OECD-SIDS program (OECD, 2004a,b).

The CAS No. 7631-86-9 is the general CAS No. for silicon dioxide which includes all forms of silicas (*e.g.* also crystalline and natural forms). Only the silica sub-classes, the synthetic amorphous silicas, are the subject of this assessment.

Synthetic amorphous silicas (SAS) are in powder form which have a low water solubility: ≤70 mg/L

Toxicokinetics

After oral ingestion, there is no accumulation of SAS in body tissues. Rapid elimination occurs after the end of exposure. Intestinal resorption appears to be insignificant in animals and humans.

After daily oral administration of 1,500 mg/kg SAS (FK 700) as aqueous suspension to rats for one month, there was no accumulation of SiO_2 in the body: the average SiO_2 content was: 1.5 µg in the liver, 6.4 µg in the kidney, and 5.3 µg in the spleen. The corresponding control values were 1.8, 7.2 and 7.8 µg SiO_2, respectively.

In a similar experiment in rats receiving 20 daily oral doses of 100 mg SAS (HDK V15) per animal (about 500 mg/kg) each, tissue values were slightly increased in liver and kidney: in liver 4.2 µg (control value 1.8 µg), in the spleen 5.5 µg (7.2 µg) and in the kidneys 14.2 µg (7.8 µg).

In 12 human volunteers, no significant increased renal excretion of SiO_2 was found following single oral ingestion of 2,500 mg (AEROSIL 175 and FK 700).

Acute Toxicity

The acute oral administration of various forms of SAS (aqueous suspension or gel) failed to produce signs of toxicity or deaths in treated animals with LD_{50} values greater than the top doses applied, either by gavage: >3100 to >20000 mg/kg in mice and rats; or in the diet for 24 hours.

Irritation

Synthetic amorphous silicas are not irritating to the skin of rabbits exposed to 0.19 g (one case) or 0.5 g of dry or moistened test item under occlusive conditions for 4 or 24 hours. All products tested as a powder (0.1 g) have shown no or only weak and transient irritating effects on the conjunctivae of the eyes of rabbits with the iris and cornea not affected at all.

Sensitization

No experimental data are available on the synthetic amorphous silicas. Medical surveillance records on workers gave no evidence of skin sensitization over decades of practical experience.

Repeated Dose Toxicity/Carcinogenicity

Fischer rats and B6C3F$_1$ mice were administered SAS in the diet at levels of 0, 1.25, 2.5, and 5% for 102 weeks. The animals were in good condition throughout and showed high survival. The tumor responses in all organs of SAS-fed rats and mice were not statistically significantly different from the controls. The NOAEL for rats and mice were 2,500 and 6,500 mg/kg-day, respectively.

Genotoxicity

There is no evidence for synthetic amorphous silica to induce mutations either *in vitro* or *in vivo* using standard genotoxicity tests.

Reproductive Toxicity

An early limited one-generation study on rats gave no evidence of adverse effects on reproduction performance at 500 mg/kg-day, the highest dose tested (NOAEL). But the reliability is poor due to the small group size of animals.

Developmental Toxicity

SAS was examined for embryotoxic and developmental effects during the gestation phase in various animals species, rat, mouse, rabbit and hamster, at oral doses up to 1,600 mg/kg-day. There were no significant signs of maternal or embryotoxic/developmental toxic effects in any species tested. The number of abnormalities seen in either soft or skeletal tissues of the test groups did not differ from the frequencies occurring spontaneously in the control animals.

Key Study/Critical Effect for Screening Criteria

The lowest NOAEL from the two-year dietary study was 2,500 mg/kg-day for rats.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD = 2,500/100 = 2.5 mg/kg-day

Drinking water guidance value = 0.09 ppm

References

OECD (2004a). IUCLID Data Set for Synthetic Amorphous Silica and Silicates: Silicon Dioxide (CAS No. 7631-86-9, 112945-52-5, 112926-00-8; Silicic Acid, Aluminum Sodium Salt (CAS No. 1344-00-9); Silicic Acid, Calcium Salt (CAS No. 1344-95-2), UNEP Publications.

OECD (2004b). Screening Information Dataset (SIDS) Initial Assessment Report for Synthetic Amorphous Silica and Silicates: Silicon Dioxide (CAS No. 7631-86-9, 112945-52-5, 112926-00-8; Silicic Acid, Aluminum Sodium Salt (CAS No. 1344-00-9); Silicic Acid, Calcium Salt (CAS No. 1344-95-2), UNEP Publications.

Toxicity Profile

Choline chloride
Cholinium chloride
(CAS No. 67-48-1)

Choline chloride, also known as cholinium chloride, is a quaternary amine salt. It dissociates in water into the corresponding positively charged quaternary hydroxyl alkylammonium ion and the negatively charged chloride ion.

Choline chloride has been reviewed in the OECD-SIDS program (OECD, 2004).

Acute Toxicity

The oral LD_{50} in rats was reported to be between 3,150 and 5,000 mg/kg (BASF AG, 1963a, 1969).

Irritation

Application of a 70% aqueous solution to the skin of rabbits for 20 hours under occlusive conditions resulted in only minor skin irritation (BASF AG, 1963b). Slight eye irritation was seen in the eyes of rabbits after instillation of a 70% aqueous solution of choline chloride; no effects were seen one day after exposure (BASF AG, 1963c).

Sensitization

No data are available in animals. In a Human Repeated Insult Patch Test, there was no evidence of dermal sensitization in two hundred subjects given 0.5% (w/v) aqueous solution of choline chloride during the induction phase and 0.2% (w/v) aqueous solution during the challenge phase (Colgate-Palmolive, 2003).

Repeated Dose Toxicity

A 72-week feeding study was conducted to investigate the impact of choline chloride on the liver tumor promoting activity of phenobarbital and DDT in diethylnitroamine-initiated Fischer 344 rats (Shivapurkar *et al.*, 1986). Animals received approximately 500 mg/kg-day choline chloride. Following the end of the exposure period, the animals were kept on the same untreated diet as the control group until study termination at week 103. Histopathology was limited to the liver and organs that developed gross abnormalities. There were no significant differences between treated and control animals on survival rates, body weights, and relative liver weights. Neither was there any increased number of neoplastic liver nodules, hepatocellular carcinomas, lung tumors, leukemia or other tumors between treated and control animals. The NOAEL for choline chloride in this study is 500 mg/kg-day.

In humans, oral administration of 10,000 mg/day choline chloride in a pilot study treating a small number of patients with Alzheimer's disease resulted in a slight hypotensive effect (Boyd *et al.*, 1977). This dose was regarded as a LOAEL by the U.S. Institute of Medicine (IOM) Standing Committee on the Scientific Evaluation of Dietary Reference Intake (2000).

Genotoxicity

Choline chloride was not mutagenic to bacteria in reverse mutation assays (Haworth *et al.*, 1984; JETOC, 1997; Litton Bionetics, 1977).

A small, but statistically significant, and dose-related increase in sister chromatid exchanges (SCEs) in Chinese Hamster Ovary (CHO) cells was reported at 50 and 500 μg/ml choline chloride in the absence of S9 only (Bloom *et al.*, 1982). No higher concentrations were examined. These results could not be confirmed in another study using CHO cells at concentrations of choline chloride up to 5,000 μg/ml. (Galloway *et al.*, 1985).

In a gene conversion assay with *Saccharomyces cerevisiae* strain D4, choline chloride was negative in the presence and absence of metabolic activation (Litton Bionetics, 1977).

No *in vivo* genotoxicity studies are available.

Carcinogenicity

No studies were located.

Reproductive Toxicity

No reliable studies have been conducted that address female fertility or reproductive toxicity by a relevant route of exposure.

Developmental Toxicity

Pregnant female mice were given in their feed 1,250 to 20,000 mg/kg choline chloride during gestational days 1 to 18 (BASF AG, 1966). Maternal body weight gain was reduced in all treated groups except for the 1,250 mg/kg group. Determination of maternal weight gain of dams with embryonic/fetal absorptions showed that there was no net weight gain at $\geq$4,160 mg/kg, but there was net weight loss in the 20,000 mg/kg group. All fetuses were resorbed in the 20,000 mg/kg group. Embryonic/fetal lethality of 35% and 69% were seen in the 4,160 and 10,800 mg/kg groups, respectively. No resorptions occurred in the 1,250 mg/kg group. Developmental toxicity was seen in all but the 1,250 mg/kg group. No statistically significant

increases in malformations were observed in any dose group. The NOAELs for maternal and developmental toxicity is 1,250 mg/kg-day.

Key Study/Critical Effect for Screening Criteria

The Standing Committee on the Scientific Evaluation of Dietary Reference Intakes selected hypotension as the critical effect from the study by Boyd *et al.* (1977) when deriving a Tolerable Upper Intake Level. Boyd *et al.* (1977) reported a LOAEL of 10,000 mg/day choline chloride (7,500 mg/day choline). An uncertainty factor of 2 was chosen because of the limited data regarding hypotension and the inter-individual variation in response to cholinergic effects. Thus, the value for the Tolerable Upper Intake Value for repeated exposure of adults to choline is 3,500 mg/day choline.

The oral RfD for choline chloride is derived by using the LOAEL of 10,000 mg/day from the Boyd *et al.* (1977) study, which is divided by an uncertainty factor of 2, to obtain a value of 3,500 mg choline/day or 50 mg choline/kg-day for a 70 kg person.

Oral RfD = 50 mg/kg-day

Drinking water guideline value = 175 ppm

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Standing Committee on the Scientific Evaluation of Dietary Reference Intake. Institute of Medicine (2000). Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline. National Academy Press, Washington D.C.

Toxicity Profile

Crystalline Silica, Cristobalite
(CAS No 14464-46-1)

Crystalline Silica, Quartz
(CAS No. 14808-60-7)

Silica is an off-white granule that occurs naturally in various crystalline and amorphous or other non-crystalline forms. Crystalline silica is characterized by silicon dioxide (SiO_2) molecules oriented in fixed, periodic patterns to form stable crystals. The primary crystalline form of silica is quartz. Other crystalline forms of silica include cristobalite, tripoli and tridymite. Particle size is a key determinate of silica toxicity, since toxicity is restricted to particles that are small enough to be deposited into the target regions of the respiratory tract.

Oral Exposure

No oral studies were located; however, crystalline silica is not expected to exhibit toxicity by the oral route. Although absorption studies were not found for crystalline silica, kinetic studies on amorphous silica show no absorption from the gastrointestinal tract.

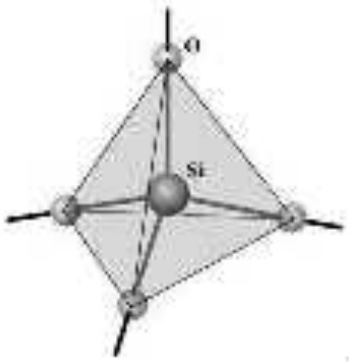
Dermal Exposure

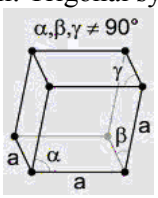
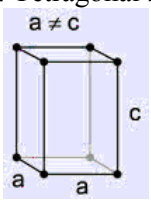
No dermal studies were located; however, crystalline silica is not expected to exhibit toxicity by the dermal route.

Inhalation Exposure

See attached OECD-SIDS Initial Targeted Assessment Profile on Quartz and Cristobalite, SIAM 32, 19-21 April 2011.

INITIAL TARGETED ASSESSMENT PROFILE (Human Health)

CAS No.	Quartz: CAS RN 14808-60-7 Cristobalite: CAS RN 14464-46-1
Chemical Name	Quartz and Cristobalite
Structural Formula	Molecular Formula: SiO_2 

Unit Cell: Trigonal symmetry	Unit Cell: Tetragonal symmetry
	
Quartz: CAS RN 14808-60-7	Cristobalite: CAS RN 14464-46-1

SUMMARY CONCLUSIONS OF THE TARGETED ASSESSMENT

NOTE: The present assessment is targeted to address the following human health endpoints: repeated dose toxicity and carcinogenicity via the inhalation route of exposure, and genotoxicity. It cannot be considered as a full SIDS Initial Assessment. Summary information on exposure is also reported here. Other endpoints for human health and the environment included in the Canadian screening assessment but have not been presented to OECD member countries, and thus are not included in this profile.

The final screening assessment will be published under the responsibility of the Government of Canada.

Rationale for Targeting the Assessment

The Government of Canada "categorized" or prioritized all 23,000 chemical substances on its Domestic Substances List (DSL) from 1999 to September 2006, as required by its *Canadian Environmental Protection Act, 1999* (CEPA 1999). Additional details may be found at http://www.chemicalsubstanceschimiques.gc.ca/about-apropos/categor/index-eng.php. Using information from Canadian industry, academic research and other countries, Government of Canada scientists applied a set of rigorous tools to the 23,000 chemical substances on the DSL. They were categorized to identify those that were: **inherently toxic** to humans or to the environment and that might be **persistent** and/or **bioaccumulative**; and substances to which people might have **greatest potential for exposure**. During this priority-setting exercise, distinct approaches were taken for identifying substances of likely concern for human health and the environment, and subsequent assessment activities may have focused on either human health or ecological endpoints. Through categorization, the Government of Canada has identified approximately 4,000 of the 23,000

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chemical substances on the DSL as priorities for further assessment, research and/or measures to control their use or release. Quartz and cristobalite were identified at that time, applying the categorization criteria, as high priorities for human health risk because they were considered to pose greatest potential for exposure and their respirable forms are classified by the International Agency for Research on Cancer as carcinogenic to humans (quartz and cristobalite) and by the National Toxicology Program as known human carcinogens (crystalline silica). These substances did not meet the ecological categorization criteria for bioaccumulation potential or inherent toxicity to aquatic organisms.

Under the Canadian legislation a determination of whether one or more of the criteria of the CANADIAN ENVIRONMENTAL PROTECTION ACT (CEPA) 1999, section 64 are met is based upon an assessment of potential risks to the environment and/or to human health associated with exposures in the general environment. For humans, this includes, but is not limited to, exposures from ambient and indoor air, drinking water, foodstuffs, and the use of consumer products. A conclusion under CEPA 1999 on the substances in the Chemicals Management Plan (CMP) Challenge is not relevant to, nor does it preclude, an assessment against the hazard criteria specified in the Controlled Products Regulations, which is part of the regulatory framework for the Workplace Hazardous Materials Information System [WHMIS] for products intended for workplace use.

Physical-chemical properties

The silicon dioxide group represents a polymorphic category containing a large number of forms identical in composition but with different atomic arrangements which afford different chemical properties. There are two sub-categories within this group: crystalline silica, to which the present substances quartz and cristobalite belong, and non-crystalline or amorphous silica. The key distinction between these sub-categories is that in crystalline substances, the building blocks are arranged in regular, repeating 3-dimensional pattern having long range order, whereas amorphous materials do not display long range order. In all forms of silica, (crystalline and non-crystalline), the silicon atom is tetrahedral and bound to four neighbouring oxygen atoms.

Quartz and cristobalite are solid at room temperature, existing normally as colourless or white crystals. The melting points for quartz and cristobalite are 1400-2000 ^{o}C and 1713-1728 ^{o}C, respectively and for both compounds, the boiling point is 2230^{o}C. Even though no experimental data were available, their vapour pressure and Henry's Law constant are likely negligible. Log K_{ow} (octanol-water partition coefficient) and log K_{oc} (organic carbon-water partition coefficient) are not applicable to these substances. The densities range from 2500-2700 kg/m^3 for quartz and 2300-2380 kg/m^3 for cristobalite.

The very similar physico-chemical properties of quartz and cristobalite reflect their closely related crystal forms. The solubility of crystalline silicates decreases as a function of silica tetrahedral packing density and long-range crystal order. For example, cristobalite has a more open framework structure than quartz and its density is lower, therefore, its solubility is higher. The water solubility of these minerals is also function of temperature, pH, particle size, and the presence of a disrupted surface layer. This may explain the variability of solubility values reported by many authors. The most probable solubility value for quartz is approximately 3.8 mg Si/L, or 6.4 mg/L expressed as the SiO_2 species, while the solubility of cristobalite is approximately 8.7 mg Si/L, or 18 mg SiO_2/L. The kinetics of dissolution of these substances is slow due to the high activation energy required to hydrolyse the Si-O-Si bond.

Human Health Targeted Endpoints

The majority of the studies described here have been reviewed by the International Agency for Research on Cancer (IARC 1997). However, additional data relevant to the screening assessment were identified up to August 2010.

Repeated dose toxicity/non-neoplastic effects (development of silicosis).

Studies on animals

Significant short-term and subchronic studies have demonstrated adverse effects in the lungs, while one of the 6 studies showed effects on the spleen in mice. Rats were exposed to 0, 10 or 100 mg/m^3 of cristobalite via inhalation for 6 hours/day during 3 days. Animals were observed 3 months after exposure. Elevated levels of granulocytes and elevated markers of cytotoxicity from the lung lavage fluid were noted in all exposed groups. Another study of similar duration (9 days) conducted in mice also identified a LOAEC of 10 mg/m^3. Effects observed included minimal interstitial thickening, accumulations of mononuclear cells and slight lymphoid tissue hypertrophy in the lungs.

In a 4-week inhalation study, female rats were exposed to 0, 0.1, 1 or 10 mg/m^3 of quartz 6 hours/day, 5 days/week. Bronchoalveolar lavage fluid was evaluated at 1, 8, and 24 weeks after exposure. Elevated levels of

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granulocytes and significant elevation of markers of cytotoxicity (Lactate dehydrogenase [LDH] and β-glucuronidase [β-glu]) were observed at 1 mg/m^3 and higher. The increased levels of LDH and β-glu were only significant at 24 weeks after exposure. A LOAEC of 1 mg/m^3 was identified at 24 weeks.

Male rats (4 animals per dose) were exposed to 0 or 3 mg/m^3 of cristobalite via inhalation for 6 hours/day, 5 days/week during 13 weeks. Pulmonary inflammation and fibrosis were observed in the exposed group at the end of treatment. When mice were similarly exposed to 5 mg/m^3 of quartz for 6 hours/day, 5 days/week for 15 or 27 weeks, the authors observed increased spleen weight and formation of plaque in the spleen.

In two separate studies, in which rats or hamsters were exposed to quartz via inhalation for at least 6 months, LOAECs of 2 and 3 mg/m^3 were identified, respectively. All the effects observed were related to inflammation and fibrosis of the lung tissue.

Several chronic studies investigated exposure of the respirable forms (i.e. accumulated via inhalation in the lung tissues) of quartz and cristobalite to rats, mice and hamsters. The following is a description of the study in which the lowest non-neoplastic LOAEC was determined. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz, containing 74% of respirable quartz, through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. The mean mass of particle at the end of the exposure period was 0.91 mg/lung. The LOAEC identified was 0.74 mg/m^3 (adjusted for 74% respirable quartz) based on lipoproteinosis, multifocal, inflammatory cell infiltrate and alveolar hyperplasia.

Human epidemiology data

In humans, the lowest observed adverse effect level was identified in a U.S. cohort study. The study was conducted on 3330 gold miners (all are males), who had an average of 9 years underground exposure during the period 1940 to 1965. The cohort was followed up through 1990. Silicosis[1] was identified through death certificates or chest X-rays. A job-exposure matrix together with work history was used to estimate individual exposure. The total silica content in the respirable dust in the mine was estimated at 13% and the median crystalline silica exposure was 0.05 mg/m^3. In this sub population of miners, 170 cases of silicosis were identified. The best predictor for risk of silicosis was cumulative exposure, which varied from less than 1% for a 0.5 mg/m^3-year exposure to 68-84% when exposed to more than 4 mg/m^3-year (based on the average daily dust exposure during the workday each year and summed over time for each miner). The main limitations identified by the authors include the limited number of radiographic surveys, the potential bias from death certificates

[1] Silicosis: Lung disease caused by inhalation of crystalline silica dust, and resulting in inflammation and scarring in forms of nodular lesions in the upper lobes of the lungs. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics). It does not follow that a history of exposure to silica necessarily results in silicosis (Nonsilicotics). The typical "Silicotic" lung nodule is shown in Figure 1.

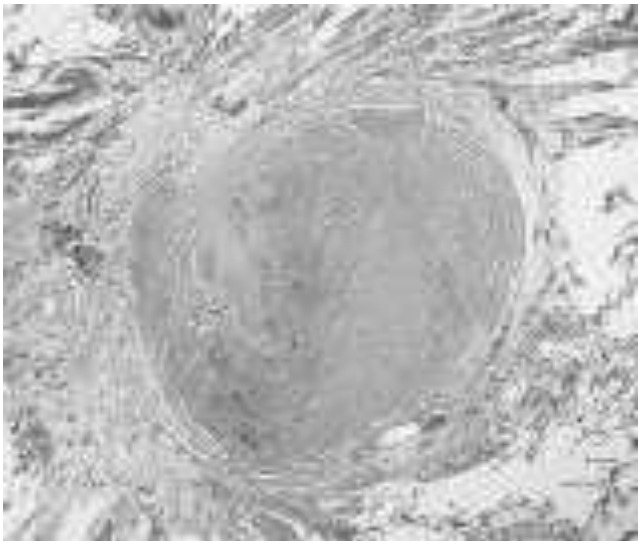


Figure 1. Silicotic nodule characterised by a central zone of hyalinised collagen with a whorled appearance and peripheral dust-containing macrophages (Rees and Murray, 2007).

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(relying on death certificates instead of relying on repeated x-rays, which were lacking for each miner, may have underestimated the number of cases) and the fact that the conversion of dust counts to

gravimetric measurements may not be accurate based on the estimation of 13% silica content in the respirable dust (although based on a relatively large number of samples (n = 82) collected in two different surveys, there was broad range of content in these samples (1% to 48%, SD = 9), and the percentage of respirable quartz may have differed in earlier years, but data were lacking for these years).

Two other human studies have identified similar LOAECs based on the critical endpoint of radiographic confirmed silicosis. A LOAEC of 0.053 mg/m^3 (mean exposure) was identified in a cross sectional study of South African gold miners and a LOAEC of 0.064 mg/m^3 (mean exposure) was derived in a mining community population-based random sample survey in Colorado.

Carcinogenicity studies

Studies on animals

Experimental studies conducted in rats have shown clear and consistent increases in lung tumours after chronic inhalation exposure. In the nine rat studies identified, five were inhalation studies and four were intratracheal instillation studies. All studies except one inhalation study showed increased incidence of lung tumours. For the inhalation studies with treatment related tumours, concentrations ranged from 1 to 50 mg/m^3 (1, 6, and 30 mg/m^3 of DQ-12 quartz; 12 and 50 mg/m^3 of Min-U-Sil 5 quartz) and duration of exposure ranged from 29 days to 2 years. In the inhalation study with no treatment-related tumours, exposure was 60 mg/m^3 of Sikron F300 quartz for 13 weeks. The following is a description of the neoplastic results in the study also identified as the critical study for non-neoplastic results. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. In the exposed group, 18 animals developed tumours (12 in females, 5 in males), as opposed to 3 and 2 for the control and positive control groups respectively. The majority (10/18) of the tumours observed were adenocarcinomas. The mean mass of particles in the lungs at the end of the exposure period was 0.91 mg/lung.

For the intratracheal instillation studies, doses ranged from 4 to 57 mg/kg-bw (based on 7, 12 or 20 mg/animal of Min-U-Sil (5) quartz or 20 mg/animal of novaculite quartz). Exposure regimes were diverse and included single instillation with observation for up to two years, to weekly instillation for 10 weeks. It is noteworthy that the single intratracheal administration of a 95% pure quartz particles (<5 μm) resulted in an increased incidence of silicotic granulomas after 3 weeks and lung tumours after 11 months. The most common tumours reported across the long term rat studies were adenocarcinomas, however other tumours such as squamous-cell carcinoma, alveolar carcinoma and bronchiole-alveolar adenoma were also reported, and all animals that developed tumours also showed some degree of fibrosis.

Of particular interest is the intratracheal instillation study, investigating the sequence of pathological events leading to lung tumors. An unspecified number of rats/sex/dose received a single intratracheal instillation of various crystalline silica dusts or ferric oxide, allowing direct administration into the bronchial tree. The doses were 12 or 20 mg of Min-U-Sil 5 quartz (MQZ), 12 mg of hydrofluoric-acid-etched Min-U-Sil 5 quartz (HFMQZ), 12 mg of cristobalite, 12 mg of tridymite and 12 mg of ferric oxide suspended in saline. All groups were observed until six months post exposure, except for both MQZ groups, the HFMQZ and the ferric oxide group which were observed up until 17 months post-exposure. Interim sacrifices were conducted at 6, 11 and 17 months. The rat lungs showed a clear progression of effects. The sequence of pathological events were, an initial inflammatory response leading to a marked hyperplasia and hypertrophy of alveolar cells after one month, and at six months hyperplasia was evident but no lung tumours were observed. In this study, lung tumours were observed starting at the 11 month sacrifice with a 17% and 42% incidence in males and females (based on 3/18 males and 8/19 females), respectively, and at 17 months incidences were 32% and 59% (based on 6/19 males and 10/17 females, respectively). No lung tumours were found in ferric oxide treated rats. Similar studies have also been conducted in hamsters and mice. Although treated mice and hamsters showed treatment related signs (inflammation or fibrosis), no tumours were observed in hamsters. No increase in the incidence of lung tumours was seen in mice treated with quartz; however silicotic granulomas and lymphoid cuffing around airways but no fibrosis were seen in the lungs of quartz-treated mice.

Human epidemiology data

There is an extensive dataset of human studies investigating the link between crystalline silica exposure and cancer. IARC (1997) identified over 50 epidemiological studies based on occupational exposure to dust containing respirable crystalline silica. Main industry sectors from which the human data is derived include gold mines, foundries, granite/stone industry, pottery workers and refractory brick workers. From the least confounded studies, it was noted that lung cancer tended to increase with the following parameters: cumulative

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exposure; duration of exposure; peak intensity of exposure; presence of radiographically defined silicosis; and length of follow-up time from date of silicosis diagnostic. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics).

Since the 1997 IARC report, a large number of epidemiological studies have been published, with the more recent studies being updates from supplementary follow-up of results from previously assessed case-control studies cohorts, new results based on refined exposure assessments or adjustment for confounders or meta-analyses of the pooled data from these epidemiology studies

In a meta-analysis of the data from 10 cohort studies of gold, tin and tungsten miners, granite workers, industrial sand, diatomaceous earth and pottery workers with quantitative exposure estimates for crystalline silica were pooled in order to analyse the risk related to lung cancer. The pooled cohort standardized mortality ratio (SMR, against national rates) [See Appendix 1 for definition] was 1.2 (Confidence Interval [CI] 1.1-1.3). The results from the case-control analyses show a statistically significant trend with duration of exposure (odds ratios (ORs) [See Appendix 1] by quintile of cumulative exposure increased from 1.0 to 1.6 [CIs of 0.85 to 2.1] and by quintile of average concentration increased from 1.0 to 1.7 [CIs of 1.1 to 2.3]), supporting the importance of the increasing lung burden of silica in the occurrence of cancer. Overall, the authors concluded that the results support the carcinogenicity conclusion presented by IARC (1997).

To investigate the link between crystalline silica, silicosis and lung cancer, epidemiological data published between 1966 and 2001 were gathered. Over 50 studies were selected and pooled according to type of study and the parameter being linked to lung cancer (i.e. silica exposure, presence of silicosis in subjects). The quality of study, adjustment for confounding factors, co-exposure to other carcinogens and availability of a more recent analysis of a same cohort were taken into consideration in the final selection of the studies. Analysis of the relationship between exposure to silica and lung cancer included 17 cohort and 13 case-control studies. For the analysis of lung cancer versus silicosis, 11 cohort and 5 case-control studies were selected. The third analysis included 6 cohort and 2 case-control studies to evaluate the risk of lung cancer in non-silicotics. A random effect model was used to conduct each meta-analysis. Pooled cancer risk ratios (RRs) were 1.32 (CI 1.23-1.41) for crystalline silica exposure, 2.37 (CI 1.98-2.84) for individuals exposed to silica with confirmed silicosis (Silicotics) and 0.96 (CI 0.81-1.15) for individuals with no evidence of silicosis (non-silicotics) with confirmed exposure to silica, supporting the general observation that silicosis has a stronger temporal relationship with crystalline silica exposure and furthermore support the view that a human silicotic response could be a preliminary stage in the development of cancer.

A more recent meta-analysis included 28 cohort, 15 case-control and two proportionate mortality ratio (PMR) [See Appendix 1] studies from a variety of occupational settings conducted between 1996 and 2005. Risk ratios (RRs) were calculated based on type of study and silicosis status using fixed and random effect models (results presented here are from the random model). RRs for all cohort studies was 1.34 (CI 1.25-1.45), and were 1.69 (CI 1.32-2.16) for silicotics, 1.25 (CI 1.18-1.33) for those with undefined silicosis status and 1.19 (CI 0.87-1.57) for non-silicotics. In the case-control studies, the general RR was 1.41 (CI1.18-1.67), and the same sub-groups as mentioned above resulted in RRs of 3.27 (CI 1.32-8.2), 1.41 (CI1.18-1.70) and 0.97 (CI 0.68-1.38), respectively. The proportionate mortality ratio for the last two studies was 1.24 (CI 1.05-1.47). The authors noted that the association between lung cancer and exposure to crystalline silica was more consistent for silicotics, i.e., those diagnosed with silicosis and RR values split into type of occupational settings in which participants worked.

Based upon the above three meta-analysis studies and the epidemiology studies discussed in IARC (1997), the following can be concluded. Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis. Cancer risk is often more significant in workers exposed to crystalline silica over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours. Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles.

There have been reports of tumours outside of the lungs in persons with high silica exposure; however, these reports are sparse and the data inconsistent and have not been unequivocally linked to exposure to either one of the crystalline forms (quartz or cristobalite). Some of the reported locations are: oesophagus, stomach, liver, skin and bone. Sufficient epidemiological or toxicological data do not currently exist for quantitative assessment of the exposure-response relationship on these other tissues or organs.

Genotoxicity

Potential genotoxicity has been assessed in multiple *in vitro* and *in vivo* assays. Table 1 below gives a brief summary of the positive results observed in each type of assay.

Table 1. Summary of positive results over total number of results for each assay and each category (all studies

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conducted with crystalline silica: quartz, except where indicated).

Assay	Animal data		Human data		Positives/Total	
	In vitro	In vivo	In vitro	In vivo[d]	In vitro	In vivo
Rec Assay	0/1				0/1	
DNA strand break	1/1	2/2	5/5[b]	1/1	6/6	3/3
Sister chromatid exchange	0/1		0/1[c]	1/1	0/2	1/1
Micronucleus	2/3	0/1	2/2[b]	1/1	4/5	1/2
Chromosome aberration	0/1			1/1	0/1	1/1
Aneuploidy/polyploidy	0/3				0/3	
Cell transformation	4/4				4/4	
Hprt mutation	1/2	2/2[a]	1/1[b]		2/3	2/2
Oxidative DNA damage		4/5	2/2		2/2	4/5
DNA binding		1/1				1/1
p53 activation		0/1				0/1

a. one assay conducted with crystalline silica: cristobalite
b. one assay conducted with "ultrafine crystalline silicon dioxide".
c. crystalline silica: tridymite
d. crystalline silica dust (subtypes not provided).

All the *in vivo* human genotoxicity studies are based on three independent studies that used blood samples from workers from diverse occupational settings with confirmed exposures to crystalline silica dust; however, quantification of exposure was not provided. After stratification by smoking status, sister chromatid exchange remained statistically significant in both smokers and non-smokers although the frequency was higher in smokers. For the chromosome aberration assay conducted as part of the same study (blood samples from workers in the stone crusher industry), the increased frequency was no longer significant after stratification. In the DNA damage study of foundry and pottery workers and the micronucleus assay of workers involved in sandblasting and related jobs, results were positive when compared to controls. However, in both studies, smoking status influenced the results, contributing to the increased DNA damage observed since results were greater in smokers versus non-smokers, and the frequency of micronuclei in nasal epithelial cells was higher in smokers (p=0.002) but when using peripheral blood lymphocytes did not differ statistically between smokers and non-smokers who were similarly exposed to silica dust,

The role of *in situ* generation of reactive oxygen species (ROS) and reactive nitrogen species (RNS) has been well established in the following types of DNA damage: small scale insertions, DNA base pair deletion, base modification, chromosomal change/loss, microsatellite instability, DNA strand break, 8-hydroxydeoxyguanosine (8-OHdG) mutation and point mutations. ROS and RNS generation is postulated to be (a part of) the DNA damage mechanism for crystalline silica. Studies are described below to support this hypothesis.

DNA was exposed *in vitro* to various crystalline silica dusts, to H_2O_2, or to both. Results show that DNA damage was limited when dust or H_2O_2 were administered alone but increased with the co-exposure. When the reactive oxygen scavenger, dimethylsulfoxide, was added to the test system, DNA strand break was inhibited, data supporting the viewpoint that it is the presence of radicals generated in response to quartz and cristobalite that causes the DNA damage and not quartz or cristobalite themselves.

Hprt mutation assays in rat alveolar epithelial cells, both *in vitro* and *in vivo,* were positive in response to quartz. The positive results *in vivo* were seen only in the presence of significant inflammatory responses in the treated animals. Also, in a parallel *in vitro* experiment, rat alveolar epithelial cells were incubated with the bronchoalveolar lavage fluid from the rats exposed to quartz. Both macrophage and neutrophil enriched lavage cells induced mutation in the exposed alveolar epithelial cells. Addition of catalase (an enzyme which inactivates H_2O_2) before incubation inhibited the increase in *hprt* mutation.

Rats were exposed to either crystalline or amorphous silica in a manner to induce the same level of

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inflammation in the lungs. The inflammatory response was assessed by measuring the proportion of neutrophils in the bronchiolar lavage fluid. The actual concentrations were 3 and 50 mg/m^3 for crystalline and amorphous silica respectively. The animals were exposed for 13 weeks. *Hprt* mutation frequency was measured in the alveolar epithelial cells at the end of the exposure period. Mutation frequency was greatly increased only in the crystalline silica treated rats; no treatment related increase was found in the rats treated with the amorphous form.

In an 8-OHdG assay conducted to monitor DNA damage by reactive oxygen species, female rats were exposed to 0, 0.3, 1.5 and 7.5 mg/animal of quartz via intratracheal instillation. Effects were observed 90 days post-exposure. A clear dose-response relationship was identified between quartz exposure and various inflammation markers (differential cell count, protein, lung surfactant lipids and tumour necrosis factor alpha). Inflammation was present starting at the lowest dose. However, 8-OHdG showed a statistically significant increase starting at 1.5 mg/animal only. Similarly, in another study, 8-OHdG and DNA strand breaks were observed at concentrations of or above 10 ug/m^3 in rat lung epithelial cells.

In the aim of investigating the role of ROS in lung carcinogenesis, rat lung epithelial cells were incubated with polymorphonuclear (PMN) leukocytes (involved in the inflammatory process and responsible for the release of certain ROS) or hydrogen peroxide. Statistically significant increases in 8-OHdG were observed in the presence of PMN or hydrogen peroxide in a dose-response manner.

In a series of experiments which used *in vitro* stimulation of macrophages with crystalline silica and *in vivo* intranasal instillation of crystalline silica in mice, it was demonstrated that that the chronic fibrosis seen in a murine model of silicosis *in vivo* is dependent on the presence of adaptor molecule ASC and Nalp3 inflammazome. These data support a potential mode of action whereby silica triggers cellular responses that in turn activate alveolar macrophages, resulting in an inflammatory response and silicosis. In mice deficient in Nalp3 inflammazome, the development of inflammation and collagen deposition was significantly reduced compared with normal mice 3 months after the initial intranasal instillation of silica.

Analysis of Lung Tumour Data

The weight of evidence for both rats and humans indicates that fibrotic and silicotic lesions in the lung result from inhalation exposure to crystalline silica and that lung cancer is secondary to those lesions in the lung. Although the mechanism of induction for the lung tumours has not been fully elucidated, there is sufficient supportive mode of action evidence from the data presented to demonstrate that a threshold approach to risk assessment is appropriate based on an understanding of the key events in the pathogenesis of crystalline silica induced lung tumours. The body of evidence include the following:

- In experimental studies, all rats that developed tumours also showed fibrosis.
- Adenocarcinomas, the most common type of tumour identified in rats, are commonly associated with fibrosis and deeply scarred lung tissue.
- Experimental rat studies showed a clear progression of the effects from initially mild inflammation, followed by fibrosis over-time, leading eventually to lung tumours.
- Tumours are not present in all treated species dosed in the same way.
- The tumours, both in rats and humans, are concentrated in the lungs only, although other organs are indirectly exposed.
- In human studies, cancer risk is often more significant in workers exposed over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours.
- Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles
- Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis.
- For genotoxicity, in vitro results were mostly mixed and in vivo results were mostly positive. However, the vast majority of the positive genotoxicity assay results can be explained by the generation of reactive oxygen species, as demonstrated experimentally, where ROS scavenging prevents the genotoxicity.
- *In vivo*, macrophage deficient mice (macrophages produce ROS in response to crystalline silica) do not develop silicosis nor do they develop tumours and the Nalp3 inflammazome, a key player in the macrophage initiated inflammatory response, is required for the development of pulmonary fibrosis after

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inhalation of silica.

- Though inhalation exposure to crystalline silica in multiple occupational settings is clear, the increase in risk, based on the several recent meta-analyses of the multiple human epidemiological studies, remains low.

It is worth noting that where aggressive engineering controls have been made to reduce silica dust levels in the workplace (Sweden), silicosis has been eliminated. By corollary, existing exposures outside of the workplace in such areas do not pose a risk for silicosis to the general population.

The respirable forms of quartz and cristobalite possess properties indicating a hazard for human health (repeated dose toxicity, carcinogenicity and genotoxicity). The mode of action in the lungs involves irritation, inflammation and reactive species formation, leading to silicosis, and eventually to tumour formation.

Exposure

Uses

Consistent with oxygen and silicon being the two most abundant elements in the Earth's crust, silicon-oxide minerals, including quartz are ubiquitous in the natural environment. In particular, as a component of sand, quartz may find use in a diverse array of applications. Several high volume uses include, but are not limited to, the use of sand as a filling material for the construction of roads and in general building activities, the use of sand and gravel aggregates as abrasives on roads in winter and the use of fly-ash, which may contain 4-14% quartz and 0.5-1% cristobalite, as a cement additive. These abrasives when used on winter roads are usually mixed with road salts and may be sand only, stone dust, sand and gravel aggregates, or pre-treated sand. They are used mainly by rural municipalities or in areas where cold temperatures diminish the efficiency of salts for de-icing. Quantities of abrasives used in Canada were 5.73×10^9 kg, 4.59×10^9 kg, and 4.93×10^9 kg for 2007, 2008 and 2009, respectively.

Industrial sand, high purity silica sand products with closely controlled sizing are expected to contain quartz and cristobalite, include lump silica (2-3mm up to 15 cm or more), silica sand (75µm to 2-3mm) and silica flour (less than 75µm). Lump silica may be used in the production of silicon alloys, silica bricks, and the linings of certain types of pulverizers (eg. ball mills and tube mills).

Silica sand may be used in the manufacture of glass and glass fibres, silicate chemicals and silicon carbide, the hydraulic fracturing of wells, foundry moulding, and for sandblasting. Silica flour may find use in the ceramics and cement industries, as a filler and extender in rubber and coatings, and as an abrasive in soaps.

Natural clays, such as bentonite and fuller's earth, are used in cat litters for their high water absorbance capacities. Quartz is a natural component of these clays, and consequently, it may be present in cat litter products. High purity α-quartz is a piezoelectric material, which means that application of a voltage induces a distortion in the crystal shape and vice versa. This ability to interconvert electrical and mechanical energy has led to the use of quartz crystals in electronic devices requiring precise timing control, for example telephones, radios, watches and computers.

According to a survey conducted in Canada, quartz and cristobalite are also used in abrasives, adsorbents, filter products (diatomaceous earth), grout and cement. These substances reportedly also find use as fillers, which add bulk and improve wear resistance, in paints and coatings, adhesives, sealants, polymer films, caulking, epoxy resins and silicones. Also, quartz is listed as an ingredient in 60 cosmetic products in Canada. The types of products include anti-wrinkle preparation, eye and face makeup, lipstick, hair dyes, shampoos and grooming products, as well as skin cleansers, moisturizers and tanning preparations.

Natural Sources

In Canada, quartz naturally occurs in many types of rock formations. Those with high silicon dioxide content (95% SiO_2 or more) include vein and massive intrusion bodies, quartz pebbles, silica sand, sandstone and quartzite. Sandstone is a sedimentary rock mostly composed of quartz grains cemented by a bonding material such as clay, calcite or iron oxide. Quartzite is a hard, compact, metamorphosed sandstone made of grains of quartz firmly bonded with a siliceous cement. Mineral aggregates (e.g., sand and gravel) have variable silicon dioxide content. Quartz is also found as crystals, aggregates or discrete particles in certain igneous rocks (e.g., granites and pegmatites), soils, sediments, air and surface water. This omnipresence is consistent with the fact that silicon is the second most abundant chemical element on Earth.

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Cristobalite is naturally produced in the ashes of volcanic eruptions, and by combustion metamorphism which is a local phenomenon of spontaneous combustion of naturally occurring substances such as bituminous rocks, coal or oil. It may be found in cavities in volcanic rocks and in thermally metamorphosed sandstones and may also be a transient stage in the diagenesis of diatomaceous shale with the result that soils made of these geologic formations may be rich in cristobalite. Unlike quartz, the natural occurrence of cristobalite is limited to specific geographic regions and mineral types.

Anthropogenic Sources

Natural quartz is isolated from ore via beneficiation, which involves milling or grinding the material into particles that are separated into desired mineral and waste. The materials obtained are either used directly or further purified. In Canada, in 2006, 2.146×10^{9} kg of pure quartz were mined, and 2.385×10^{11} kg of sand and gravel aggregates were produced. The proportion of quartz in silica sand deposits and gravel aggregates will vary from one site to another.

Cristobalite can form from silica melts during the preparation of silica glass; quartz is not obtained from melts but is manufactured at elevated temperature and pressure via a hydrothermal process. Cristobalite also forms during the calcination[2] of diatomaceous earth.

Human Exposure Estimate

Ambient air

The exposure assessment is focussed on respirable quartz and cristobalite, which in ambient air comprises a component of total particulate matter (PM). In Canada, data on the concentrations of silicon in PM was available and used as a surrogate for quartz and cristobalite. This approach is conservative because the measured silicon includes all silicon-containing substances and therefore represents the upper limit for quartz and cristobalite in ambient air.

The National Air Pollution Surveillance (NAPS) Program measured concentrations in $\mu g/m^3$ of silicon in PM with aerodynamic radii less than 2.5 µm ($PM_{2.5}$ (dichot)), and from 2.5 to 10 µm (PM_{10} (dichot)) (the total particulate matter with aerodynamic radii less than 10 µm (PM_{10}) is obtained by adding these values) in Canada. In 2009, as part of the NAPS Program, silicon concentrations were determined on over 1600 samples of $PM_{2.5}$(dichot) and over 1500 samples of PM_{10}(dichot) at 24 urban locations across Canada. An estimate of exposure to quartz and cristobalite can be obtained by assuming that all the silicon in the PM is represented stoichiometrically as SiO_2, and multiplying the reported concentration of silicon by 2.14 to obtain a value for silica.

The intake of respirable quartz and cristobalite by the general population of Canada is estimated using a range covering the lowest 50^{th} percentile SiO_2 concentration in PM_{10}, measured in Pt. Petre, ON, (0.12 $\mu g/m^3$) to the highest 50^{th} percentile concentration in PM_{10} measured in Calgary, AB (2.1 $\mu g/m^3$). The 50^{th} percentile SiO_2 concentrations ranged from 0.1 to 2.1 $\mu g/m^3$ across the survey sites; the top of this range is quite close to the average of the maximum values for the 24 sites (3.7 $\mu g/m^3$). The outdoor data were used to represent the indoor levels, because information on indoor silicon concentrations was not available, and the range of PM_{10} measured indoors is generally lower than the outdoor range. Thus, this approach conservatively overestimates indoor exposure in homes.

The highest exposure group based on these calculations is children ages 0.5 to 4 years with an estimated daily intake ranging from 0.07 to 5.26 µg/kg-bw per day; the estimated daily intake decreases with age due to changes in the ratio of inhalation rates to body weights; the daily intake of adults, 20-59 years old, is estimated to range from 0.03 to 2.00 µg/kg-bw per day.

Consumer Products

Exposure to respirable quartz from the use of cosmetic products, which contained quartz as an ingredient, was considered low because they are not formulated for spray application, the loose powders were reported to contain less than 0.1% quartz, and in these products the substance is not expected to be associated with other components of the formulation and not available in a free form.

For consumer Do It Yourself (DIY) activities around the home, the highest mean breathing zone concentration of particles from sanding dry wall (median cut-point of 10µm) of 6.31 mg/m^3, was used to derive an upper-

[2] Calcinations: Heat treating a substance, but without fusion, to bring about change in its physical or chemical constitution.

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bound exposure estimate ranging from 2 to10 µg/kg-bw per event.

Quartz is used to formulate a large number of paints and coatings. To estimate potential inhalation exposure to quartz from these products, the spray painting of wall paints with an airless spray gun was considered appropriate as a conservative scenario. Exposure to respirable paint particles was estimated using data from controlled a laboratory study in which walls of poorly ventilated test rooms were painted by professional painters using an airless sprayer to apply interior latex paint. The maximum concentration of 13% quartz in paint in Canada was used to estimate exposure. The upper-bound estimate of exposure to quartz, based on the maximum concentration of 13% quartz in paint in the Canadian market and the maximum concentration of respirable paint particles measured in these controlled studies when recommended personal protective equipment is used, is 0.954 µg/kg-bw per event.

Inhalation of ambient air containing quartz and cristobalite is the dominant pathway of chronic exposure (excluding that from DIY activities) for the general population. Because SiO_2 makes up only approximately 5% of PM_{10}, silicon concentrations (expressed as SiO_2) measured in the Canadian NAPS survey of 24 urban locations were considered most relevant to the estimation of exposure by the general population. Quartz and cristobalite comprise only a portion of the total SiO_2 in PM_{10}, therefore, the use of the total silicon concentration to represent the upper bound crystalline silica concentrations results in an overestimation of exposure.

Appendix 1: Definitions of Epidemiological Terms in the ITAP

SMR (Standardized Mortality Ratio): The ratio (x 100) of observed to expected deaths in a study population. Expected deaths are calculated by applying a set of standard age-specific mortality rates to the age distribution of the study population. Standardized ratios are only useful for comparisons. They have no intrinsic meaning.

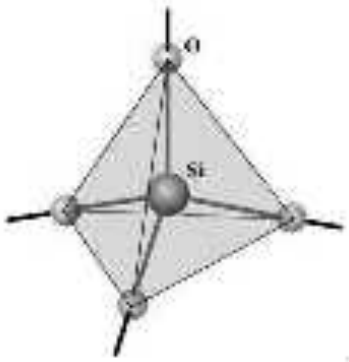
OR (Odds Ratio): In epidemiological case-control studies, a relative measure of disease occurrence. The odds in favour of a particular disease occurring in an exposed group are divided by the odds in favour of its occurring in an unexposed group. If the condition being studied is rare, the odds ratio is a close approximation to the relative risk.

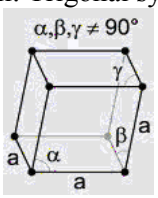
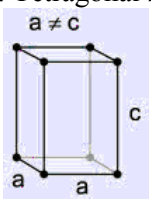
RR (Risk Ratio): The probability of the occurrence of a disease in a group that has been exposed to some environmental, medicinal, microbial, or toxic influence, relative to its probability in a randomly selected population.

PMR (Proportionate Mortality Ratio): Proportionate mortality is the proportion of deaths in a specified population over a period of time attributable to different causes. Each cause is expressed as a percentage of all deaths, and the sum of the causes must add to 100%. These proportions are not mortality rates, since the denominator is all deaths, not the population in which the deaths occurred. Thus, proportionate mortality ratio is a measure of the frequency of occurrence of the proportionate mortality in a defined population during a specified interval of time.

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INITIAL TARGETED ASSESSMENT PROFILE (Human Health)

CAS No.	Quartz: CAS RN 14808-60-7 Cristobalite: CAS RN 14464-46-1
Chemical Name	Quartz and Cristobalite
Structural Formula	Molecular Formula: SiO_2 

Unit Cell: Trigonal symmetry	Unit Cell: Tetragonal symmetry
	
Quartz: CAS RN 14808-60-7	Cristobalite: CAS RN 14464-46-1

SUMMARY CONCLUSIONS OF THE TARGETED ASSESSMENT

NOTE: The present assessment is targeted to address the following human health endpoints: repeated dose toxicity and carcinogenicity via the inhalation route of exposure, and genotoxicity. It cannot be considered as a full SIDS Initial Assessment. Summary information on exposure is also reported here. Other endpoints for human health and the environment included in the Canadian screening assessment but have not been presented to OECD member countries, and thus are not included in this profile.

The final screening assessment will be published under the responsibility of the Government of Canada.

Rationale for Targeting the Assessment

The Government of Canada "categorized" or prioritized all 23,000 chemical substances on its Domestic Substances List (DSL) from 1999 to September 2006, as required by its *Canadian Environmental Protection Act, 1999* (CEPA 1999). Additional details may be found at http://www.chemicalsubstanceschimiques.gc.ca/about-apropos/categor/index-eng.php. Using information from Canadian industry, academic research and other countries, Government of Canada scientists applied a set of rigorous tools to the 23,000 chemical substances on the DSL. They were categorized to identify those that were: **inherently toxic** to humans or to the environment and that might be **persistent** and/or **bioaccumulative**; and substances to which people might have **greatest potential for exposure**. During this priority-setting exercise, distinct approaches were taken for identifying substances of likely concern for human health and the environment, and subsequent assessment activities may have focused on either human health or ecological endpoints. Through categorization, the Government of Canada has identified approximately 4,000 of the 23,000

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chemical substances on the DSL as priorities for further assessment, research and/or measures to control their use or release. Quartz and cristobalite were identified at that time, applying the categorization criteria, as high priorities for human health risk because they were considered to pose greatest potential for exposure and their respirable forms are classified by the International Agency for Research on Cancer as carcinogenic to humans (quartz and cristobalite) and by the National Toxicology Program as known human carcinogens (crystalline silica). These substances did not meet the ecological categorization criteria for bioaccumulation potential or inherent toxicity to aquatic organisms.

Under the Canadian legislation a determination of whether one or more of the criteria of the CANADIAN ENVIRONMENTAL PROTECTION ACT (CEPA) 1999, section 64 are met is based upon an assessment of potential risks to the environment and/or to human health associated with exposures in the general environment. For humans, this includes, but is not limited to, exposures from ambient and indoor air, drinking water, foodstuffs, and the use of consumer products. A conclusion under CEPA 1999 on the substances in the Chemicals Management Plan (CMP) Challenge is not relevant to, nor does it preclude, an assessment against the hazard criteria specified in the Controlled Products Regulations, which is part of the regulatory framework for the Workplace Hazardous Materials Information System [WHMIS] for products intended for workplace use.

Physical-chemical properties

The silicon dioxide group represents a polymorphic category containing a large number of forms identical in composition but with different atomic arrangements which afford different chemical properties. There are two sub-categories within this group: crystalline silica, to which the present substances quartz and cristobalite belong, and non-crystalline or amorphous silica. The key distinction between these sub-categories is that in crystalline substances, the building blocks are arranged in regular, repeating 3-dimensional pattern having long range order, whereas amorphous materials do not display long range order. In all forms of silica, (crystalline and non-crystalline), the silicon atom is tetrahedral and bound to four neighbouring oxygen atoms.

Quartz and cristobalite are solid at room temperature, existing normally as colourless or white crystals. The melting points for quartz and cristobalite are 1400-2000 ^{o}C and 1713-1728 ^{o}C, respectively and for both compounds, the boiling point is 2230^{o}C. Even though no experimental data were available, their vapour pressure and Henry's Law constant are likely negligible. Log K_{ow} (octanol-water partition coefficient) and log K_{oc} (organic carbon-water partition coefficient) are not applicable to these substances. The densities range from 2500-2700 kg/m^3 for quartz and 2300-2380 kg/m^3 for cristobalite.

The very similar physico-chemical properties of quartz and cristobalite reflect their closely related crystal forms. The solubility of crystalline silicates decreases as a function of silica tetrahedral packing density and long-range crystal order. For example, cristobalite has a more open framework structure than quartz and its density is lower, therefore, its solubility is higher. The water solubility of these minerals is also function of temperature, pH, particle size, and the presence of a disrupted surface layer. This may explain the variability of solubility values reported by many authors. The most probable solubility value for quartz is approximately 3.8 mg Si/L, or 6.4 mg/L expressed as the SiO_2 species, while the solubility of cristobalite is approximately 8.7 mg Si/L, or 18 mg SiO_2/L. The kinetics of dissolution of these substances is slow due to the high activation energy required to hydrolyse the Si-O-Si bond.

Human Health Targeted Endpoints

The majority of the studies described here have been reviewed by the International Agency for Research on Cancer (IARC 1997). However, additional data relevant to the screening assessment were identified up to August 2010.

Repeated dose toxicity/non-neoplastic effects (development of silicosis).

Studies on animals

Significant short-term and subchronic studies have demonstrated adverse effects in the lungs, while one of the 6 studies showed effects on the spleen in mice. Rats were exposed to 0, 10 or 100 mg/m^3 of cristobalite via inhalation for 6 hours/day during 3 days. Animals were observed 3 months after exposure. Elevated levels of granulocytes and elevated markers of cytotoxicity from the lung lavage fluid were noted in all exposed groups. Another study of similar duration (9 days) conducted in mice also identified a LOAEC of 10 mg/m^3. Effects observed included minimal interstitial thickening, accumulations of mononuclear cells and slight lymphoid tissue hypertrophy in the lungs.

In a 4-week inhalation study, female rats were exposed to 0, 0.1, 1 or 10 mg/m^3 of quartz 6 hours/day, 5 days/week. Bronchoalveolar lavage fluid was evaluated at 1, 8, and 24 weeks after exposure. Elevated levels of

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granulocytes and significant elevation of markers of cytotoxicity (Lactate dehydrogenase [LDH] and β-glucuronidase [β-glu]) were observed at 1 mg/m^3 and higher. The increased levels of LDH and β-glu were only significant at 24 weeks after exposure. A LOAEC of 1 mg/m^3 was identified at 24 weeks.

Male rats (4 animals per dose) were exposed to 0 or 3 mg/m^3 of cristobalite via inhalation for 6 hours/day, 5 days/week during 13 weeks. Pulmonary inflammation and fibrosis were observed in the exposed group at the end of treatment. When mice were similarly exposed to 5 mg/m^3 of quartz for 6 hours/day, 5 days/week for 15 or 27 weeks, the authors observed increased spleen weight and formation of plaque in the spleen.

In two separate studies, in which rats or hamsters were exposed to quartz via inhalation for at least 6 months, LOAECs of 2 and 3 mg/m^3 were identified, respectively. All the effects observed were related to inflammation and fibrosis of the lung tissue.

Several chronic studies investigated exposure of the respirable forms (i.e. accumulated via inhalation in the lung tissues) of quartz and cristobalite to rats, mice and hamsters. The following is a description of the study in which the lowest non-neoplastic LOAEC was determined. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz, containing 74% of respirable quartz, through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. The mean mass of particle at the end of the exposure period was 0.91 mg/lung. The LOAEC identified was 0.74 mg/m^3 (adjusted for 74% respirable quartz) based on lipoproteinosis, multifocal, inflammatory cell infiltrate and alveolar hyperplasia.

Human epidemiology data

In humans, the lowest observed adverse effect level was identified in a U.S. cohort study. The study was conducted on 3330 gold miners (all are males), who had an average of 9 years underground exposure during the period 1940 to 1965. The cohort was followed up through 1990. Silicosis[1] was identified through death certificates or chest X-rays. A job-exposure matrix together with work history was used to estimate individual exposure. The total silica content in the respirable dust in the mine was estimated at 13% and the median crystalline silica exposure was 0.05 mg/m^3. In this sub population of miners, 170 cases of silicosis were identified. The best predictor for risk of silicosis was cumulative exposure, which varied from less than 1% for a 0.5 mg/m^3-year exposure to 68-84% when exposed to more than 4 mg/m^3-year (based on the average daily dust exposure during the workday each year and summed over time for each miner). The main limitations identified by the authors include the limited number of radiographic surveys, the potential bias from death certificates

[1] Silicosis: Lung disease caused by inhalation of crystalline silica dust, and resulting in inflammation and scarring in forms of nodular lesions in the upper lobes of the lungs. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics). It does not follow that a history of exposure to silica necessarily results in silicosis (Nonsilicotics). The typical "Silicotic" lung nodule is shown in Figure 1.

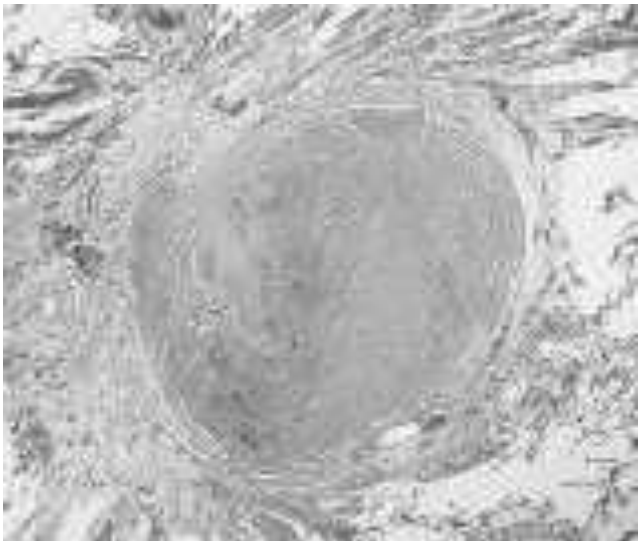


Figure 1. Silicotic nodule characterised by a central zone of hyalinised collagen with a whorled appearance and peripheral dust-containing macrophages (Rees and Murray, 2007).

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(relying on death certificates instead of relying on repeated x-rays, which were lacking for each miner, may have underestimated the number of cases) and the fact that the conversion of dust counts to

gravimetric measurements may not be accurate based on the estimation of 13% silica content in the respirable dust (although based on a relatively large number of samples (n = 82) collected in two different surveys, there was broad range of content in these samples (1% to 48%, SD = 9), and the percentage of respirable quartz may have differed in earlier years, but data were lacking for these years).

Two other human studies have identified similar LOAECs based on the critical endpoint of radiographic confirmed silicosis. A LOAEC of 0.053 mg/m^3 (mean exposure) was identified in a cross sectional study of South African gold miners and a LOAEC of 0.064 mg/m^3 (mean exposure) was derived in a mining community population-based random sample survey in Colorado.

Carcinogenicity studies

Studies on animals

Experimental studies conducted in rats have shown clear and consistent increases in lung tumours after chronic inhalation exposure. In the nine rat studies identified, five were inhalation studies and four were intratracheal instillation studies. All studies except one inhalation study showed increased incidence of lung tumours. For the inhalation studies with treatment related tumours, concentrations ranged from 1 to 50 mg/m^3 (1, 6, and 30 mg/m^3 of DQ-12 quartz; 12 and 50 mg/m^3 of Min-U-Sil 5 quartz) and duration of exposure ranged from 29 days to 2 years. In the inhalation study with no treatment-related tumours, exposure was 60 mg/m^3 of Sikron F300 quartz for 13 weeks. The following is a description of the neoplastic results in the study also identified as the critical study for non-neoplastic results. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. In the exposed group, 18 animals developed tumours (12 in females, 5 in males), as opposed to 3 and 2 for the control and positive control groups respectively. The majority (10/18) of the tumours observed were adenocarcinomas. The mean mass of particles in the lungs at the end of the exposure period was 0.91 mg/lung.

For the intratracheal instillation studies, doses ranged from 4 to 57 mg/kg-bw (based on 7, 12 or 20 mg/animal of Min-U-Sil (5) quartz or 20 mg/animal of novaculite quartz). Exposure regimes were diverse and included single instillation with observation for up to two years, to weekly instillation for 10 weeks. It is noteworthy that the single intratracheal administration of a 95% pure quartz particles (<5 μm) resulted in an increased incidence of silicotic granulomas after 3 weeks and lung tumours after 11 months. The most common tumours reported across the long term rat studies were adenocarcinomas, however other tumours such as squamous-cell carcinoma, alveolar carcinoma and bronchiole-alveolar adenoma were also reported, and all animals that developed tumours also showed some degree of fibrosis.

Of particular interest is the intratracheal instillation study, investigating the sequence of pathological events leading to lung tumors. An unspecified number of rats/sex/dose received a single intratracheal instillation of various crystalline silica dusts or ferric oxide, allowing direct administration into the bronchial tree. The doses were 12 or 20 mg of Min-U-Sil 5 quartz (MQZ), 12 mg of hydrofluoric-acid-etched Min-U-Sil 5 quartz (HFMQZ), 12 mg of cristobalite, 12 mg of tridymite and 12 mg of ferric oxide suspended in saline. All groups were observed until six months post exposure, except for both MQZ groups, the HFMQZ and the ferric oxide group which were observed up until 17 months post-exposure. Interim sacrifices were conducted at 6, 11 and 17 months. The rat lungs showed a clear progression of effects. The sequence of pathological events were, an initial inflammatory response leading to a marked hyperplasia and hypertrophy of alveolar cells after one month, and at six months hyperplasia was evident but no lung tumours were observed. In this study, lung tumours were observed starting at the 11 month sacrifice with a 17% and 42% incidence in males and females (based on 3/18 males and 8/19 females), respectively, and at 17 months incidences were 32% and 59% (based on 6/19 males and 10/17 females, respectively). No lung tumours were found in ferric oxide treated rats. Similar studies have also been conducted in hamsters and mice. Although treated mice and hamsters showed treatment related signs (inflammation or fibrosis), no tumours were observed in hamsters. No increase in the incidence of lung tumours was seen in mice treated with quartz; however silicotic granulomas and lymphoid cuffing around airways but no fibrosis were seen in the lungs of quartz-treated mice.

Human epidemiology data

There is an extensive dataset of human studies investigating the link between crystalline silica exposure and cancer. IARC (1997) identified over 50 epidemiological studies based on occupational exposure to dust containing respirable crystalline silica. Main industry sectors from which the human data is derived include gold mines, foundries, granite/stone industry, pottery workers and refractory brick workers. From the least confounded studies, it was noted that lung cancer tended to increase with the following parameters: cumulative

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exposure; duration of exposure; peak intensity of exposure; presence of radiographically defined silicosis; and length of follow-up time from date of silicosis diagnostic. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics).

Since the 1997 IARC report, a large number of epidemiological studies have been published, with the more recent studies being updates from supplementary follow-up of results from previously assessed case-control studies cohorts, new results based on refined exposure assessments or adjustment for confounders or meta-analyses of the pooled data from these epidemiology studies

In a meta-analysis of the data from 10 cohort studies of gold, tin and tungsten miners, granite workers, industrial sand, diatomaceous earth and pottery workers with quantitative exposure estimates for crystalline silica were pooled in order to analyse the risk related to lung cancer. The pooled cohort standardized mortality ratio (SMR, against national rates) [See Appendix 1 for definition] was 1.2 (Confidence Interval [CI] 1.1-1.3). The results from the case-control analyses show a statistically significant trend with duration of exposure (odds ratios (ORs) [See Appendix 1] by quintile of cumulative exposure increased from 1.0 to 1.6 [CIs of 0.85 to 2.1] and by quintile of average concentration increased from 1.0 to 1.7 [CIs of 1.1 to 2.3]), supporting the importance of the increasing lung burden of silica in the occurrence of cancer. Overall, the authors concluded that the results support the carcinogenicity conclusion presented by IARC (1997).

To investigate the link between crystalline silica, silicosis and lung cancer, epidemiological data published between 1966 and 2001 were gathered. Over 50 studies were selected and pooled according to type of study and the parameter being linked to lung cancer (i.e. silica exposure, presence of silicosis in subjects). The quality of study, adjustment for confounding factors, co-exposure to other carcinogens and availability of a more recent analysis of a same cohort were taken into consideration in the final selection of the studies. Analysis of the relationship between exposure to silica and lung cancer included 17 cohort and 13 case-control studies. For the analysis of lung cancer versus silicosis, 11 cohort and 5 case-control studies were selected. The third analysis included 6 cohort and 2 case-control studies to evaluate the risk of lung cancer in non-silicotics. A random effect model was used to conduct each meta-analysis. Pooled cancer risk ratios (RRs) were 1.32 (CI 1.23-1.41) for crystalline silica exposure, 2.37 (CI 1.98-2.84) for individuals exposed to silica with confirmed silicosis (Silicotics) and 0.96 (CI 0.81-1.15) for individuals with no evidence of silicosis (non-silicotics) with confirmed exposure to silica, supporting the general observation that silicosis has a stronger temporal relationship with crystalline silica exposure and furthermore support the view that a human silicotic response could be a preliminary stage in the development of cancer.

A more recent meta-analysis included 28 cohort, 15 case-control and two proportionate mortality ratio (PMR) [See Appendix 1] studies from a variety of occupational settings conducted between 1996 and 2005. Risk ratios (RRs) were calculated based on type of study and silicosis status using fixed and random effect models (results presented here are from the random model). RRs for all cohort studies was 1.34 (CI 1.25-1.45), and were 1.69 (CI 1.32-2.16) for silicotics, 1.25 (CI 1.18-1.33) for those with undefined silicosis status and 1.19 (CI 0.87-1.57) for non-silicotics. In the case-control studies, the general RR was 1.41 (CI1.18-1.67), and the same sub-groups as mentioned above resulted in RRs of 3.27 (CI 1.32-8.2), 1.41 (CI1.18-1.70) and 0.97 (CI 0.68-1.38), respectively. The proportionate mortality ratio for the last two studies was 1.24 (CI 1.05-1.47). The authors noted that the association between lung cancer and exposure to crystalline silica was more consistent for silicotics, i.e., those diagnosed with silicosis and RR values split into type of occupational settings in which participants worked.

Based upon the above three meta-analysis studies and the epidemiology studies discussed in IARC (1997), the following can be concluded. Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis. Cancer risk is often more significant in workers exposed to crystalline silica over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours. Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles.

There have been reports of tumours outside of the lungs in persons with high silica exposure; however, these reports are sparse and the data inconsistent and have not been unequivocally linked to exposure to either one of the crystalline forms (quartz or cristobalite). Some of the reported locations are: oesophagus, stomach, liver, skin and bone. Sufficient epidemiological or toxicological data do not currently exist for quantitative assessment of the exposure-response relationship on these other tissues or organs.

Genotoxicity

Potential genotoxicity has been assessed in multiple *in vitro* and *in vivo* assays. Table 1 below gives a brief summary of the positive results observed in each type of assay.

Table 1. Summary of positive results over total number of results for each assay and each category (all studies

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conducted with crystalline silica: quartz, except where indicated).

Assay	Animal data		Human data		Positives/Total	
	In vitro	In vivo	In vitro	In vivo[d]	In vitro	In vivo
Rec Assay	0/1				0/1	
DNA strand break	1/1	2/2	5/5[b]	1/1	6/6	3/3
Sister chromatid exchange	0/1		0/1[c]	1/1	0/2	1/1
Micronucleus	2/3	0/1	2/2[b]	1/1	4/5	1/2
Chromosome aberration	0/1			1/1	0/1	1/1
Aneuploidy/polyploidy	0/3				0/3	
Cell transformation	4/4				4/4	
Hprt mutation	1/2	2/2[a]	1/1[b]		2/3	2/2
Oxidative DNA damage		4/5	2/2		2/2	4/5
DNA binding		1/1				1/1
p53 activation		0/1				0/1

a. one assay conducted with crystalline silica: cristobalite
b. one assay conducted with "ultrafine crystalline silicon dioxide".
c. crystalline silica: tridymite
d. crystalline silica dust (subtypes not provided).

All the *in vivo* human genotoxicity studies are based on three independent studies that used blood samples from workers from diverse occupational settings with confirmed exposures to crystalline silica dust; however, quantification of exposure was not provided. After stratification by smoking status, sister chromatid exchange remained statistically significant in both smokers and non-smokers although the frequency was higher in smokers. For the chromosome aberration assay conducted as part of the same study (blood samples from workers in the stone crusher industry), the increased frequency was no longer significant after stratification. In the DNA damage study of foundry and pottery workers and the micronucleus assay of workers involved in sandblasting and related jobs, results were positive when compared to controls. However, in both studies, smoking status influenced the results, contributing to the increased DNA damage observed since results were greater in smokers versus non-smokers, and the frequency of micronuclei in nasal epithelial cells was higher in smokers (p=0.002) but when using peripheral blood lymphocytes did not differ statistically between smokers and non-smokers who were similarly exposed to silica dust,

The role of *in situ* generation of reactive oxygen species (ROS) and reactive nitrogen species (RNS) has been well established in the following types of DNA damage: small scale insertions, DNA base pair deletion, base modification, chromosomal change/loss, microsatellite instability, DNA strand break, 8-hydroxydeoxyguanosine (8-OHdG) mutation and point mutations. ROS and RNS generation is postulated to be (a part of) the DNA damage mechanism for crystalline silica. Studies are described below to support this hypothesis.

DNA was exposed *in vitro* to various crystalline silica dusts, to H_2O_2, or to both. Results show that DNA damage was limited when dust or H_2O_2 were administered alone but increased with the co-exposure. When the reactive oxygen scavenger, dimethylsulfoxide, was added to the test system, DNA strand break was inhibited, data supporting the viewpoint that it is the presence of radicals generated in response to quartz and cristobalite that causes the DNA damage and not quartz or cristobalite themselves.

Hprt mutation assays in rat alveolar epithelial cells, both *in vitro* and *in vivo,* were positive in response to quartz. The positive results *in vivo* were seen only in the presence of significant inflammatory responses in the treated animals. Also, in a parallel *in vitro* experiment, rat alveolar epithelial cells were incubated with the bronchoalveolar lavage fluid from the rats exposed to quartz. Both macrophage and neutrophil enriched lavage cells induced mutation in the exposed alveolar epithelial cells. Addition of catalase (an enzyme which inactivates H_2O_2) before incubation inhibited the increase in *hprt* mutation.

Rats were exposed to either crystalline or amorphous silica in a manner to induce the same level of

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inflammation in the lungs. The inflammatory response was assessed by measuring the proportion of neutrophils in the bronchiolar lavage fluid. The actual concentrations were 3 and 50 mg/m^3 for crystalline and amorphous silica respectively. The animals were exposed for 13 weeks. *Hprt* mutation frequency was measured in the alveolar epithelial cells at the end of the exposure period. Mutation frequency was greatly increased only in the crystalline silica treated rats; no treatment related increase was found in the rats treated with the amorphous form.

In an 8-OHdG assay conducted to monitor DNA damage by reactive oxygen species, female rats were exposed to 0, 0.3, 1.5 and 7.5 mg/animal of quartz via intratracheal instillation. Effects were observed 90 days post-exposure. A clear dose-response relationship was identified between quartz exposure and various inflammation markers (differential cell count, protein, lung surfactant lipids and tumour necrosis factor alpha). Inflammation was present starting at the lowest dose. However, 8-OHdG showed a statistically significant increase starting at 1.5 mg/animal only. Similarly, in another study, 8-OHdG and DNA strand breaks were observed at concentrations of or above 10 ug/m^3 in rat lung epithelial cells.

In the aim of investigating the role of ROS in lung carcinogenesis, rat lung epithelial cells were incubated with polymorphonuclear (PMN) leukocytes (involved in the inflammatory process and responsible for the release of certain ROS) or hydrogen peroxide. Statistically significant increases in 8-OHdG were observed in the presence of PMN or hydrogen peroxide in a dose-response manner.

In a series of experiments which used *in vitro* stimulation of macrophages with crystalline silica and *in vivo* intranasal instillation of crystalline silica in mice, it was demonstrated that that the chronic fibrosis seen in a murine model of silicosis *in vivo* is dependent on the presence of adaptor molecule ASC and Nalp3 inflammazome. These data support a potential mode of action whereby silica triggers cellular responses that in turn activate alveolar macrophages, resulting in an inflammatory response and silicosis. In mice deficient in Nalp3 inflammazome, the development of inflammation and collagen deposition was significantly reduced compared with normal mice 3 months after the initial intranasal instillation of silica.

Analysis of Lung Tumour Data

The weight of evidence for both rats and humans indicates that fibrotic and silicotic lesions in the lung result from inhalation exposure to crystalline silica and that lung cancer is secondary to those lesions in the lung. Although the mechanism of induction for the lung tumours has not been fully elucidated, there is sufficient supportive mode of action evidence from the data presented to demonstrate that a threshold approach to risk assessment is appropriate based on an understanding of the key events in the pathogenesis of crystalline silica induced lung tumours. The body of evidence include the following:

- In experimental studies, all rats that developed tumours also showed fibrosis.
- Adenocarcinomas, the most common type of tumour identified in rats, are commonly associated with fibrosis and deeply scarred lung tissue.
- Experimental rat studies showed a clear progression of the effects from initially mild inflammation, followed by fibrosis over-time, leading eventually to lung tumours.
- Tumours are not present in all treated species dosed in the same way.
- The tumours, both in rats and humans, are concentrated in the lungs only, although other organs are indirectly exposed.
- In human studies, cancer risk is often more significant in workers exposed over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours.
- Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles
- Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis.
- For genotoxicity, in vitro results were mostly mixed and in vivo results were mostly positive. However, the vast majority of the positive genotoxicity assay results can be explained by the generation of reactive oxygen species, as demonstrated experimentally, where ROS scavenging prevents the genotoxicity.
- *In vivo*, macrophage deficient mice (macrophages produce ROS in response to crystalline silica) do not develop silicosis nor do they develop tumours and the Nalp3 inflammazome, a key player in the macrophage initiated inflammatory response, is required for the development of pulmonary fibrosis after

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inhalation of silica.

- Though inhalation exposure to crystalline silica in multiple occupational settings is clear, the increase in risk, based on the several recent meta-analyses of the multiple human epidemiological studies, remains low.

It is worth noting that where aggressive engineering controls have been made to reduce silica dust levels in the workplace (Sweden), silicosis has been eliminated. By corollary, existing exposures outside of the workplace in such areas do not pose a risk for silicosis to the general population.

The respirable forms of quartz and cristobalite possess properties indicating a hazard for human health (repeated dose toxicity, carcinogenicity and genotoxicity). The mode of action in the lungs involves irritation, inflammation and reactive species formation, leading to silicosis, and eventually to tumour formation.

Exposure

Uses

Consistent with oxygen and silicon being the two most abundant elements in the Earth's crust, silicon-oxide minerals, including quartz are ubiquitous in the natural environment. In particular, as a component of sand, quartz may find use in a diverse array of applications. Several high volume uses include, but are not limited to, the use of sand as a filling material for the construction of roads and in general building activities, the use of sand and gravel aggregates as abrasives on roads in winter and the use of fly-ash, which may contain 4-14% quartz and 0.5-1% cristobalite, as a cement additive. These abrasives when used on winter roads are usually mixed with road salts and may be sand only, stone dust, sand and gravel aggregates, or pre-treated sand. They are used mainly by rural municipalities or in areas where cold temperatures diminish the efficiency of salts for de-icing. Quantities of abrasives used in Canada were 5.73×10^9 kg, 4.59×10^9 kg, and 4.93×10^9 kg for 2007, 2008 and 2009, respectively.

Industrial sand, high purity silica sand products with closely controlled sizing are expected to contain quartz and cristobalite, include lump silica (2-3mm up to 15 cm or more), silica sand (75µm to 2-3mm) and silica flour (less than 75µm). Lump silica may be used in the production of silicon alloys, silica bricks, and the linings of certain types of pulverizers (eg. ball mills and tube mills).

Silica sand may be used in the manufacture of glass and glass fibres, silicate chemicals and silicon carbide, the hydraulic fracturing of wells, foundry moulding, and for sandblasting. Silica flour may find use in the ceramics and cement industries, as a filler and extender in rubber and coatings, and as an abrasive in soaps.

Natural clays, such as bentonite and fuller's earth, are used in cat litters for their high water absorbance capacities. Quartz is a natural component of these clays, and consequently, it may be present in cat litter products. High purity α-quartz is a piezoelectric material, which means that application of a voltage induces a distortion in the crystal shape and vice versa. This ability to interconvert electrical and mechanical energy has led to the use of quartz crystals in electronic devices requiring precise timing control, for example telephones, radios, watches and computers.

According to a survey conducted in Canada, quartz and cristobalite are also used in abrasives, adsorbents, filter products (diatomaceous earth), grout and cement. These substances reportedly also find use as fillers, which add bulk and improve wear resistance, in paints and coatings, adhesives, sealants, polymer films, caulking, epoxy resins and silicones. Also, quartz is listed as an ingredient in 60 cosmetic products in Canada. The types of products include anti-wrinkle preparation, eye and face makeup, lipstick, hair dyes, shampoos and grooming products, as well as skin cleansers, moisturizers and tanning preparations.

Natural Sources

In Canada, quartz naturally occurs in many types of rock formations. Those with high silicon dioxide content (95% SiO_2 or more) include vein and massive intrusion bodies, quartz pebbles, silica sand, sandstone and quartzite. Sandstone is a sedimentary rock mostly composed of quartz grains cemented by a bonding material such as clay, calcite or iron oxide. Quartzite is a hard, compact, metamorphosed sandstone made of grains of quartz firmly bonded with a siliceous cement. Mineral aggregates (e.g., sand and gravel) have variable silicon dioxide content. Quartz is also found as crystals, aggregates or discrete particles in certain igneous rocks (e.g., granites and pegmatites), soils, sediments, air and surface water. This omnipresence is consistent with the fact that silicon is the second most abundant chemical element on Earth.

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Cristobalite is naturally produced in the ashes of volcanic eruptions, and by combustion metamorphism which is a local phenomenon of spontaneous combustion of naturally occurring substances such as bituminous rocks, coal or oil. It may be found in cavities in volcanic rocks and in thermally metamorphosed sandstones and may also be a transient stage in the diagenesis of diatomaceous shale with the result that soils made of these geologic formations may be rich in cristobalite. Unlike quartz, the natural occurrence of cristobalite is limited to specific geographic regions and mineral types.

Anthropogenic Sources

Natural quartz is isolated from ore via beneficiation, which involves milling or grinding the material into particles that are separated into desired mineral and waste. The materials obtained are either used directly or further purified. In Canada, in 2006, 2.146×10^{9} kg of pure quartz were mined, and 2.385×10^{11} kg of sand and gravel aggregates were produced. The proportion of quartz in silica sand deposits and gravel aggregates will vary from one site to another.

Cristobalite can form from silica melts during the preparation of silica glass; quartz is not obtained from melts but is manufactured at elevated temperature and pressure via a hydrothermal process. Cristobalite also forms during the calcination[2] of diatomaceous earth.

Human Exposure Estimate

Ambient air

The exposure assessment is focussed on respirable quartz and cristobalite, which in ambient air comprises a component of total particulate matter (PM). In Canada, data on the concentrations of silicon in PM was available and used as a surrogate for quartz and cristobalite. This approach is conservative because the measured silicon includes all silicon-containing substances and therefore represents the upper limit for quartz and cristobalite in ambient air.

The National Air Pollution Surveillance (NAPS) Program measured concentrations in $\mu g/m^3$ of silicon in PM with aerodynamic radii less than 2.5 µm ($PM_{2.5}$ (dichot)), and from 2.5 to 10 µm (PM_{10} (dichot)) (the total particulate matter with aerodynamic radii less than 10 µm (PM_{10}) is obtained by adding these values) in Canada. In 2009, as part of the NAPS Program, silicon concentrations were determined on over 1600 samples of $PM_{2.5}$(dichot) and over 1500 samples of PM_{10}(dichot) at 24 urban locations across Canada. An estimate of exposure to quartz and cristobalite can be obtained by assuming that all the silicon in the PM is represented stoichiometrically as SiO_2, and multiplying the reported concentration of silicon by 2.14 to obtain a value for silica.

The intake of respirable quartz and cristobalite by the general population of Canada is estimated using a range covering the lowest 50^{th} percentile SiO_2 concentration in PM_{10}, measured in Pt. Petre, ON, (0.12 $\mu g/m^3$) to the highest 50^{th} percentile concentration in PM_{10} measured in Calgary, AB (2.1 $\mu g/m^3$). The 50^{th} percentile SiO_2 concentrations ranged from 0.1 to 2.1 $\mu g/m^3$ across the survey sites; the top of this range is quite close to the average of the maximum values for the 24 sites (3.7 $\mu g/m^3$). The outdoor data were used to represent the indoor levels, because information on indoor silicon concentrations was not available, and the range of PM_{10} measured indoors is generally lower than the outdoor range. Thus, this approach conservatively overestimates indoor exposure in homes.

The highest exposure group based on these calculations is children ages 0.5 to 4 years with an estimated daily intake ranging from 0.07 to 5.26 µg/kg-bw per day; the estimated daily intake decreases with age due to changes in the ratio of inhalation rates to body weights; the daily intake of adults, 20-59 years old, is estimated to range from 0.03 to 2.00 µg/kg-bw per day.

Consumer Products

Exposure to respirable quartz from the use of cosmetic products, which contained quartz as an ingredient, was considered low because they are not formulated for spray application, the loose powders were reported to contain less than 0.1% quartz, and in these products the substance is not expected to be associated with other components of the formulation and not available in a free form.

For consumer Do It Yourself (DIY) activities around the home, the highest mean breathing zone concentration of particles from sanding dry wall (median cut-point of 10µm) of 6.31 mg/m^3, was used to derive an upper-

[2] Calcinations: Heat treating a substance, but without fusion, to bring about change in its physical or chemical constitution.

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bound exposure estimate ranging from 2 to10 µg/kg-bw per event.

Quartz is used to formulate a large number of paints and coatings. To estimate potential inhalation exposure to quartz from these products, the spray painting of wall paints with an airless spray gun was considered appropriate as a conservative scenario. Exposure to respirable paint particles was estimated using data from controlled a laboratory study in which walls of poorly ventilated test rooms were painted by professional painters using an airless sprayer to apply interior latex paint. The maximum concentration of 13% quartz in paint in Canada was used to estimate exposure. The upper-bound estimate of exposure to quartz, based on the maximum concentration of 13% quartz in paint in the Canadian market and the maximum concentration of respirable paint particles measured in these controlled studies when recommended personal protective equipment is used, is 0.954 µg/kg-bw per event.

Inhalation of ambient air containing quartz and cristobalite is the dominant pathway of chronic exposure (excluding that from DIY activities) for the general population. Because SiO_2 makes up only approximately 5% of PM_{10}, silicon concentrations (expressed as SiO_2) measured in the Canadian NAPS survey of 24 urban locations were considered most relevant to the estimation of exposure by the general population. Quartz and cristobalite comprise only a portion of the total SiO_2 in PM_{10}, therefore, the use of the total silicon concentration to represent the upper bound crystalline silica concentrations results in an overestimation of exposure.

Appendix 1: Definitions of Epidemiological Terms in the ITAP

SMR (Standardized Mortality Ratio): The ratio (x 100) of observed to expected deaths in a study population. Expected deaths are calculated by applying a set of standard age-specific mortality rates to the age distribution of the study population. Standardized ratios are only useful for comparisons. They have no intrinsic meaning.

OR (Odds Ratio): In epidemiological case-control studies, a relative measure of disease occurrence. The odds in favour of a particular disease occurring in an exposed group are divided by the odds in favour of its occurring in an unexposed group. If the condition being studied is rare, the odds ratio is a close approximation to the relative risk.

RR (Risk Ratio): The probability of the occurrence of a disease in a group that has been exposed to some environmental, medicinal, microbial, or toxic influence, relative to its probability in a randomly selected population.

PMR (Proportionate Mortality Ratio): Proportionate mortality is the proportion of deaths in a specified population over a period of time attributable to different causes. Each cause is expressed as a percentage of all deaths, and the sum of the causes must add to 100%. These proportions are not mortality rates, since the denominator is all deaths, not the population in which the deaths occurred. Thus, proportionate mortality ratio is a measure of the frequency of occurrence of the proportionate mortality in a defined population during a specified interval of time.

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Toxicity Profile

Diammonium peroxidisulfate
Ammonium persulfate
(CAS No. 7727-54-0)

Diammonium peroxisulfate or ammonium persulfate has been reviewed in the OECD-SIDS program (OECD, 2005a,b).

Ammonium persulfate is distributed into the water compartment in the ionic form of the ammonium cation and persulfate ion. The persulfate anion will readily hydrolyze (decompose) into sulfate ions.

Acute Toxicity

The acute oral LD_{50} in rats is 495 mg/kg, and the acute dermal LD_{50}s in rats and rabbits are >5,000 mg/kg. In acute inhalation studies in rats, the 4-hour LC_{50} was generally greater than the maximum attainable concentration (>2,950 mg/m^3 for ammonium persulfate).

Irritation

Ammonium persulfate is slightly irritating to the eye and skin of rabbits. Studies in humans indicate that aqueous solutions of 5% persulfate or higher can cause skin irritation.

Sensitization

Results of animal skin sensitization tests (Buehler Test and Maximization Test) were negative when persulfate was applied topically, but was positive when persulfate was injected intradermally in induction and challenge phases in a non-standard Maximization Test. Numerous dermal challenge tests indicate that all persulfates are dermal and respiratory sensitizers in humans occupationally exposed to persulfates in hairdressing salons and, in one case, in a production facility. In controlled clinical trials with non-occupationally exposed-subjects (ammonium and sodium salts), no sensitization reactions were observed.

Repeated Dose Toxicity

Rats were fed in their diet 0, 300, 1,000 or 3,000 ppm sodium persulfate (0, 23, 100 and 225 mg/kg/day) for 90 days. On day 48 of the study, the concentration of the group receiving 1,000 ppm was increased to 5,000 ppm for the remainder of the study. Body weights was decreased in the two highest dose groups during the last six weeks of treatment. There were no treatment-related effects on urinalysis, clinical chemistry or hematology parameters. Pathological findings were limited to the 3,000

ppm group only and consisted of necrosis and atrophy of the gastrointestinal tract epithelial lining. The absence of the gastrointestional lesions in the group receiving 1,000 ppm for 8 weeks, followed by 5000 ppm for 5 weeks, indicates that the lesions are related both to concentration in diet (dose) and length of exposure. There were no treatment-related pathological findings in reproductive organs or any other organ system or tissue.

Genotoxicity

Sodium persulfate was not genotoxic in a bacterial reverse mutation (Ames) assay or in an unscheduled DNA synthesis (UDS) assay with rat hepatocytes. It was also not active in a rat bone marrow micronucleus assay and when tested *in vivo* in a rat hepatocyte UDS assay.

Carcinogenicity

A 51-week dermal study in female SENCAR mice exposed to 0.2 ml of a 200 mg/ml solution of ammonium persulfate showed that it is neither a tumor promoter nor a complete carcinogen when applied to the skin.

Reproductive/Developmental Toxicity

In a developmental/reproduction study with ammonium persulfate in rats (OECD 421), no effects on reproductive performance, fertility, fetal anomalies, fetal viability, spermatogenesis, spermatogenic cycle were reported up to 250 mg/kg/day. Dose levels were chosen based on the acute lethality studies for the ammonium salt and on a 90-day repeat-dose study in rats with the sodium salt (high dose: 225 mg/kg/day). In the developmental/reproduction study, animals were dosed prior to and during mating through gestation until lactation day 4. There was a transient depression in pup body weight at the 250 mg/kg dose level on lactation day 0 which resolved by day 4. This effect was not considered adverse. Based on the available data, the persulfates do not show evidence of reproductive or developmental toxicity. The NOAEL is 250 mg/kg/day.

Key Study/Critical Effect for Screening Criteria

The Australian drinking water guideline value for sulfate may apply to sulfate (500 ppm, health; 250 ppm, aesthetic). There are no existing drinking water guideline values for ammonium ions.

References

OECD (2005a). IUCLID Data Set for Ammonium persulfate (CAS No. 7727-54-0); Potassium persulfate (CAS No. 7727- 27-1); Sodium persulfate (CAS No. 7775-27-1), UNEP Publications.

OECD (2005b). Screening Information Dataset (SIDS) Initial Assessment Report for Ammonium persulfate (CAS No. 7727-54-0); Potassium persulfate (CAS No. 7727-27-1); Sodium persulfate (CAS No. 7775-27-1), UNEP Publications.

Toxicity Profile

Diatomaceous Earth, Calcined
(CAS No. 91053-39-3)

Silica is an off-white granule that occurs naturally in various crystalline and amorphous or other non-crystalline forms. Crystalline silica is characterized by silicon dioxide (SiO_2) molecules oriented in fixed, periodic patterns to form stable crystals. The primary crystalline form of silica is quartz. Other crystalline forms of silica include cristobalite, tripoli and tridymite. Particle size is a key determinate of silica toxicity, since toxicity is restricted to particles that are small enough to be deposited into the target regions of the respiratory tract.

Uncalcined diatomaceous earth (CAS No. 61790-53-2) typically contains around 1% crystalline silica. When diatomaceous earth is subjected to pressure or is processed ("calcined") at temperatures above 1000°C some of the amorphous silica is converted to crystalline silica in the form of cristobalite. Calcined diatomaceous earth can contain anywhere from 1% to 75% cristobalite.

Oral Exposure

No oral studies were located; however, crystalline silica is not expected to exhibit toxicity by the oral route. Although absorption studies were not found for crystalline silica, kinetic studies on amorphous silica show no absorption from the gastrointestinal tract.

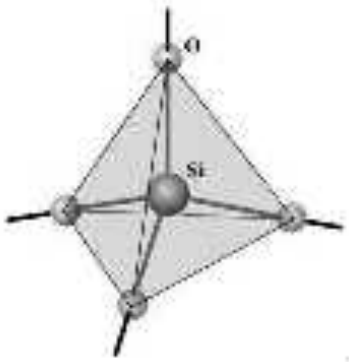
Dermal Exposure

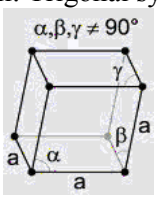
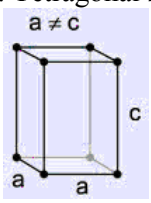
No dermal studies were located; however, crystalline silica is not expected to exhibit toxicity by the dermal route.

Inhalation Exposure

See attached OECD-SIDS Initial Targeted Assessment Profile on Quartz and Cristobalite, SIAM 32, 19-21 April 2011.

INITIAL TARGETED ASSESSMENT PROFILE (Human Health)

CAS No.	Quartz: CAS RN 14808-60-7 Cristobalite: CAS RN 14464-46-1
Chemical Name	Quartz and Cristobalite
Structural Formula	Molecular Formula: SiO_2 

Unit Cell: Trigonal symmetry	Unit Cell: Tetragonal symmetry
	
Quartz: CAS RN 14808-60-7	Cristobalite: CAS RN 14464-46-1

SUMMARY CONCLUSIONS OF THE TARGETED ASSESSMENT

NOTE: The present assessment is targeted to address the following human health endpoints: repeated dose toxicity and carcinogenicity via the inhalation route of exposure, and genotoxicity. It cannot be considered as a full SIDS Initial Assessment. Summary information on exposure is also reported here. Other endpoints for human health and the environment included in the Canadian screening assessment but have not been presented to OECD member countries, and thus are not included in this profile.

The final screening assessment will be published under the responsibility of the Government of Canada.

Rationale for Targeting the Assessment

The Government of Canada "categorized" or prioritized all 23,000 chemical substances on its Domestic Substances List (DSL) from 1999 to September 2006, as required by its *Canadian Environmental Protection Act, 1999* (CEPA 1999). Additional details may be found at http://www.chemicalsubstanceschimiques.gc.ca/about-apropos/categor/index-eng.php. Using information from Canadian industry, academic research and other countries, Government of Canada scientists applied a set of rigorous tools to the 23,000 chemical substances on the DSL. They were categorized to identify those that were: **inherently toxic** to humans or to the environment and that might be **persistent** and/or **bioaccumulative**; and substances to which people might have **greatest potential for exposure**. During this priority-setting exercise, distinct approaches were taken for identifying substances of likely concern for human health and the environment, and subsequent assessment activities may have focused on either human health or ecological endpoints. Through categorization, the Government of Canada has identified approximately 4,000 of the 23,000

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chemical substances on the DSL as priorities for further assessment, research and/or measures to control their use or release. Quartz and cristobalite were identified at that time, applying the categorization criteria, as high priorities for human health risk because they were considered to pose greatest potential for exposure and their respirable forms are classified by the International Agency for Research on Cancer as carcinogenic to humans (quartz and cristobalite) and by the National Toxicology Program as known human carcinogens (crystalline silica). These substances did not meet the ecological categorization criteria for bioaccumulation potential or inherent toxicity to aquatic organisms.

Under the Canadian legislation a determination of whether one or more of the criteria of the CANADIAN ENVIRONMENTAL PROTECTION ACT (CEPA) 1999, section 64 are met is based upon an assessment of potential risks to the environment and/or to human health associated with exposures in the general environment. For humans, this includes, but is not limited to, exposures from ambient and indoor air, drinking water, foodstuffs, and the use of consumer products. A conclusion under CEPA 1999 on the substances in the Chemicals Management Plan (CMP) Challenge is not relevant to, nor does it preclude, an assessment against the hazard criteria specified in the Controlled Products Regulations, which is part of the regulatory framework for the Workplace Hazardous Materials Information System [WHMIS] for products intended for workplace use.

Physical-chemical properties

The silicon dioxide group represents a polymorphic category containing a large number of forms identical in composition but with different atomic arrangements which afford different chemical properties. There are two sub-categories within this group: crystalline silica, to which the present substances quartz and cristobalite belong, and non-crystalline or amorphous silica. The key distinction between these sub-categories is that in crystalline substances, the building blocks are arranged in regular, repeating 3-dimensional pattern having long range order, whereas amorphous materials do not display long range order. In all forms of silica, (crystalline and non-crystalline), the silicon atom is tetrahedral and bound to four neighbouring oxygen atoms.

Quartz and cristobalite are solid at room temperature, existing normally as colourless or white crystals. The melting points for quartz and cristobalite are 1400-2000 ^{o}C and 1713-1728 ^{o}C, respectively and for both compounds, the boiling point is 2230^{o}C. Even though no experimental data were available, their vapour pressure and Henry's Law constant are likely negligible. Log K_{ow} (octanol-water partition coefficient) and log K_{oc} (organic carbon-water partition coefficient) are not applicable to these substances. The densities range from 2500-2700 kg/m^3 for quartz and 2300-2380 kg/m^3 for cristobalite.

The very similar physico-chemical properties of quartz and cristobalite reflect their closely related crystal forms. The solubility of crystalline silicates decreases as a function of silica tetrahedral packing density and long-range crystal order. For example, cristobalite has a more open framework structure than quartz and its density is lower, therefore, its solubility is higher. The water solubility of these minerals is also function of temperature, pH, particle size, and the presence of a disrupted surface layer. This may explain the variability of solubility values reported by many authors. The most probable solubility value for quartz is approximately 3.8 mg Si/L, or 6.4 mg/L expressed as the SiO_2 species, while the solubility of cristobalite is approximately 8.7 mg Si/L, or 18 mg SiO_2/L. The kinetics of dissolution of these substances is slow due to the high activation energy required to hydrolyse the Si-O-Si bond.

Human Health Targeted Endpoints

The majority of the studies described here have been reviewed by the International Agency for Research on Cancer (IARC 1997). However, additional data relevant to the screening assessment were identified up to August 2010.

Repeated dose toxicity/non-neoplastic effects (development of silicosis).

Studies on animals

Significant short-term and subchronic studies have demonstrated adverse effects in the lungs, while one of the 6 studies showed effects on the spleen in mice. Rats were exposed to 0, 10 or 100 mg/m^3 of cristobalite via inhalation for 6 hours/day during 3 days. Animals were observed 3 months after exposure. Elevated levels of granulocytes and elevated markers of cytotoxicity from the lung lavage fluid were noted in all exposed groups. Another study of similar duration (9 days) conducted in mice also identified a LOAEC of 10 mg/m^3. Effects observed included minimal interstitial thickening, accumulations of mononuclear cells and slight lymphoid tissue hypertrophy in the lungs.

In a 4-week inhalation study, female rats were exposed to 0, 0.1, 1 or 10 mg/m^3 of quartz 6 hours/day, 5 days/week. Bronchoalveolar lavage fluid was evaluated at 1, 8, and 24 weeks after exposure. Elevated levels of

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granulocytes and significant elevation of markers of cytotoxicity (Lactate dehydrogenase [LDH] and β-glucuronidase [β-glu]) were observed at 1 mg/m^3 and higher. The increased levels of LDH and β-glu were only significant at 24 weeks after exposure. A LOAEC of 1 mg/m^3 was identified at 24 weeks.

Male rats (4 animals per dose) were exposed to 0 or 3 mg/m^3 of cristobalite via inhalation for 6 hours/day, 5 days/week during 13 weeks. Pulmonary inflammation and fibrosis were observed in the exposed group at the end of treatment. When mice were similarly exposed to 5 mg/m^3 of quartz for 6 hours/day, 5 days/week for 15 or 27 weeks, the authors observed increased spleen weight and formation of plaque in the spleen.

In two separate studies, in which rats or hamsters were exposed to quartz via inhalation for at least 6 months, LOAECs of 2 and 3 mg/m^3 were identified, respectively. All the effects observed were related to inflammation and fibrosis of the lung tissue.

Several chronic studies investigated exposure of the respirable forms (i.e. accumulated via inhalation in the lung tissues) of quartz and cristobalite to rats, mice and hamsters. The following is a description of the study in which the lowest non-neoplastic LOAEC was determined. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz, containing 74% of respirable quartz, through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. The mean mass of particle at the end of the exposure period was 0.91 mg/lung. The LOAEC identified was 0.74 mg/m^3 (adjusted for 74% respirable quartz) based on lipoproteinosis, multifocal, inflammatory cell infiltrate and alveolar hyperplasia.

Human epidemiology data

In humans, the lowest observed adverse effect level was identified in a U.S. cohort study. The study was conducted on 3330 gold miners (all are males), who had an average of 9 years underground exposure during the period 1940 to 1965. The cohort was followed up through 1990. Silicosis[1] was identified through death certificates or chest X-rays. A job-exposure matrix together with work history was used to estimate individual exposure. The total silica content in the respirable dust in the mine was estimated at 13% and the median crystalline silica exposure was 0.05 mg/m^3. In this sub population of miners, 170 cases of silicosis were identified. The best predictor for risk of silicosis was cumulative exposure, which varied from less than 1% for a 0.5 mg/m^3-year exposure to 68-84% when exposed to more than 4 mg/m^3-year (based on the average daily dust exposure during the workday each year and summed over time for each miner). The main limitations identified by the authors include the limited number of radiographic surveys, the potential bias from death certificates

[1] Silicosis: Lung disease caused by inhalation of crystalline silica dust, and resulting in inflammation and scarring in forms of nodular lesions in the upper lobes of the lungs. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics). It does not follow that a history of exposure to silica necessarily results in silicosis (Nonsilicotics). The typical "Silicotic" lung nodule is shown in Figure 1.

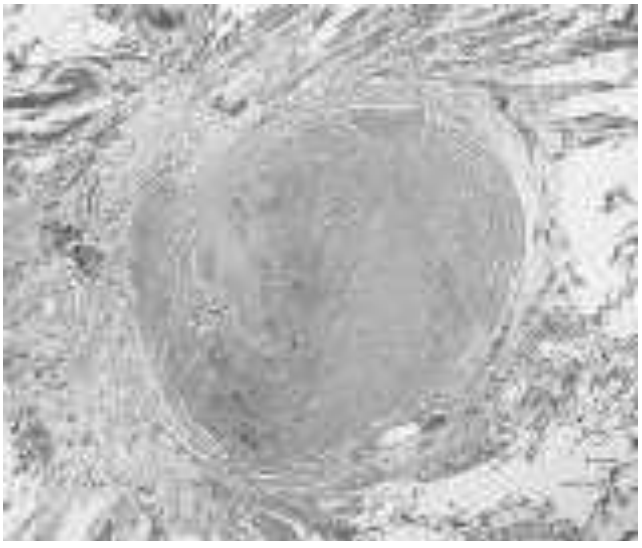


Figure 1. Silicotic nodule characterised by a central zone of hyalinised collagen with a whorled appearance and peripheral dust-containing macrophages (Rees and Murray, 2007).

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(relying on death certificates instead of relying on repeated x-rays, which were lacking for each miner, may have underestimated the number of cases) and the fact that the conversion of dust counts to

gravimetric measurements may not be accurate based on the estimation of 13% silica content in the respirable dust (although based on a relatively large number of samples (n = 82) collected in two different surveys, there was broad range of content in these samples (1% to 48%, SD = 9), and the percentage of respirable quartz may have differed in earlier years, but data were lacking for these years).

Two other human studies have identified similar LOAECs based on the critical endpoint of radiographic confirmed silicosis. A LOAEC of 0.053 mg/m^3 (mean exposure) was identified in a cross sectional study of South African gold miners and a LOAEC of 0.064 mg/m^3 (mean exposure) was derived in a mining community population-based random sample survey in Colorado.

Carcinogenicity studies

Studies on animals

Experimental studies conducted in rats have shown clear and consistent increases in lung tumours after chronic inhalation exposure. In the nine rat studies identified, five were inhalation studies and four were intratracheal instillation studies. All studies except one inhalation study showed increased incidence of lung tumours. For the inhalation studies with treatment related tumours, concentrations ranged from 1 to 50 mg/m^3 (1, 6, and 30 mg/m^3 of DQ-12 quartz; 12 and 50 mg/m^3 of Min-U-Sil 5 quartz) and duration of exposure ranged from 29 days to 2 years. In the inhalation study with no treatment-related tumours, exposure was 60 mg/m^3 of Sikron F300 quartz for 13 weeks. The following is a description of the neoplastic results in the study also identified as the critical study for non-neoplastic results. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. In the exposed group, 18 animals developed tumours (12 in females, 5 in males), as opposed to 3 and 2 for the control and positive control groups respectively. The majority (10/18) of the tumours observed were adenocarcinomas. The mean mass of particles in the lungs at the end of the exposure period was 0.91 mg/lung.

For the intratracheal instillation studies, doses ranged from 4 to 57 mg/kg-bw (based on 7, 12 or 20 mg/animal of Min-U-Sil (5) quartz or 20 mg/animal of novaculite quartz). Exposure regimes were diverse and included single instillation with observation for up to two years, to weekly instillation for 10 weeks. It is noteworthy that the single intratracheal administration of a 95% pure quartz particles (<5 μm) resulted in an increased incidence of silicotic granulomas after 3 weeks and lung tumours after 11 months. The most common tumours reported across the long term rat studies were adenocarcinomas, however other tumours such as squamous-cell carcinoma, alveolar carcinoma and bronchiole-alveolar adenoma were also reported, and all animals that developed tumours also showed some degree of fibrosis.

Of particular interest is the intratracheal instillation study, investigating the sequence of pathological events leading to lung tumors. An unspecified number of rats/sex/dose received a single intratracheal instillation of various crystalline silica dusts or ferric oxide, allowing direct administration into the bronchial tree. The doses were 12 or 20 mg of Min-U-Sil 5 quartz (MQZ), 12 mg of hydrofluoric-acid-etched Min-U-Sil 5 quartz (HFMQZ), 12 mg of cristobalite, 12 mg of tridymite and 12 mg of ferric oxide suspended in saline. All groups were observed until six months post exposure, except for both MQZ groups, the HFMQZ and the ferric oxide group which were observed up until 17 months post-exposure. Interim sacrifices were conducted at 6, 11 and 17 months. The rat lungs showed a clear progression of effects. The sequence of pathological events were, an initial inflammatory response leading to a marked hyperplasia and hypertrophy of alveolar cells after one month, and at six months hyperplasia was evident but no lung tumours were observed. In this study, lung tumours were observed starting at the 11 month sacrifice with a 17% and 42% incidence in males and females (based on 3/18 males and 8/19 females), respectively, and at 17 months incidences were 32% and 59% (based on 6/19 males and 10/17 females, respectively). No lung tumours were found in ferric oxide treated rats. Similar studies have also been conducted in hamsters and mice. Although treated mice and hamsters showed treatment related signs (inflammation or fibrosis), no tumours were observed in hamsters. No increase in the incidence of lung tumours was seen in mice treated with quartz; however silicotic granulomas and lymphoid cuffing around airways but no fibrosis were seen in the lungs of quartz-treated mice.

Human epidemiology data

There is an extensive dataset of human studies investigating the link between crystalline silica exposure and cancer. IARC (1997) identified over 50 epidemiological studies based on occupational exposure to dust containing respirable crystalline silica. Main industry sectors from which the human data is derived include gold mines, foundries, granite/stone industry, pottery workers and refractory brick workers. From the least confounded studies, it was noted that lung cancer tended to increase with the following parameters: cumulative

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exposure; duration of exposure; peak intensity of exposure; presence of radiographically defined silicosis; and length of follow-up time from date of silicosis diagnostic. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics).

Since the 1997 IARC report, a large number of epidemiological studies have been published, with the more recent studies being updates from supplementary follow-up of results from previously assessed case-control studies cohorts, new results based on refined exposure assessments or adjustment for confounders or meta-analyses of the pooled data from these epidemiology studies

In a meta-analysis of the data from 10 cohort studies of gold, tin and tungsten miners, granite workers, industrial sand, diatomaceous earth and pottery workers with quantitative exposure estimates for crystalline silica were pooled in order to analyse the risk related to lung cancer. The pooled cohort standardized mortality ratio (SMR, against national rates) [See Appendix 1 for definition] was 1.2 (Confidence Interval [CI] 1.1-1.3). The results from the case-control analyses show a statistically significant trend with duration of exposure (odds ratios (ORs) [See Appendix 1] by quintile of cumulative exposure increased from 1.0 to 1.6 [CIs of 0.85 to 2.1] and by quintile of average concentration increased from 1.0 to 1.7 [CIs of 1.1 to 2.3]), supporting the importance of the increasing lung burden of silica in the occurrence of cancer. Overall, the authors concluded that the results support the carcinogenicity conclusion presented by IARC (1997).

To investigate the link between crystalline silica, silicosis and lung cancer, epidemiological data published between 1966 and 2001 were gathered. Over 50 studies were selected and pooled according to type of study and the parameter being linked to lung cancer (i.e. silica exposure, presence of silicosis in subjects). The quality of study, adjustment for confounding factors, co-exposure to other carcinogens and availability of a more recent analysis of a same cohort were taken into consideration in the final selection of the studies. Analysis of the relationship between exposure to silica and lung cancer included 17 cohort and 13 case-control studies. For the analysis of lung cancer versus silicosis, 11 cohort and 5 case-control studies were selected. The third analysis included 6 cohort and 2 case-control studies to evaluate the risk of lung cancer in non-silicotics. A random effect model was used to conduct each meta-analysis. Pooled cancer risk ratios (RRs) were 1.32 (CI 1.23-1.41) for crystalline silica exposure, 2.37 (CI 1.98-2.84) for individuals exposed to silica with confirmed silicosis (Silicotics) and 0.96 (CI 0.81-1.15) for individuals with no evidence of silicosis (non-silicotics) with confirmed exposure to silica, supporting the general observation that silicosis has a stronger temporal relationship with crystalline silica exposure and furthermore support the view that a human silicotic response could be a preliminary stage in the development of cancer.

A more recent meta-analysis included 28 cohort, 15 case-control and two proportionate mortality ratio (PMR) [See Appendix 1] studies from a variety of occupational settings conducted between 1996 and 2005. Risk ratios (RRs) were calculated based on type of study and silicosis status using fixed and random effect models (results presented here are from the random model). RRs for all cohort studies was 1.34 (CI 1.25-1.45), and were 1.69 (CI 1.32-2.16) for silicotics, 1.25 (CI 1.18-1.33) for those with undefined silicosis status and 1.19 (CI 0.87-1.57) for non-silicotics. In the case-control studies, the general RR was 1.41 (CI1.18-1.67), and the same sub-groups as mentioned above resulted in RRs of 3.27 (CI 1.32-8.2), 1.41 (CI1.18-1.70) and 0.97 (CI 0.68-1.38), respectively. The proportionate mortality ratio for the last two studies was 1.24 (CI 1.05-1.47). The authors noted that the association between lung cancer and exposure to crystalline silica was more consistent for silicotics, i.e., those diagnosed with silicosis and RR values split into type of occupational settings in which participants worked.

Based upon the above three meta-analysis studies and the epidemiology studies discussed in IARC (1997), the following can be concluded. Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis. Cancer risk is often more significant in workers exposed to crystalline silica over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours. Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles.

There have been reports of tumours outside of the lungs in persons with high silica exposure; however, these reports are sparse and the data inconsistent and have not been unequivocally linked to exposure to either one of the crystalline forms (quartz or cristobalite). Some of the reported locations are: oesophagus, stomach, liver, skin and bone. Sufficient epidemiological or toxicological data do not currently exist for quantitative assessment of the exposure-response relationship on these other tissues or organs.

Genotoxicity

Potential genotoxicity has been assessed in multiple *in vitro* and *in vivo* assays. Table 1 below gives a brief summary of the positive results observed in each type of assay.

Table 1. Summary of positive results over total number of results for each assay and each category (all studies

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conducted with crystalline silica: quartz, except where indicated).

Assay	Animal data		Human data		Positives/Total	
	In vitro	In vivo	In vitro	In vivo[d]	In vitro	In vivo
Rec Assay	0/1				0/1	
DNA strand break	1/1	2/2	5/5[b]	1/1	6/6	3/3
Sister chromatid exchange	0/1		0/1[c]	1/1	0/2	1/1
Micronucleus	2/3	0/1	2/2[b]	1/1	4/5	1/2
Chromosome aberration	0/1			1/1	0/1	1/1
Aneuploidy/polyploidy	0/3				0/3	
Cell transformation	4/4				4/4	
Hprt mutation	1/2	2/2[a]	1/1[b]		2/3	2/2
Oxidative DNA damage		4/5	2/2		2/2	4/5
DNA binding		1/1				1/1
p53 activation		0/1				0/1

a. one assay conducted with crystalline silica: cristobalite
b. one assay conducted with "ultrafine crystalline silicon dioxide".
c. crystalline silica: tridymite
d. crystalline silica dust (subtypes not provided).

All the *in vivo* human genotoxicity studies are based on three independent studies that used blood samples from workers from diverse occupational settings with confirmed exposures to crystalline silica dust; however, quantification of exposure was not provided. After stratification by smoking status, sister chromatid exchange remained statistically significant in both smokers and non-smokers although the frequency was higher in smokers. For the chromosome aberration assay conducted as part of the same study (blood samples from workers in the stone crusher industry), the increased frequency was no longer significant after stratification. In the DNA damage study of foundry and pottery workers and the micronucleus assay of workers involved in sandblasting and related jobs, results were positive when compared to controls. However, in both studies, smoking status influenced the results, contributing to the increased DNA damage observed since results were greater in smokers versus non-smokers, and the frequency of micronuclei in nasal epithelial cells was higher in smokers (p=0.002) but when using peripheral blood lymphocytes did not differ statistically between smokers and non-smokers who were similarly exposed to silica dust,

The role of *in situ* generation of reactive oxygen species (ROS) and reactive nitrogen species (RNS) has been well established in the following types of DNA damage: small scale insertions, DNA base pair deletion, base modification, chromosomal change/loss, microsatellite instability, DNA strand break, 8-hydroxydeoxyguanosine (8-OHdG) mutation and point mutations. ROS and RNS generation is postulated to be (a part of) the DNA damage mechanism for crystalline silica. Studies are described below to support this hypothesis.

DNA was exposed *in vitro* to various crystalline silica dusts, to H_2O_2, or to both. Results show that DNA damage was limited when dust or H_2O_2 were administered alone but increased with the co-exposure. When the reactive oxygen scavenger, dimethylsulfoxide, was added to the test system, DNA strand break was inhibited, data supporting the viewpoint that it is the presence of radicals generated in response to quartz and cristobalite that causes the DNA damage and not quartz or cristobalite themselves.

Hprt mutation assays in rat alveolar epithelial cells, both *in vitro* and *in vivo,* were positive in response to quartz. The positive results *in vivo* were seen only in the presence of significant inflammatory responses in the treated animals. Also, in a parallel *in vitro* experiment, rat alveolar epithelial cells were incubated with the bronchoalveolar lavage fluid from the rats exposed to quartz. Both macrophage and neutrophil enriched lavage cells induced mutation in the exposed alveolar epithelial cells. Addition of catalase (an enzyme which inactivates H_2O_2) before incubation inhibited the increase in *hprt* mutation.

Rats were exposed to either crystalline or amorphous silica in a manner to induce the same level of

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inflammation in the lungs. The inflammatory response was assessed by measuring the proportion of neutrophils in the bronchiolar lavage fluid. The actual concentrations were 3 and 50 mg/m^3 for crystalline and amorphous silica respectively. The animals were exposed for 13 weeks. *Hprt* mutation frequency was measured in the alveolar epithelial cells at the end of the exposure period. Mutation frequency was greatly increased only in the crystalline silica treated rats; no treatment related increase was found in the rats treated with the amorphous form.

In an 8-OHdG assay conducted to monitor DNA damage by reactive oxygen species, female rats were exposed to 0, 0.3, 1.5 and 7.5 mg/animal of quartz via intratracheal instillation. Effects were observed 90 days post-exposure. A clear dose-response relationship was identified between quartz exposure and various inflammation markers (differential cell count, protein, lung surfactant lipids and tumour necrosis factor alpha). Inflammation was present starting at the lowest dose. However, 8-OHdG showed a statistically significant increase starting at 1.5 mg/animal only. Similarly, in another study, 8-OHdG and DNA strand breaks were observed at concentrations of or above 10 ug/m^3 in rat lung epithelial cells.

In the aim of investigating the role of ROS in lung carcinogenesis, rat lung epithelial cells were incubated with polymorphonuclear (PMN) leukocytes (involved in the inflammatory process and responsible for the release of certain ROS) or hydrogen peroxide. Statistically significant increases in 8-OHdG were observed in the presence of PMN or hydrogen peroxide in a dose-response manner.

In a series of experiments which used *in vitro* stimulation of macrophages with crystalline silica and *in vivo* intranasal instillation of crystalline silica in mice, it was demonstrated that that the chronic fibrosis seen in a murine model of silicosis *in vivo* is dependent on the presence of adaptor molecule ASC and Nalp3 inflammazome. These data support a potential mode of action whereby silica triggers cellular responses that in turn activate alveolar macrophages, resulting in an inflammatory response and silicosis. In mice deficient in Nalp3 inflammazome, the development of inflammation and collagen deposition was significantly reduced compared with normal mice 3 months after the initial intranasal instillation of silica.

Analysis of Lung Tumour Data

The weight of evidence for both rats and humans indicates that fibrotic and silicotic lesions in the lung result from inhalation exposure to crystalline silica and that lung cancer is secondary to those lesions in the lung. Although the mechanism of induction for the lung tumours has not been fully elucidated, there is sufficient supportive mode of action evidence from the data presented to demonstrate that a threshold approach to risk assessment is appropriate based on an understanding of the key events in the pathogenesis of crystalline silica induced lung tumours. The body of evidence include the following:

- In experimental studies, all rats that developed tumours also showed fibrosis.
- Adenocarcinomas, the most common type of tumour identified in rats, are commonly associated with fibrosis and deeply scarred lung tissue.
- Experimental rat studies showed a clear progression of the effects from initially mild inflammation, followed by fibrosis over-time, leading eventually to lung tumours.
- Tumours are not present in all treated species dosed in the same way.
- The tumours, both in rats and humans, are concentrated in the lungs only, although other organs are indirectly exposed.
- In human studies, cancer risk is often more significant in workers exposed over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours.
- Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles
- Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis.
- For genotoxicity, in vitro results were mostly mixed and in vivo results were mostly positive. However, the vast majority of the positive genotoxicity assay results can be explained by the generation of reactive oxygen species, as demonstrated experimentally, where ROS scavenging prevents the genotoxicity.
- *In vivo*, macrophage deficient mice (macrophages produce ROS in response to crystalline silica) do not develop silicosis nor do they develop tumours and the Nalp3 inflammazome, a key player in the macrophage initiated inflammatory response, is required for the development of pulmonary fibrosis after

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inhalation of silica.

- Though inhalation exposure to crystalline silica in multiple occupational settings is clear, the increase in risk, based on the several recent meta-analyses of the multiple human epidemiological studies, remains low.

It is worth noting that where aggressive engineering controls have been made to reduce silica dust levels in the workplace (Sweden), silicosis has been eliminated. By corollary, existing exposures outside of the workplace in such areas do not pose a risk for silicosis to the general population.

The respirable forms of quartz and cristobalite possess properties indicating a hazard for human health (repeated dose toxicity, carcinogenicity and genotoxicity). The mode of action in the lungs involves irritation, inflammation and reactive species formation, leading to silicosis, and eventually to tumour formation.

Exposure

Uses

Consistent with oxygen and silicon being the two most abundant elements in the Earth's crust, silicon-oxide minerals, including quartz are ubiquitous in the natural environment. In particular, as a component of sand, quartz may find use in a diverse array of applications. Several high volume uses include, but are not limited to, the use of sand as a filling material for the construction of roads and in general building activities, the use of sand and gravel aggregates as abrasives on roads in winter and the use of fly-ash, which may contain 4-14% quartz and 0.5-1% cristobalite, as a cement additive. These abrasives when used on winter roads are usually mixed with road salts and may be sand only, stone dust, sand and gravel aggregates, or pre-treated sand. They are used mainly by rural municipalities or in areas where cold temperatures diminish the efficiency of salts for de-icing. Quantities of abrasives used in Canada were 5.73×10^9 kg, 4.59×10^9 kg, and 4.93×10^9 kg for 2007, 2008 and 2009, respectively.

Industrial sand, high purity silica sand products with closely controlled sizing are expected to contain quartz and cristobalite, include lump silica (2-3mm up to 15 cm or more), silica sand (75µm to 2-3mm) and silica flour (less than 75µm). Lump silica may be used in the production of silicon alloys, silica bricks, and the linings of certain types of pulverizers (eg. ball mills and tube mills).

Silica sand may be used in the manufacture of glass and glass fibres, silicate chemicals and silicon carbide, the hydraulic fracturing of wells, foundry moulding, and for sandblasting. Silica flour may find use in the ceramics and cement industries, as a filler and extender in rubber and coatings, and as an abrasive in soaps.

Natural clays, such as bentonite and fuller's earth, are used in cat litters for their high water absorbance capacities. Quartz is a natural component of these clays, and consequently, it may be present in cat litter products. High purity α-quartz is a piezoelectric material, which means that application of a voltage induces a distortion in the crystal shape and vice versa. This ability to interconvert electrical and mechanical energy has led to the use of quartz crystals in electronic devices requiring precise timing control, for example telephones, radios, watches and computers.

According to a survey conducted in Canada, quartz and cristobalite are also used in abrasives, adsorbents, filter products (diatomaceous earth), grout and cement. These substances reportedly also find use as fillers, which add bulk and improve wear resistance, in paints and coatings, adhesives, sealants, polymer films, caulking, epoxy resins and silicones. Also, quartz is listed as an ingredient in 60 cosmetic products in Canada. The types of products include anti-wrinkle preparation, eye and face makeup, lipstick, hair dyes, shampoos and grooming products, as well as skin cleansers, moisturizers and tanning preparations.

Natural Sources

In Canada, quartz naturally occurs in many types of rock formations. Those with high silicon dioxide content (95% SiO_2 or more) include vein and massive intrusion bodies, quartz pebbles, silica sand, sandstone and quartzite. Sandstone is a sedimentary rock mostly composed of quartz grains cemented by a bonding material such as clay, calcite or iron oxide. Quartzite is a hard, compact, metamorphosed sandstone made of grains of quartz firmly bonded with a siliceous cement. Mineral aggregates (e.g., sand and gravel) have variable silicon dioxide content. Quartz is also found as crystals, aggregates or discrete particles in certain igneous rocks (e.g., granites and pegmatites), soils, sediments, air and surface water. This omnipresence is consistent with the fact that silicon is the second most abundant chemical element on Earth.

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Cristobalite is naturally produced in the ashes of volcanic eruptions, and by combustion metamorphism which is a local phenomenon of spontaneous combustion of naturally occurring substances such as bituminous rocks, coal or oil. It may be found in cavities in volcanic rocks and in thermally metamorphosed sandstones and may also be a transient stage in the diagenesis of diatomaceous shale with the result that soils made of these geologic formations may be rich in cristobalite. Unlike quartz, the natural occurrence of cristobalite is limited to specific geographic regions and mineral types.

Anthropogenic Sources

Natural quartz is isolated from ore via beneficiation, which involves milling or grinding the material into particles that are separated into desired mineral and waste. The materials obtained are either used directly or further purified. In Canada, in 2006, 2.146×10^{9} kg of pure quartz were mined, and 2.385×10^{11} kg of sand and gravel aggregates were produced. The proportion of quartz in silica sand deposits and gravel aggregates will vary from one site to another.

Cristobalite can form from silica melts during the preparation of silica glass; quartz is not obtained from melts but is manufactured at elevated temperature and pressure via a hydrothermal process. Cristobalite also forms during the calcination[2] of diatomaceous earth.

Human Exposure Estimate

Ambient air

The exposure assessment is focussed on respirable quartz and cristobalite, which in ambient air comprises a component of total particulate matter (PM). In Canada, data on the concentrations of silicon in PM was available and used as a surrogate for quartz and cristobalite. This approach is conservative because the measured silicon includes all silicon-containing substances and therefore represents the upper limit for quartz and cristobalite in ambient air.

The National Air Pollution Surveillance (NAPS) Program measured concentrations in $\mu g/m^3$ of silicon in PM with aerodynamic radii less than 2.5 µm ($PM_{2.5}$ (dichot)), and from 2.5 to 10 µm (PM_{10} (dichot)) (the total particulate matter with aerodynamic radii less than 10 µm (PM_{10}) is obtained by adding these values) in Canada. In 2009, as part of the NAPS Program, silicon concentrations were determined on over 1600 samples of $PM_{2.5}$(dichot) and over 1500 samples of PM_{10}(dichot) at 24 urban locations across Canada. An estimate of exposure to quartz and cristobalite can be obtained by assuming that all the silicon in the PM is represented stoichiometrically as SiO_2, and multiplying the reported concentration of silicon by 2.14 to obtain a value for silica.

The intake of respirable quartz and cristobalite by the general population of Canada is estimated using a range covering the lowest 50^{th} percentile SiO_2 concentration in PM_{10}, measured in Pt. Petre, ON, (0.12 $\mu g/m^3$) to the highest 50^{th} percentile concentration in PM_{10} measured in Calgary, AB (2.1 $\mu g/m^3$). The 50^{th} percentile SiO_2 concentrations ranged from 0.1 to 2.1 $\mu g/m^3$ across the survey sites; the top of this range is quite close to the average of the maximum values for the 24 sites (3.7 $\mu g/m^3$). The outdoor data were used to represent the indoor levels, because information on indoor silicon concentrations was not available, and the range of PM_{10} measured indoors is generally lower than the outdoor range. Thus, this approach conservatively overestimates indoor exposure in homes.

The highest exposure group based on these calculations is children ages 0.5 to 4 years with an estimated daily intake ranging from 0.07 to 5.26 µg/kg-bw per day; the estimated daily intake decreases with age due to changes in the ratio of inhalation rates to body weights; the daily intake of adults, 20-59 years old, is estimated to range from 0.03 to 2.00 µg/kg-bw per day.

Consumer Products

Exposure to respirable quartz from the use of cosmetic products, which contained quartz as an ingredient, was considered low because they are not formulated for spray application, the loose powders were reported to contain less than 0.1% quartz, and in these products the substance is not expected to be associated with other components of the formulation and not available in a free form.

For consumer Do It Yourself (DIY) activities around the home, the highest mean breathing zone concentration of particles from sanding dry wall (median cut-point of 10µm) of 6.31 mg/m^3, was used to derive an upper-

[2] Calcinations: Heat treating a substance, but without fusion, to bring about change in its physical or chemical constitution.

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bound exposure estimate ranging from 2 to10 µg/kg-bw per event.

Quartz is used to formulate a large number of paints and coatings. To estimate potential inhalation exposure to quartz from these products, the spray painting of wall paints with an airless spray gun was considered appropriate as a conservative scenario. Exposure to respirable paint particles was estimated using data from controlled a laboratory study in which walls of poorly ventilated test rooms were painted by professional painters using an airless sprayer to apply interior latex paint. The maximum concentration of 13% quartz in paint in Canada was used to estimate exposure. The upper-bound estimate of exposure to quartz, based on the maximum concentration of 13% quartz in paint in the Canadian market and the maximum concentration of respirable paint particles measured in these controlled studies when recommended personal protective equipment is used, is 0.954 µg/kg-bw per event.

Inhalation of ambient air containing quartz and cristobalite is the dominant pathway of chronic exposure (excluding that from DIY activities) for the general population. Because SiO_2 makes up only approximately 5% of PM_{10}, silicon concentrations (expressed as SiO_2) measured in the Canadian NAPS survey of 24 urban locations were considered most relevant to the estimation of exposure by the general population. Quartz and cristobalite comprise only a portion of the total SiO_2 in PM_{10}, therefore, the use of the total silicon concentration to represent the upper bound crystalline silica concentrations results in an overestimation of exposure.

Appendix 1: Definitions of Epidemiological Terms in the ITAP

SMR (Standardized Mortality Ratio): The ratio (x 100) of observed to expected deaths in a study population. Expected deaths are calculated by applying a set of standard age-specific mortality rates to the age distribution of the study population. Standardized ratios are only useful for comparisons. They have no intrinsic meaning.

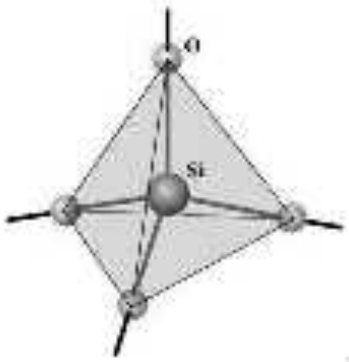
OR (Odds Ratio): In epidemiological case-control studies, a relative measure of disease occurrence. The odds in favour of a particular disease occurring in an exposed group are divided by the odds in favour of its occurring in an unexposed group. If the condition being studied is rare, the odds ratio is a close approximation to the relative risk.

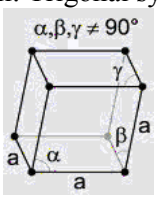
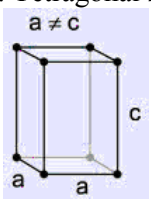
RR (Risk Ratio): The probability of the occurrence of a disease in a group that has been exposed to some environmental, medicinal, microbial, or toxic influence, relative to its probability in a randomly selected population.

PMR (Proportionate Mortality Ratio): Proportionate mortality is the proportion of deaths in a specified population over a period of time attributable to different causes. Each cause is expressed as a percentage of all deaths, and the sum of the causes must add to 100%. These proportions are not mortality rates, since the denominator is all deaths, not the population in which the deaths occurred. Thus, proportionate mortality ratio is a measure of the frequency of occurrence of the proportionate mortality in a defined population during a specified interval of time.

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INITIAL TARGETED ASSESSMENT PROFILE (Human Health)

CAS No.	Quartz: CAS RN 14808-60-7 Cristobalite: CAS RN 14464-46-1
Chemical Name	Quartz and Cristobalite
Structural Formula	Molecular Formula: SiO_2 

Unit Cell: Trigonal symmetry	Unit Cell: Tetragonal symmetry
	
Quartz: CAS RN 14808-60-7	Cristobalite: CAS RN 14464-46-1

SUMMARY CONCLUSIONS OF THE TARGETED ASSESSMENT

NOTE: The present assessment is targeted to address the following human health endpoints: repeated dose toxicity and carcinogenicity via the inhalation route of exposure, and genotoxicity. It cannot be considered as a full SIDS Initial Assessment. Summary information on exposure is also reported here. Other endpoints for human health and the environment included in the Canadian screening assessment but have not been presented to OECD member countries, and thus are not included in this profile.

The final screening assessment will be published under the responsibility of the Government of Canada.

Rationale for Targeting the Assessment

The Government of Canada "categorized" or prioritized all 23,000 chemical substances on its Domestic Substances List (DSL) from 1999 to September 2006, as required by its *Canadian Environmental Protection Act, 1999* (CEPA 1999). Additional details may be found at http://www.chemicalsubstanceschimiques.gc.ca/about-apropos/categor/index-eng.php. Using information from Canadian industry, academic research and other countries, Government of Canada scientists applied a set of rigorous tools to the 23,000 chemical substances on the DSL. They were categorized to identify those that were: **inherently toxic** to humans or to the environment and that might be **persistent** and/or **bioaccumulative**; and substances to which people might have **greatest potential for exposure**. During this priority-setting exercise, distinct approaches were taken for identifying substances of likely concern for human health and the environment, and subsequent assessment activities may have focused on either human health or ecological endpoints. Through categorization, the Government of Canada has identified approximately 4,000 of the 23,000

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chemical substances on the DSL as priorities for further assessment, research and/or measures to control their use or release. Quartz and cristobalite were identified at that time, applying the categorization criteria, as high priorities for human health risk because they were considered to pose greatest potential for exposure and their respirable forms are classified by the International Agency for Research on Cancer as carcinogenic to humans (quartz and cristobalite) and by the National Toxicology Program as known human carcinogens (crystalline silica). These substances did not meet the ecological categorization criteria for bioaccumulation potential or inherent toxicity to aquatic organisms.

Under the Canadian legislation a determination of whether one or more of the criteria of the CANADIAN ENVIRONMENTAL PROTECTION ACT (CEPA) 1999, section 64 are met is based upon an assessment of potential risks to the environment and/or to human health associated with exposures in the general environment. For humans, this includes, but is not limited to, exposures from ambient and indoor air, drinking water, foodstuffs, and the use of consumer products. A conclusion under CEPA 1999 on the substances in the Chemicals Management Plan (CMP) Challenge is not relevant to, nor does it preclude, an assessment against the hazard criteria specified in the Controlled Products Regulations, which is part of the regulatory framework for the Workplace Hazardous Materials Information System [WHMIS] for products intended for workplace use.

Physical-chemical properties

The silicon dioxide group represents a polymorphic category containing a large number of forms identical in composition but with different atomic arrangements which afford different chemical properties. There are two sub-categories within this group: crystalline silica, to which the present substances quartz and cristobalite belong, and non-crystalline or amorphous silica. The key distinction between these sub-categories is that in crystalline substances, the building blocks are arranged in regular, repeating 3-dimensional pattern having long range order, whereas amorphous materials do not display long range order. In all forms of silica, (crystalline and non-crystalline), the silicon atom is tetrahedral and bound to four neighbouring oxygen atoms.

Quartz and cristobalite are solid at room temperature, existing normally as colourless or white crystals. The melting points for quartz and cristobalite are 1400-2000 ^{o}C and 1713-1728 ^{o}C, respectively and for both compounds, the boiling point is 2230^{o}C. Even though no experimental data were available, their vapour pressure and Henry's Law constant are likely negligible. Log K_{ow} (octanol-water partition coefficient) and log K_{oc} (organic carbon-water partition coefficient) are not applicable to these substances. The densities range from 2500-2700 kg/m^3 for quartz and 2300-2380 kg/m^3 for cristobalite.

The very similar physico-chemical properties of quartz and cristobalite reflect their closely related crystal forms. The solubility of crystalline silicates decreases as a function of silica tetrahedral packing density and long-range crystal order. For example, cristobalite has a more open framework structure than quartz and its density is lower, therefore, its solubility is higher. The water solubility of these minerals is also function of temperature, pH, particle size, and the presence of a disrupted surface layer. This may explain the variability of solubility values reported by many authors. The most probable solubility value for quartz is approximately 3.8 mg Si/L, or 6.4 mg/L expressed as the SiO_2 species, while the solubility of cristobalite is approximately 8.7 mg Si/L, or 18 mg SiO_2/L. The kinetics of dissolution of these substances is slow due to the high activation energy required to hydrolyse the Si-O-Si bond.

Human Health Targeted Endpoints

The majority of the studies described here have been reviewed by the International Agency for Research on Cancer (IARC 1997). However, additional data relevant to the screening assessment were identified up to August 2010.

Repeated dose toxicity/non-neoplastic effects (development of silicosis).

Studies on animals

Significant short-term and subchronic studies have demonstrated adverse effects in the lungs, while one of the 6 studies showed effects on the spleen in mice. Rats were exposed to 0, 10 or 100 mg/m^3 of cristobalite via inhalation for 6 hours/day during 3 days. Animals were observed 3 months after exposure. Elevated levels of granulocytes and elevated markers of cytotoxicity from the lung lavage fluid were noted in all exposed groups. Another study of similar duration (9 days) conducted in mice also identified a LOAEC of 10 mg/m^3. Effects observed included minimal interstitial thickening, accumulations of mononuclear cells and slight lymphoid tissue hypertrophy in the lungs.

In a 4-week inhalation study, female rats were exposed to 0, 0.1, 1 or 10 mg/m^3 of quartz 6 hours/day, 5 days/week. Bronchoalveolar lavage fluid was evaluated at 1, 8, and 24 weeks after exposure. Elevated levels of

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granulocytes and significant elevation of markers of cytotoxicity (Lactate dehydrogenase [LDH] and β-glucuronidase [β-glu]) were observed at 1 mg/m^3 and higher. The increased levels of LDH and β-glu were only significant at 24 weeks after exposure. A LOAEC of 1 mg/m^3 was identified at 24 weeks.

Male rats (4 animals per dose) were exposed to 0 or 3 mg/m^3 of cristobalite via inhalation for 6 hours/day, 5 days/week during 13 weeks. Pulmonary inflammation and fibrosis were observed in the exposed group at the end of treatment. When mice were similarly exposed to 5 mg/m^3 of quartz for 6 hours/day, 5 days/week for 15 or 27 weeks, the authors observed increased spleen weight and formation of plaque in the spleen.

In two separate studies, in which rats or hamsters were exposed to quartz via inhalation for at least 6 months, LOAECs of 2 and 3 mg/m^3 were identified, respectively. All the effects observed were related to inflammation and fibrosis of the lung tissue.

Several chronic studies investigated exposure of the respirable forms (i.e. accumulated via inhalation in the lung tissues) of quartz and cristobalite to rats, mice and hamsters. The following is a description of the study in which the lowest non-neoplastic LOAEC was determined. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz, containing 74% of respirable quartz, through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. The mean mass of particle at the end of the exposure period was 0.91 mg/lung. The LOAEC identified was 0.74 mg/m^3 (adjusted for 74% respirable quartz) based on lipoproteinosis, multifocal, inflammatory cell infiltrate and alveolar hyperplasia.

Human epidemiology data

In humans, the lowest observed adverse effect level was identified in a U.S. cohort study. The study was conducted on 3330 gold miners (all are males), who had an average of 9 years underground exposure during the period 1940 to 1965. The cohort was followed up through 1990. Silicosis[1] was identified through death certificates or chest X-rays. A job-exposure matrix together with work history was used to estimate individual exposure. The total silica content in the respirable dust in the mine was estimated at 13% and the median crystalline silica exposure was 0.05 mg/m^3. In this sub population of miners, 170 cases of silicosis were identified. The best predictor for risk of silicosis was cumulative exposure, which varied from less than 1% for a 0.5 mg/m^3-year exposure to 68-84% when exposed to more than 4 mg/m^3-year (based on the average daily dust exposure during the workday each year and summed over time for each miner). The main limitations identified by the authors include the limited number of radiographic surveys, the potential bias from death certificates

[1] Silicosis: Lung disease caused by inhalation of crystalline silica dust, and resulting in inflammation and scarring in forms of nodular lesions in the upper lobes of the lungs. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics). It does not follow that a history of exposure to silica necessarily results in silicosis (Nonsilicotics). The typical "Silicotic" lung nodule is shown in Figure 1.

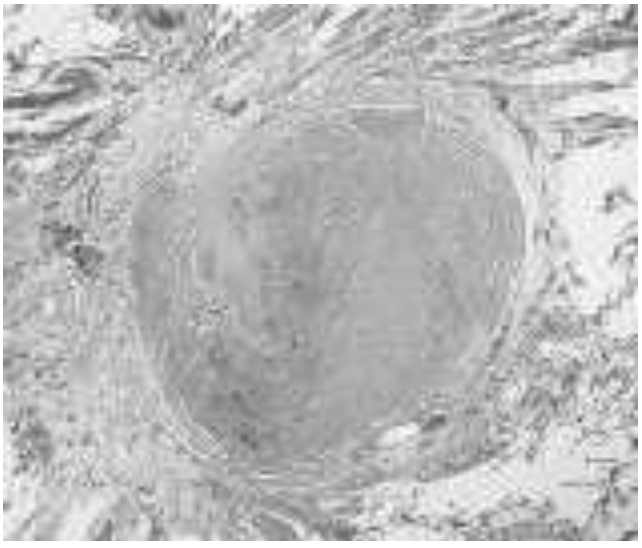


Figure 1. Silicotic nodule characterised by a central zone of hyalinised collagen with a whorled appearance and peripheral dust-containing macrophages (Rees and Murray, 2007).

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(relying on death certificates instead of relying on repeated x-rays, which were lacking for each miner, may have underestimated the number of cases) and the fact that the conversion of dust counts to

gravimetric measurements may not be accurate based on the estimation of 13% silica content in the respirable dust (although based on a relatively large number of samples (n = 82) collected in two different surveys, there was broad range of content in these samples (1% to 48%, SD = 9), and the percentage of respirable quartz may have differed in earlier years, but data were lacking for these years).

Two other human studies have identified similar LOAECs based on the critical endpoint of radiographic confirmed silicosis. A LOAEC of 0.053 mg/m^3 (mean exposure) was identified in a cross sectional study of South African gold miners and a LOAEC of 0.064 mg/m^3 (mean exposure) was derived in a mining community population-based random sample survey in Colorado.

Carcinogenicity studies

Studies on animals

Experimental studies conducted in rats have shown clear and consistent increases in lung tumours after chronic inhalation exposure. In the nine rat studies identified, five were inhalation studies and four were intratracheal instillation studies. All studies except one inhalation study showed increased incidence of lung tumours. For the inhalation studies with treatment related tumours, concentrations ranged from 1 to 50 mg/m^3 (1, 6, and 30 mg/m^3 of DQ-12 quartz; 12 and 50 mg/m^3 of Min-U-Sil 5 quartz) and duration of exposure ranged from 29 days to 2 years. In the inhalation study with no treatment-related tumours, exposure was 60 mg/m^3 of Sikron F300 quartz for 13 weeks. The following is a description of the neoplastic results in the study also identified as the critical study for non-neoplastic results. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. In the exposed group, 18 animals developed tumours (12 in females, 5 in males), as opposed to 3 and 2 for the control and positive control groups respectively. The majority (10/18) of the tumours observed were adenocarcinomas. The mean mass of particles in the lungs at the end of the exposure period was 0.91 mg/lung.

For the intratracheal instillation studies, doses ranged from 4 to 57 mg/kg-bw (based on 7, 12 or 20 mg/animal of Min-U-Sil (5) quartz or 20 mg/animal of novaculite quartz). Exposure regimes were diverse and included single instillation with observation for up to two years, to weekly instillation for 10 weeks. It is noteworthy that the single intratracheal administration of a 95% pure quartz particles (<5 μm) resulted in an increased incidence of silicotic granulomas after 3 weeks and lung tumours after 11 months. The most common tumours reported across the long term rat studies were adenocarcinomas, however other tumours such as squamous-cell carcinoma, alveolar carcinoma and bronchiole-alveolar adenoma were also reported, and all animals that developed tumours also showed some degree of fibrosis.

Of particular interest is the intratracheal instillation study, investigating the sequence of pathological events leading to lung tumors. An unspecified number of rats/sex/dose received a single intratracheal instillation of various crystalline silica dusts or ferric oxide, allowing direct administration into the bronchial tree. The doses were 12 or 20 mg of Min-U-Sil 5 quartz (MQZ), 12 mg of hydrofluoric-acid-etched Min-U-Sil 5 quartz (HFMQZ), 12 mg of cristobalite, 12 mg of tridymite and 12 mg of ferric oxide suspended in saline. All groups were observed until six months post exposure, except for both MQZ groups, the HFMQZ and the ferric oxide group which were observed up until 17 months post-exposure. Interim sacrifices were conducted at 6, 11 and 17 months. The rat lungs showed a clear progression of effects. The sequence of pathological events were, an initial inflammatory response leading to a marked hyperplasia and hypertrophy of alveolar cells after one month, and at six months hyperplasia was evident but no lung tumours were observed. In this study, lung tumours were observed starting at the 11 month sacrifice with a 17% and 42% incidence in males and females (based on 3/18 males and 8/19 females), respectively, and at 17 months incidences were 32% and 59% (based on 6/19 males and 10/17 females, respectively). No lung tumours were found in ferric oxide treated rats. Similar studies have also been conducted in hamsters and mice. Although treated mice and hamsters showed treatment related signs (inflammation or fibrosis), no tumours were observed in hamsters. No increase in the incidence of lung tumours was seen in mice treated with quartz; however silicotic granulomas and lymphoid cuffing around airways but no fibrosis were seen in the lungs of quartz-treated mice.

Human epidemiology data

There is an extensive dataset of human studies investigating the link between crystalline silica exposure and cancer. IARC (1997) identified over 50 epidemiological studies based on occupational exposure to dust containing respirable crystalline silica. Main industry sectors from which the human data is derived include gold mines, foundries, granite/stone industry, pottery workers and refractory brick workers. From the least confounded studies, it was noted that lung cancer tended to increase with the following parameters: cumulative

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exposure; duration of exposure; peak intensity of exposure; presence of radiographically defined silicosis; and length of follow-up time from date of silicosis diagnostic. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics).

Since the 1997 IARC report, a large number of epidemiological studies have been published, with the more recent studies being updates from supplementary follow-up of results from previously assessed case-control studies cohorts, new results based on refined exposure assessments or adjustment for confounders or meta-analyses of the pooled data from these epidemiology studies

In a meta-analysis of the data from 10 cohort studies of gold, tin and tungsten miners, granite workers, industrial sand, diatomaceous earth and pottery workers with quantitative exposure estimates for crystalline silica were pooled in order to analyse the risk related to lung cancer. The pooled cohort standardized mortality ratio (SMR, against national rates) [See Appendix 1 for definition] was 1.2 (Confidence Interval [CI] 1.1-1.3). The results from the case-control analyses show a statistically significant trend with duration of exposure (odds ratios (ORs) [See Appendix 1] by quintile of cumulative exposure increased from 1.0 to 1.6 [CIs of 0.85 to 2.1] and by quintile of average concentration increased from 1.0 to 1.7 [CIs of 1.1 to 2.3]), supporting the importance of the increasing lung burden of silica in the occurrence of cancer. Overall, the authors concluded that the results support the carcinogenicity conclusion presented by IARC (1997).

To investigate the link between crystalline silica, silicosis and lung cancer, epidemiological data published between 1966 and 2001 were gathered. Over 50 studies were selected and pooled according to type of study and the parameter being linked to lung cancer (i.e. silica exposure, presence of silicosis in subjects). The quality of study, adjustment for confounding factors, co-exposure to other carcinogens and availability of a more recent analysis of a same cohort were taken into consideration in the final selection of the studies. Analysis of the relationship between exposure to silica and lung cancer included 17 cohort and 13 case-control studies. For the analysis of lung cancer versus silicosis, 11 cohort and 5 case-control studies were selected. The third analysis included 6 cohort and 2 case-control studies to evaluate the risk of lung cancer in non-silicotics. A random effect model was used to conduct each meta-analysis. Pooled cancer risk ratios (RRs) were 1.32 (CI 1.23-1.41) for crystalline silica exposure, 2.37 (CI 1.98-2.84) for individuals exposed to silica with confirmed silicosis (Silicotics) and 0.96 (CI 0.81-1.15) for individuals with no evidence of silicosis (non-silicotics) with confirmed exposure to silica, supporting the general observation that silicosis has a stronger temporal relationship with crystalline silica exposure and furthermore support the view that a human silicotic response could be a preliminary stage in the development of cancer.

A more recent meta-analysis included 28 cohort, 15 case-control and two proportionate mortality ratio (PMR) [See Appendix 1] studies from a variety of occupational settings conducted between 1996 and 2005. Risk ratios (RRs) were calculated based on type of study and silicosis status using fixed and random effect models (results presented here are from the random model). RRs for all cohort studies was 1.34 (CI 1.25-1.45), and were 1.69 (CI 1.32-2.16) for silicotics, 1.25 (CI 1.18-1.33) for those with undefined silicosis status and 1.19 (CI 0.87-1.57) for non-silicotics. In the case-control studies, the general RR was 1.41 (CI1.18-1.67), and the same sub-groups as mentioned above resulted in RRs of 3.27 (CI 1.32-8.2), 1.41 (CI1.18-1.70) and 0.97 (CI 0.68-1.38), respectively. The proportionate mortality ratio for the last two studies was 1.24 (CI 1.05-1.47). The authors noted that the association between lung cancer and exposure to crystalline silica was more consistent for silicotics, i.e., those diagnosed with silicosis and RR values split into type of occupational settings in which participants worked.

Based upon the above three meta-analysis studies and the epidemiology studies discussed in IARC (1997), the following can be concluded. Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis. Cancer risk is often more significant in workers exposed to crystalline silica over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours. Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles.

There have been reports of tumours outside of the lungs in persons with high silica exposure; however, these reports are sparse and the data inconsistent and have not been unequivocally linked to exposure to either one of the crystalline forms (quartz or cristobalite). Some of the reported locations are: oesophagus, stomach, liver, skin and bone. Sufficient epidemiological or toxicological data do not currently exist for quantitative assessment of the exposure-response relationship on these other tissues or organs.

Genotoxicity

Potential genotoxicity has been assessed in multiple *in vitro* and *in vivo* assays. Table 1 below gives a brief summary of the positive results observed in each type of assay.

Table 1. Summary of positive results over total number of results for each assay and each category (all studies

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conducted with crystalline silica: quartz, except where indicated).

Assay	Animal data		Human data		Positives/Total	
	In vitro	In vivo	In vitro	In vivo[d]	In vitro	In vivo
Rec Assay	0/1				0/1	
DNA strand break	1/1	2/2	5/5[b]	1/1	6/6	3/3
Sister chromatid exchange	0/1		0/1[c]	1/1	0/2	1/1
Micronucleus	2/3	0/1	2/2[b]	1/1	4/5	1/2
Chromosome aberration	0/1			1/1	0/1	1/1
Aneuploidy/polyploidy	0/3				0/3	
Cell transformation	4/4				4/4	
Hprt mutation	1/2	2/2[a]	1/1[b]		2/3	2/2
Oxidative DNA damage		4/5	2/2		2/2	4/5
DNA binding		1/1				1/1
p53 activation		0/1				0/1

a. one assay conducted with crystalline silica: cristobalite
b. one assay conducted with "ultrafine crystalline silicon dioxide".
c. crystalline silica: tridymite
d. crystalline silica dust (subtypes not provided).

All the *in vivo* human genotoxicity studies are based on three independent studies that used blood samples from workers from diverse occupational settings with confirmed exposures to crystalline silica dust; however, quantification of exposure was not provided. After stratification by smoking status, sister chromatid exchange remained statistically significant in both smokers and non-smokers although the frequency was higher in smokers. For the chromosome aberration assay conducted as part of the same study (blood samples from workers in the stone crusher industry), the increased frequency was no longer significant after stratification. In the DNA damage study of foundry and pottery workers and the micronucleus assay of workers involved in sandblasting and related jobs, results were positive when compared to controls. However, in both studies, smoking status influenced the results, contributing to the increased DNA damage observed since results were greater in smokers versus non-smokers, and the frequency of micronuclei in nasal epithelial cells was higher in smokers (p=0.002) but when using peripheral blood lymphocytes did not differ statistically between smokers and non-smokers who were similarly exposed to silica dust,

The role of *in situ* generation of reactive oxygen species (ROS) and reactive nitrogen species (RNS) has been well established in the following types of DNA damage: small scale insertions, DNA base pair deletion, base modification, chromosomal change/loss, microsatellite instability, DNA strand break, 8-hydroxydeoxyguanosine (8-OHdG) mutation and point mutations. ROS and RNS generation is postulated to be (a part of) the DNA damage mechanism for crystalline silica. Studies are described below to support this hypothesis.

DNA was exposed *in vitro* to various crystalline silica dusts, to H_2O_2, or to both. Results show that DNA damage was limited when dust or H_2O_2 were administered alone but increased with the co-exposure. When the reactive oxygen scavenger, dimethylsulfoxide, was added to the test system, DNA strand break was inhibited, data supporting the viewpoint that it is the presence of radicals generated in response to quartz and cristobalite that causes the DNA damage and not quartz or cristobalite themselves.

Hprt mutation assays in rat alveolar epithelial cells, both *in vitro* and *in vivo,* were positive in response to quartz. The positive results *in vivo* were seen only in the presence of significant inflammatory responses in the treated animals. Also, in a parallel *in vitro* experiment, rat alveolar epithelial cells were incubated with the bronchoalveolar lavage fluid from the rats exposed to quartz. Both macrophage and neutrophil enriched lavage cells induced mutation in the exposed alveolar epithelial cells. Addition of catalase (an enzyme which inactivates H_2O_2) before incubation inhibited the increase in *hprt* mutation.

Rats were exposed to either crystalline or amorphous silica in a manner to induce the same level of

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inflammation in the lungs. The inflammatory response was assessed by measuring the proportion of neutrophils in the bronchiolar lavage fluid. The actual concentrations were 3 and 50 mg/m^3 for crystalline and amorphous silica respectively. The animals were exposed for 13 weeks. *Hprt* mutation frequency was measured in the alveolar epithelial cells at the end of the exposure period. Mutation frequency was greatly increased only in the crystalline silica treated rats; no treatment related increase was found in the rats treated with the amorphous form.

In an 8-OHdG assay conducted to monitor DNA damage by reactive oxygen species, female rats were exposed to 0, 0.3, 1.5 and 7.5 mg/animal of quartz via intratracheal instillation. Effects were observed 90 days post-exposure. A clear dose-response relationship was identified between quartz exposure and various inflammation markers (differential cell count, protein, lung surfactant lipids and tumour necrosis factor alpha). Inflammation was present starting at the lowest dose. However, 8-OHdG showed a statistically significant increase starting at 1.5 mg/animal only. Similarly, in another study, 8-OHdG and DNA strand breaks were observed at concentrations of or above 10 ug/m^3 in rat lung epithelial cells.

In the aim of investigating the role of ROS in lung carcinogenesis, rat lung epithelial cells were incubated with polymorphonuclear (PMN) leukocytes (involved in the inflammatory process and responsible for the release of certain ROS) or hydrogen peroxide. Statistically significant increases in 8-OHdG were observed in the presence of PMN or hydrogen peroxide in a dose-response manner.

In a series of experiments which used *in vitro* stimulation of macrophages with crystalline silica and *in vivo* intranasal instillation of crystalline silica in mice, it was demonstrated that that the chronic fibrosis seen in a murine model of silicosis *in vivo* is dependent on the presence of adaptor molecule ASC and Nalp3 inflammazome. These data support a potential mode of action whereby silica triggers cellular responses that in turn activate alveolar macrophages, resulting in an inflammatory response and silicosis. In mice deficient in Nalp3 inflammazome, the development of inflammation and collagen deposition was significantly reduced compared with normal mice 3 months after the initial intranasal instillation of silica.

Analysis of Lung Tumour Data

The weight of evidence for both rats and humans indicates that fibrotic and silicotic lesions in the lung result from inhalation exposure to crystalline silica and that lung cancer is secondary to those lesions in the lung. Although the mechanism of induction for the lung tumours has not been fully elucidated, there is sufficient supportive mode of action evidence from the data presented to demonstrate that a threshold approach to risk assessment is appropriate based on an understanding of the key events in the pathogenesis of crystalline silica induced lung tumours. The body of evidence include the following:

- In experimental studies, all rats that developed tumours also showed fibrosis.
- Adenocarcinomas, the most common type of tumour identified in rats, are commonly associated with fibrosis and deeply scarred lung tissue.
- Experimental rat studies showed a clear progression of the effects from initially mild inflammation, followed by fibrosis over-time, leading eventually to lung tumours.
- Tumours are not present in all treated species dosed in the same way.
- The tumours, both in rats and humans, are concentrated in the lungs only, although other organs are indirectly exposed.
- In human studies, cancer risk is often more significant in workers exposed over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours.
- Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles
- Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis.
- For genotoxicity, in vitro results were mostly mixed and in vivo results were mostly positive. However, the vast majority of the positive genotoxicity assay results can be explained by the generation of reactive oxygen species, as demonstrated experimentally, where ROS scavenging prevents the genotoxicity.
- *In vivo*, macrophage deficient mice (macrophages produce ROS in response to crystalline silica) do not develop silicosis nor do they develop tumours and the Nalp3 inflammazome, a key player in the macrophage initiated inflammatory response, is required for the development of pulmonary fibrosis after

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inhalation of silica.

- Though inhalation exposure to crystalline silica in multiple occupational settings is clear, the increase in risk, based on the several recent meta-analyses of the multiple human epidemiological studies, remains low.

It is worth noting that where aggressive engineering controls have been made to reduce silica dust levels in the workplace (Sweden), silicosis has been eliminated. By corollary, existing exposures outside of the workplace in such areas do not pose a risk for silicosis to the general population.

The respirable forms of quartz and cristobalite possess properties indicating a hazard for human health (repeated dose toxicity, carcinogenicity and genotoxicity). The mode of action in the lungs involves irritation, inflammation and reactive species formation, leading to silicosis, and eventually to tumour formation.

Exposure

Uses

Consistent with oxygen and silicon being the two most abundant elements in the Earth's crust, silicon-oxide minerals, including quartz are ubiquitous in the natural environment. In particular, as a component of sand, quartz may find use in a diverse array of applications. Several high volume uses include, but are not limited to, the use of sand as a filling material for the construction of roads and in general building activities, the use of sand and gravel aggregates as abrasives on roads in winter and the use of fly-ash, which may contain 4-14% quartz and 0.5-1% cristobalite, as a cement additive. These abrasives when used on winter roads are usually mixed with road salts and may be sand only, stone dust, sand and gravel aggregates, or pre-treated sand. They are used mainly by rural municipalities or in areas where cold temperatures diminish the efficiency of salts for de-icing. Quantities of abrasives used in Canada were 5.73×10^9 kg, 4.59×10^9 kg, and 4.93×10^9 kg for 2007, 2008 and 2009, respectively.

Industrial sand, high purity silica sand products with closely controlled sizing are expected to contain quartz and cristobalite, include lump silica (2-3mm up to 15 cm or more), silica sand (75µm to 2-3mm) and silica flour (less than 75µm). Lump silica may be used in the production of silicon alloys, silica bricks, and the linings of certain types of pulverizers (eg. ball mills and tube mills).

Silica sand may be used in the manufacture of glass and glass fibres, silicate chemicals and silicon carbide, the hydraulic fracturing of wells, foundry moulding, and for sandblasting. Silica flour may find use in the ceramics and cement industries, as a filler and extender in rubber and coatings, and as an abrasive in soaps.

Natural clays, such as bentonite and fuller's earth, are used in cat litters for their high water absorbance capacities. Quartz is a natural component of these clays, and consequently, it may be present in cat litter products. High purity α-quartz is a piezoelectric material, which means that application of a voltage induces a distortion in the crystal shape and vice versa. This ability to interconvert electrical and mechanical energy has led to the use of quartz crystals in electronic devices requiring precise timing control, for example telephones, radios, watches and computers.

According to a survey conducted in Canada, quartz and cristobalite are also used in abrasives, adsorbents, filter products (diatomaceous earth), grout and cement. These substances reportedly also find use as fillers, which add bulk and improve wear resistance, in paints and coatings, adhesives, sealants, polymer films, caulking, epoxy resins and silicones. Also, quartz is listed as an ingredient in 60 cosmetic products in Canada. The types of products include anti-wrinkle preparation, eye and face makeup, lipstick, hair dyes, shampoos and grooming products, as well as skin cleansers, moisturizers and tanning preparations.

Natural Sources

In Canada, quartz naturally occurs in many types of rock formations. Those with high silicon dioxide content (95% SiO_2 or more) include vein and massive intrusion bodies, quartz pebbles, silica sand, sandstone and quartzite. Sandstone is a sedimentary rock mostly composed of quartz grains cemented by a bonding material such as clay, calcite or iron oxide. Quartzite is a hard, compact, metamorphosed sandstone made of grains of quartz firmly bonded with a siliceous cement. Mineral aggregates (e.g., sand and gravel) have variable silicon dioxide content. Quartz is also found as crystals, aggregates or discrete particles in certain igneous rocks (e.g., granites and pegmatites), soils, sediments, air and surface water. This omnipresence is consistent with the fact that silicon is the second most abundant chemical element on Earth.

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Cristobalite is naturally produced in the ashes of volcanic eruptions, and by combustion metamorphism which is a local phenomenon of spontaneous combustion of naturally occurring substances such as bituminous rocks, coal or oil. It may be found in cavities in volcanic rocks and in thermally metamorphosed sandstones and may also be a transient stage in the diagenesis of diatomaceous shale with the result that soils made of these geologic formations may be rich in cristobalite. Unlike quartz, the natural occurrence of cristobalite is limited to specific geographic regions and mineral types.

Anthropogenic Sources

Natural quartz is isolated from ore via beneficiation, which involves milling or grinding the material into particles that are separated into desired mineral and waste. The materials obtained are either used directly or further purified. In Canada, in 2006, 2.146×10^{9} kg of pure quartz were mined, and 2.385×10^{11} kg of sand and gravel aggregates were produced. The proportion of quartz in silica sand deposits and gravel aggregates will vary from one site to another.

Cristobalite can form from silica melts during the preparation of silica glass; quartz is not obtained from melts but is manufactured at elevated temperature and pressure via a hydrothermal process. Cristobalite also forms during the calcination[2] of diatomaceous earth.

Human Exposure Estimate

Ambient air

The exposure assessment is focussed on respirable quartz and cristobalite, which in ambient air comprises a component of total particulate matter (PM). In Canada, data on the concentrations of silicon in PM was available and used as a surrogate for quartz and cristobalite. This approach is conservative because the measured silicon includes all silicon-containing substances and therefore represents the upper limit for quartz and cristobalite in ambient air.

The National Air Pollution Surveillance (NAPS) Program measured concentrations in $\mu g/m^3$ of silicon in PM with aerodynamic radii less than 2.5 µm ($PM_{2.5}$ (dichot)), and from 2.5 to 10 µm (PM_{10} (dichot)) (the total particulate matter with aerodynamic radii less than 10 µm (PM_{10}) is obtained by adding these values) in Canada. In 2009, as part of the NAPS Program, silicon concentrations were determined on over 1600 samples of $PM_{2.5}$(dichot) and over 1500 samples of PM_{10}(dichot) at 24 urban locations across Canada. An estimate of exposure to quartz and cristobalite can be obtained by assuming that all the silicon in the PM is represented stoichiometrically as SiO_2, and multiplying the reported concentration of silicon by 2.14 to obtain a value for silica.

The intake of respirable quartz and cristobalite by the general population of Canada is estimated using a range covering the lowest 50^{th} percentile SiO_2 concentration in PM_{10}, measured in Pt. Petre, ON, (0.12 $\mu g/m^3$) to the highest 50^{th} percentile concentration in PM_{10} measured in Calgary, AB (2.1 $\mu g/m^3$). The 50^{th} percentile SiO_2 concentrations ranged from 0.1 to 2.1 $\mu g/m^3$ across the survey sites; the top of this range is quite close to the average of the maximum values for the 24 sites (3.7 $\mu g/m^3$). The outdoor data were used to represent the indoor levels, because information on indoor silicon concentrations was not available, and the range of PM_{10} measured indoors is generally lower than the outdoor range. Thus, this approach conservatively overestimates indoor exposure in homes.

The highest exposure group based on these calculations is children ages 0.5 to 4 years with an estimated daily intake ranging from 0.07 to 5.26 µg/kg-bw per day; the estimated daily intake decreases with age due to changes in the ratio of inhalation rates to body weights; the daily intake of adults, 20-59 years old, is estimated to range from 0.03 to 2.00 µg/kg-bw per day.

Consumer Products

Exposure to respirable quartz from the use of cosmetic products, which contained quartz as an ingredient, was considered low because they are not formulated for spray application, the loose powders were reported to contain less than 0.1% quartz, and in these products the substance is not expected to be associated with other components of the formulation and not available in a free form.

For consumer Do It Yourself (DIY) activities around the home, the highest mean breathing zone concentration of particles from sanding dry wall (median cut-point of 10µm) of 6.31 mg/m^3, was used to derive an upper-

[2] Calcinations: Heat treating a substance, but without fusion, to bring about change in its physical or chemical constitution.

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bound exposure estimate ranging from 2 to10 µg/kg-bw per event.

Quartz is used to formulate a large number of paints and coatings. To estimate potential inhalation exposure to quartz from these products, the spray painting of wall paints with an airless spray gun was considered appropriate as a conservative scenario. Exposure to respirable paint particles was estimated using data from controlled a laboratory study in which walls of poorly ventilated test rooms were painted by professional painters using an airless sprayer to apply interior latex paint. The maximum concentration of 13% quartz in paint in Canada was used to estimate exposure. The upper-bound estimate of exposure to quartz, based on the maximum concentration of 13% quartz in paint in the Canadian market and the maximum concentration of respirable paint particles measured in these controlled studies when recommended personal protective equipment is used, is 0.954 µg/kg-bw per event.

Inhalation of ambient air containing quartz and cristobalite is the dominant pathway of chronic exposure (excluding that from DIY activities) for the general population. Because SiO_2 makes up only approximately 5% of PM_{10}, silicon concentrations (expressed as SiO_2) measured in the Canadian NAPS survey of 24 urban locations were considered most relevant to the estimation of exposure by the general population. Quartz and cristobalite comprise only a portion of the total SiO_2 in PM_{10}, therefore, the use of the total silicon concentration to represent the upper bound crystalline silica concentrations results in an overestimation of exposure.

Appendix 1: Definitions of Epidemiological Terms in the ITAP

SMR (Standardized Mortality Ratio): The ratio (x 100) of observed to expected deaths in a study population. Expected deaths are calculated by applying a set of standard age-specific mortality rates to the age distribution of the study population. Standardized ratios are only useful for comparisons. They have no intrinsic meaning.

OR (Odds Ratio): In epidemiological case-control studies, a relative measure of disease occurrence. The odds in favour of a particular disease occurring in an exposed group are divided by the odds in favour of its occurring in an unexposed group. If the condition being studied is rare, the odds ratio is a close approximation to the relative risk.

RR (Risk Ratio): The probability of the occurrence of a disease in a group that has been exposed to some environmental, medicinal, microbial, or toxic influence, relative to its probability in a randomly selected population.

PMR (Proportionate Mortality Ratio): Proportionate mortality is the proportion of deaths in a specified population over a period of time attributable to different causes. Each cause is expressed as a percentage of all deaths, and the sum of the causes must add to 100%. These proportions are not mortality rates, since the denominator is all deaths, not the population in which the deaths occurred. Thus, proportionate mortality ratio is a measure of the frequency of occurrence of the proportionate mortality in a defined population during a specified interval of time.

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Toxicity Profile

Glycerine
(CAS No. 56-81-5)

Glycerine is also known as glycerol or 1,2,3-propanetriol.

Acute Toxicity

The oral LD_{50} values are >5,000 to 58,400 mg/kg in rats, 4,250 to 38,000 mg/kg in mice, 7,750 and 10,000 mg/kg in guinea pigs (OECD 2002). The oral LD_{50} value of 4,250 mg/kg in mice is not consistent with the range of values found in the available literature and is considered unreliable because of the lack of documentation of the study. No deaths were seen in rabbits following dermal application for 8 hours under occlusive conditions. The dermal LD_{50} is >18,700 mg/kg (Hine *et al.*, 1953).

Irritation

0.5 mL of undiluted glycerine was applied to the skin of rabbits for 24 hours. There was no signs of irritation (Weil, 1971). 0.1 mL of undiluted glycerine was instilled into the eye of rabbits. There was no evidence of irritation (Weil, 1971).

Sensitization

Male guinea pigs were given ten 0.1 mL injections of a 0.1% solution of synthetic or natural glycerine in isotonic saline every other day over 20 days. Following a two-week period, an 0.05 mL injection was given of the 0.1% glycerine solution. There was no sensitizing response (Hine *et al.*, 1953).

Repeated Dose Toxicity (Oral Studies only)

The repeated dose toxicity studies on glycerine by the oral route are listed in the OECD-SIDS SIAR and summarized in the dossier (OECD 2002). Many of these studies have limited toxicity assessments and/or deficient study designs. The key study for assessing the repeated dose toxicity of glycerine is the 2-year rat dietary study by Hine *et al.* (1953).

Male and female Long-Evans rats were given in their diet 0, 5, 10 or 20% synthetic or natural glycerine for two years. The estimated daily intake was 0, 2,000, 4,000 or 8,000 mg/kg-day for males, and 0, 2,500, 5,000 or 10,000 mg/kg-day for females. For the high-dose animals, treatment was discontinued after one year for reasons that was not stated in the report. Data on mortality and clinical observations were not reported. There was a slight increase in food consumption in the $\geq$5% natural glycerine group males. No adverse effects were reported in males or females at any dose level. The NOAEL is 20% in the diet which corresponds to 8,000 and 10,000 mg/kg-day for

males and females, respectively (Hine *et al.*, 1953).

Genotoxicity

Glycerine was not mutagenic to *S. typhimurium* strains TA1535, TA1537, TA98 and TA1000 with or without metabolic activation (Haworth *et al.*, 1983). In another Ames test, glycerine was not mutagenic to *S. typhimurium* strains TA98, TA100, TA1535, TA1537 and TA1538 with or without metabolic activation (Doolittle *et al.*, 1988).

Glycerine was not mutagenic in an *in vitro* mammalian cell HGPRT mutation test (Doolittle *et al.*, 1988). No increased chromosomal aberrations were seen when Chinese Hamster Ovary cells (CHO) cells were treated with glycerine with or without metabolic activation (Doolittle *et al.*, 1988). Nor was there any induction of sister chromatid exchanges (SHEs) in CHO cells with or without metabolic activation, or unscheduled DNA synthesis in rat hepatocytes (Doolittle *et al.*, 1988).

Glycerine was not genotoxic in a rat bone marrow chromosomal aberration test (OECD 2002).

Carcinogenicity

No increased incidence of tumors were seen in rats given glycerine (natural or synthetic) in the diet for 12 or 24 months. Doses were 5, 10 and 20% (Hine *et al.*, 1953).

Reproductive Toxicity

A two-generation reproductive toxicity study was conducted in rats dosed with a 20% solution of glycerine in water. There were no treatment-related effects on growth, reproductive performance, fertility, and no histopathological changes in the tissues examined. Although the data were limited, a NOAEL of 2,000 mg/kg-day was determined (OECD 2002).

Developmental Toxicity

Rats, mice and rabbits were dosed by oral gavage with 1,310, 1,280 and 1,180 mg/kg-day glycerine, respectively during an unspecified period of gestation. The OECD-SIDS SIAR states that the protocol was in reasonable agreement with the OECD TG 414 for pre-natal developmental toxicity studies. There was no maternal toxicity or teratogenic effects seen at any of the dose levels (OECD 2002).

Key Study/Critical Effect for Screening Criteria

The NOAEL from the two-year dietary study (Hine *et al.*, 1953) is 20% glycerine in the diet, which corresponded to 10,000 and 8,000 mg/kg-day for males and females, respectively.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD = 8,000/100 = 80 mg/kg-day

Drinking water guidance value = 280 ppm

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Toxicity Profile

Guar Gum
(CAS No. 9000-30-0)

Guar gum (CAS No. 9000-30-0) is the milled endosperm of the leguminous plant *Cyanopsis tetragonolobus*. Structurally, it is a galactomannan consisting of a main chain of D-mannose with a side chain of D-galactose at approximately every second mannose unit. The mannose units are β-(l-4) linked, and the single D-galactose units are joined to the main chain by α-(1-6) linkages. The estimated molecular weight of guar gum cranges from 200,000 to 300,000 daltons (Glickman, 1969).

Guar gum is approved for use as a food additive by the U.S. Food and Drug Administration and is on the list of substances "generally recognized as safe" (CFR 1974).

Acute Toxicity

The oral LD_{50} is 8,100 mg/kg for mice and 9,400 mg/kg for rats (Bailey and Morgareidge, 1948).

Irritation

No data were found.

Sensitization

There are reports of respiratory sensitization in workers exposed occupationally to guar gum dusts (Maio, 1986).

Repeat Dose Toxicity Studies

F344 rats and $B6C3F_1$ mice were given diets containing 0, 6,300, 12,500, 25,000, 50,000 or 100,000 ppm guar gum for 13 weeks (NTP, 1982). Mean body weights were decreased in male rats (100,000 ppm group) and in female mice (50,000 and 100,000 ppm). A dose-related decrease in feed consumption was observed for male and female rats; male and female mice were comparable or higher than that of controls. There were no compound-related clinical signs or histopathological effects.

F344 rats and $B6C3F_1$ mice were given diets containing 0, 25,000 ppm or 50,000 ppm guar gum for 103 weeks (NTP, 1982). Mean body weights of the high-dose females were lower than those of the controls after week 20 for mice and week 40 for rats. No compound-related clinical signs or adverse effects on survival were observed. Feed consumption by dosed rats and mice of either sex was lower than that of controls.

There were no non-neoplastic histopathological effects in either rats or mice that were treatment-related.

Genotoxicity

Guar gum was not mutagenic to *Salmonella typhimurium* TA 1530 or G-46 when tested without metabolic activation; however, it was mutagenic to *Saccharomyces cerevisiae* D-3 (Green, 1977). Guar gum also was reported to cause chromosomal aberrations in human embryonic lung cells WI-38 (Green, 1977). No *in vivo* genotoxicity studies have been conducted on guar gum.

Carcinogenicity

F344 rats and B6C3F$_1$ mice were given diets containing 0, 25,000 ppm or 50,000 ppm guar gum for 103 weeks (NTP, 1982). There were increased incidences of adenomas of the pituitary in male rats and pheochromocytomas of the adrenal in female rats that were statistically significant, but these differences were considered to be unrelated to guar gum administration. When pituitary adenomas or carcinomas and when pheochromocytomas or malignant pheochromocytomas are combined, the statistical differences disappear. Hepatocellular carcinomas occurred in treated male mice at incidences that were significantly lower than that in controls. The combined incidence of male mice with either hepatocellular adenomas or carcinomas was also significantly lower in the high-dose group. It was concluded that under conditions of this bioassay, guar gum was not carcinogenic for F344 rats or B6C3F$_1$ mice.

Reproductive Toxicity

No data were found.

Developmental Toxicity

Female rabbits were given daily (6 hours/day) dermal administration of 0, 2, 10 and 50 mg/kg guar gum during gestational days 6 through 18 (IRDC, 1988). Mortalities included 2 deaths at 50 mg/kg and 1 death at 10 mg/kg. A single animal was killed in extremis. A dose-related increase in dermal irritation (including erythema, edema, and desquamation) was observed in animals receiving 10 and 50 mg/kg. The number of early resorptions was significantly increased and the number of viable fetuses was correspondingly decreased at 50 mg/kg/day ($p<0.05$). The frequency of fetal malformations and variations in the treated groups was comparable to that of the control group at all dose levels. The NOEL for this study is 2 mg/kg/day.

Key Study/Critical Effect for Screening Criteria

The key studies for the determination of a drinking water guidance value is the NTP two-year chronic bioassays. The LOAELs are based on decreased mean body weights

in female mice and rats fed 50,000 ppm guar gum in diet for 103 weeks. The NOAELs for these studies are 25,000 ppm guar gum.

Rat: NOAEL (mg/kg/day) = 25,000 ppm * 0.05 = 1,250 mg/kg/day

Mouse: NOAEL (mg/kg/day) = 25,000 ppm * 0.13 = 3,250 mg/kg/day

Where 0.05 and 0.13 are the fraction of body weight that rats and mice, respectively, consume per day as food (U.S. EPA).

The lowest NOAEL of 1,250 mg/kg/day for the rat will be used to derive a drinking water guidance value.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD = 1,250/100 = 12.5 mg/kg/day

Drinking water guideline = 44 ppm

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Toxicity Profile

Hydrochloric acid
(CAS No. 7647-01-0)

Hydrochloric acid has been reviewed in the OECD-SIDS program (OECD, 2002a,b).

Hydrochloric acid (HCl) or hydrogen chloride is readily dissociated in water into hydrated protons and chloride ion.

Acute Toxicity

The oral LD_{50} value of hydrogen chloride is reported to be 238 to 277 mg/kg for female rats (Hoechst AG, 1966), and 900 mg/kg for rabbits (Loewy and Munzer, 1923). The lethal dose by dermal exposure is >5,010 mg/kg for rabbits (Monsanto, 1976). The LC_{50} values for HCl are reported to be 23.7 - 60.9 mg/L/5min, 5.7- 7.0 mg/L/30min and 4.2 4.7 mg/L/60min for rats; and 20.9 mg/L/5min, 3.9 mg/L/30min and 1.7 mg/L/60min for mice (Darmer *et al.*, 1974; Hartzell *et al.*, 1990; MacEwean *et al.*, 1974).

Irritation

Concentrations >3.3% cause skin irritation, and concentrations >17% cause corrosion in animal studies (OECD, 2002a,b). An aqueous solution (4%) of hydrogen chloride was slightly irritating (Agner and Serup, 1988), and a 10% solution was determined to be 'Irritating to skin' for the EU Dangerous Preparations Directive, in human volunteer experiments (York *et al.*, 1996).

0.1 mL of 10% aqueous solution of HCl was highly irritating to the eyes of rabbits (Jacobs, 1992); 0.03 mL or more of 5% HCl was corrosive to the eyes of rabbits (Griffith *et al.*, 1980); 0.1 mL of a 3.3% aqueous solution of HCL was slightly irritating the eyes of rabbits (Hoechst AG, 1966); and 0.1 mL of a 0.33% aqueous solution of HCl was not irritating to the eyes of rabbits. (Hoechst AG, 1966).

Sensitization

Hydrogen chloride is not a skin sensitizer to guinea pigs and humans (Gad *et al.*, 1986).

Repeated Dose Toxicity

Rats were fed diets containing 280 to 1,250 mmol/kg hydrochloric acid (10.2 to 45.6 mg/kg) for 7-12 weeks. There was increased water intake in all treated groups. All animals fed diet containing 937 mmol/kg and above for 9 weeks, and half of the animals fed diet containing 900 mmol/kg for 12 weeks died. Also at doses $\geq$937

mmol/kg, there was decreased body weight, food consumption, blood pH, femur length, rate of ash in bone (Upotn and L'Estrange, 1977). In another study with rats, hydrochloric acid was administered via drinking water at pH 2-3 (study duration not provided). Decreased protein levels in urine and decreased urine volumes were observed in the treatment groups (Clausing and Gottschalk, 1989).

Genotoxicity

While consistent negative results have been obtained in the bacterial systems, positive results have been obtained in the non-bacterial systems (OECD, 2002a,b). The positive results were observed at high concentrations, but they were considered to be artifacts due to the low pH. Positive results were obtained in a sex-linked recessive lethal study with *D. melanogaster*; only one dose level was tested (Stumm-Tegethoff, 1966) There are no mammalian studies on *in vivo* mutagenicity with hydrogen chloride

Carcinogenicity (Oral Studies only)

A ten-month study has been conducted using mice (Dyer *et al.*, 1946). Because the methods such as strain used, duration and dose of administration, presence of co-administration substance, were not appropriate, it cannot be used for the assessment of carcinogenicity of hydrochloric acid.

Reproductive Toxicity

No reliable studies were identified by the oral route.

Developmental Toxicity

No reliable studies were identified by the oral route.

Key Study/Critical Effect for Screening Criteria

The Australian drinking water guideline value for pH may apply to hydrochloric acid.

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Toxicity Profile

Magnesium chloride
(CAS No. 7786-30-3)

Acute Toxicity

The oral LD_{50} of magnesium chloride hexahydrate in rats is >2,000 mg/kg. The dermal LD_{50} of magnesium chloride hexahydrate in rats is >2,000 mg/kg.

Irritation

Magnesium chloride hexahydrate was applied topically to the EPISKIN-SM™ for 15 min followed by a 42 hour post-incubation period and immediate determination of cytotoxic effects via MTT reduction assay. The test item showed no irritant effects.

Single ocular instillation of magnesium chloride hexahydrate to rabbits at a dose of 0.1 g produced irritant effects, which were fully reversible within 6, 4 and 2 days post-instillation in animal no. 1, 2 and 3, respectively. Based on these findings, magnesium chloride hexahydrate is not an eye irritant.

Sensitization

Magnesium chloride hexahydrate was not a skin sensitizer when tested in guinea pigs.

Repeated Dose Toxicity

In an OECD 422 study, Wistar rats at dosages of 250, 500 and 1,000 mg/kg magnesium chloride hexahydrate revealed no major toxicological findings. The cause of death of animals during the conduct of the study could not be determined (a plausible cause may be gavage error or regurgitation). The NOAEL for this study is 1,000 mg/kg/day.

Groups of 50 male and 50 female $B6C3F_1$ mice were given magnesium hexahydrate at dose levels of 0, 0.5% and 2% in the diet for 96 weeks, after which all animals received the control diet for 8 weeks and were then necropsied. In the 2% females, a decrease in body weight was observed. However, survival rates did not differ between the treatment and control groups for males or females and clinical signs and urinary, hematological or serum clinical chemistry parameters showed no treatment-related effects. Therefore, this change was considered not to be of biological significance. The NOAEL for female and male mice was 2% in feed, which corresponded to 3,930 and 2,810 mg/kg/day, respectively.

Genotoxicity

Magnesium chloride was not genotoxic in the *in vitro* mouse lymphoma assay and in the *in vitro* chromosomal aberration assay using human lymphocytes.

Carcinogenicity

Male and female $B6C3F_1$ mice were given in their fed 0, 0.5% or 2% magnesium chloride hexahydrate for 96 weeks, after which all animals received the control diet for 8 weeks and were then necropsied. Tumors were mainly found in the skin/subcutis, liver and lymphatic system. With the exception of a significant decrease in the incidence of liver tumors among the 2% males, there were no differences in the tumor incidences between the treated and control animals.

Reproductive/Developmental Toxicity

In an OECD 422 study, Wistar rats at dosages of 0, 250, 500 or 1,000 mg/kg showed no treatment-related reproductive or developmental effects. The NOAEL for this study is 1,000 mg/kg/day.

Key Study/Critical Effect for Screening Criteria

The Australian drinking water guideline value for chloride may apply to magnesium chloride.

Reference

ECHA REACH database: http://apps.echa.europa.eu/registered/registered-sub.aspx

Toxicity Profile

Magnesium nitrate
(CAS No. 10377-60-3)

Acute Toxicity

The acute oral LD_{50} in rats is >5,000 mg/kg.

Irritation

No studies are available.

Sensitization

Magnesium nitrate is not a skin sensitizer based on results of a Local Lymph Node Assay (LLNA).

Repeat Dose Toxicity Studies

No studies are available.

Genotoxicity

Magnesium nitrate hexahydrate is not mutagenic in the *Salmonella typhimurium* reverse mutation assay and in the *Escherichia coli* reverse mutation assay.

Carcinogenicity

No data are available.

Reproductive Toxicity

No data are available.

Developmental Toxicity

No data are available.

Key Study/Critical Effect for Screening Criteria

The Australian drinking water guidance value for nitrates may apply to magnesium nitrate.

Reference

ECHA REACH database: http://apps.echa.europa.eu/registered/registered-sub.aspx

Toxicity Profile

Vinylidene chloride/methacrylate copolymer (CAS No. 25038-72-6)

No toxicity information exists for this substance.

As a polymer, vinylidene chloride/methacrylate copolymer is not expected to be absorbed by the oral, dermal or inhalation routes of exposure due to its large molecular weight. It is also expected to be stable in biological media and resistant to metabolism.

This polymers are expected to be essentially acutely non-toxic by the oral, dermal and inhalation routes of exposure. Under certain conditions, dusts may be formed, which is to be considered as a nuisance dust. The polymers are expected to be non-irritating and not dermal sensitizers.

Toxicity Profile

Potassium Borate
Dipotassium Tetraborate
(CAS No. 1332-77-0)

Toxicity data on borax and boric acid will be used to read across to potassium borate ($B_4K_2O_7$). The rationale is as follows:

Borax is also known as sodium borate, sodium tetraborate, or disodium tetraborate. With water content, borax can refer to a group of compounds that differ in their crystal water content, but typically it is disodium tetraborate decahydrate with the chemical structure ($Na_2B_4O_7 \bullet 10H_2O$). Borax is moderately soluble in water, with the main species in freshwater being the borate ion $[B(OH)_4]^-$ and boric acid $B(OH)_3$, depending on the pH. The relative proportion of boric acid and borate ions is controlled by pH: $B(OH)_3 + 2H_2O \Leftrightarrow [B(OH)_4]^- + H_3O^-$. In dilute aqueous solutions, boric acid does not dissociate at pH <7; at pH values between 7 and 11, both boric acid and borate ions are present. In dilute aqueous solutions and physiological conditions, the predominant species present is un-dissociated boric acid. So, the consideration of boric acid addresses the relevant toxicological properties of borax.

Exposure to borates are often expressed in terms of boron (B) equivalents based on the fraction of boron in the source substance on a molecular weight basis. The B-equivalents used are a generic designation rather than a designation of the element boron. The factor for converting dipotassium tetraborate to B-equivalents is 0.185.

Acute Toxicity

The acute oral LD_{50} value in rats for disodium tetraborate decahydrate is 5,560 mg/kg [628 mg B/kg] (Meyding and Foglhian 1961; Austria 2008). The acute dermal LD_{50} for disodium tetraborate decahydrate is >2,000 mg/kg [226 mg B/kg] (Reagan and Becci, 1985a; Austria 2008). The acute inhalation 4-hour LC_{50} is >2.03 mg/L [0.23 mg B/L] (Wnorowski 1994a; Austria 2008).

Irritation

Disodium tetraborate hydrate is mildly irritating to the abraded skin of rabbits (Roudabush *et al.* 1964; Austria 2008). In another study, it was non-irritating to the skin of rabbits with erythema and edema scores of 0 (Reagan and Becci 1985b; Austria 2008). Disodium tetraborate hydrate is irritating to the eyes of rabbits (Reagan and Becci 1985c; Doyle 1989; Austria 2008). In the study by Doyle (1989), the test substance was ground to a fine powder to reduce the glassy, sharp crystals.

Sensitization

Dosodium tetraborate hydrate was not considered a skin sensitizer to the skin of guinea pigs (Wnorowski 1994b; Austria 2008).

Repeated Dose Toxicity

Rats were administered in their feed 0, 52.5, 175, 525, 1,750 or 5,250 ppm B equivalent (as boric acid or borax) for 90 days (Weir 1962; Weir and Fisher, 1972). The average intake has been estimated to be approximately 0, 2.6, 8.8, 26, 87.5 or 262.5 mg B/kg-day, respectively (U.S. EPA 2004). By week 6, all of the animals in the highest dose died. Clinical signs in the top two dose levels were rapid respiration, hunched position, bloody nasal discharge, urine stains on the abdomen, inflamed eyes, desquamation and swollen paws and tail. There was also reduced food consumption and body weight gain. The 1,750 ppm females showed reduced (liver, spleen and ovary weights; the 1,750 ppm males showed reduced kidney and adrenal weights. The adrenals of 4 of the 1,750 ppm males showed minor increases in lipid content and size of the cells in the zona reticularis. Atropied testis (complete atrophy of the spermatogenic epithelium and decreased in the size of the seminiferous tubules) was seen in all of the 1,750 ppm males. One 525 ppm male given boric acid had partial testicular atrophy; no effects were seen in male rats given disodium tetraborate decahydrate at this dose level.

Male and female B6CF$_1$ mice were administered 0, 1,200, 2,500, 5,000, 10,000 or 20,000 ppm boric acid for 13 or 16 weeks (NTP 1987). These dietary levels correspond to approximately 0, 34, 70, 141, 281 and 563 mg B/kg-day for males, respectively; and 0, 47, 97, 194, 388 and 776 mg B/kg-day for females, respectively. There >60% mortality in the 20,000 ppm group as well as hyperkeratosis and acanthosis. At 10,000 ppm, there was 10% mortality in the males. Degeneration or atrophy of the seminiferous tubules occurred in the $\geq$5,000 ppm males. Minimal to mild extramedullary hematopoiesis of the spleen was observed in all dose groups.

Male and female SD rats were administered in their feed 0, 117, 350 or 1,170 ppm borax or boric acid for two years (Weir 1966a,b; Weir and Fisher 1972). The average intake has been estimated to be approximately 0, 5.9, 17.5 or 58.5 mg B/kg-day, respectively (U.S. EPA 2004). The 1,170 ppm rats had decreased food consumption during the first 13 weeks of the study and suppressed growth throughout the study. Signs of toxicity in the 1,170 ppm animals included swelling and desquamation of the paws, scaly tails, inflammation of the eyelids, and bloody discharge from the eyes. All of the 1,170 ppm males had testicular atrophy at the 6, 12 and 24 month time points. The seminiferous epithelium was atrophied, and the tubular size in the testes was decreased. There were significant decreases in the absolute and relative testes weights. Brain and relative thyroid weights were increased. The NOAEL for this study is 350 ppm borax or boric acid (17.5 mg B/kg-day).

Male and female B6C3F$_1$ mice were given 0, 2,500 or 5,000 ppm boric acid in their feed for 103 weeks (NTP, 1987). These dose levels were equivalent to 0, 275 or 550 mg/kg-day boric acid or 0, 48 or 96 mg B/kg-day. At termination, the survival rates were 82, 60 and 44% in the control, low- and high-dose males, respectively; and 66, 66 and 74% in the control, low- and high-dose females, respectively. There was testicular atrophy and interstitial cell hyperplasia in the 5,000 ppm males. A dose-related increase in the incidences of splenic lymphoid depletion in male mice was also observed. NTP considered this lesion to be associated with stress and debilitation, and it is reflected in the increased mortality in these groups of male mice.

Genotoxicity

Disodium tetraborate decahydrate was not mutagenic when tested *in vitro* using V79 Chinese hamster cells, C3H/10T1/2 mouse embryo fibroblasts, and diploid human foreskin fibroblasts (Landolph 1985).

Boric acid has been tested in a variety of *in vitro* genotoxicity tests (NTP 1987; Haworth et al. 1983; Landolph 1985; Bakke 1991; Stewart 1991; Rudd 1991; U.S. EPA 2004). No evidence of mutagenicity of genotoxicity was observed.

Boric acid was not genotoxic in a mouse bone marrow micronucleus assay at oral doses of 0, 900, 1,800 and 3,500 mg/kg given on two consecutive days (O'Loughlin 1991).

Carcinogenicity

No carcinogenic effects were seen in the two-year rat dietary studies on disodium tetraborate decahydrate and boric acid (Weir 1966a,b; Weir and Fisher 1972). The dose levels in feed were 0, 117, 350 or 1,170 ppm borax or boric acid, which were estimated to be approximately 0, 5.9, 17.5 or 58.5 mg B/kg-day, respectively.

Male and female B6C3F$_1$ mice were given 0, 2,500 or 5,000 ppm boric acid in their feed for 103 weeks (NTP, 1987). These dose levels were equivalent to 0, 275 or 550 mg/kg-day boric acid or 0, 48 or 96 mg B/kg-day. No carcinogenic effects were observed.

Reproductive Toxicity

Three-generation reproductive toxicity studies were conducted in albino rats (strain not specified) with boric acid or sodium tetraborate decahydrate (Weir and Fisher 1972; reviewed in Moore 1997). Groups of rats (8 males and 16 females) were fed a diet that contained 0, 117, 350 or 1,170 ppm boron as borax or boric acid (approximately 0, 5.9, 17.5 or 58.5 mg B/kg-day, respectively). Male and female body weight gains in both studies were reduced in the 58.5 mg B/kg-day groups. Mating between treated males and females in the high-dose groups showed complete infertility, which was attributed to both sexes. Males had grossly atrophied testes and histologic examination showed an absence of viable sperm. When treated females were subsequently mated with control males, there was reduced fertility. Only 2/16 females produced live litters in the borax study, and one other female became pregnant and aborted her litter. None of the pups survived until weaning. One of 16 females fed boric acid produced a litter with six live pups; three females became pregnant and aborted their litters. Only three pups survived to weaning of the six living pups. Histologic examinations from both studies showed that much of the decrease in female fertility was a product of reduced ovulation. The cause of the mortality in pups during the postnatal period is unknown. At the lower dose levels, the effects were minor with no obvious effects on fertility. The NOAEL was determined to be 17.5 mg B/kg-day.

In a continuous breeding protocol, male and female CD-1 mice were given 0, 1,000, 4,500 or 9,000 ppm boric acid in their feed (Fail *et al.* 1991). No litters were occurred

in the high-dose breeding pairs. In the mid-dose, there was a successful first litter, after which there was a progressive decrease in fertility; only one pair produced a fourth and fifth litter. All fertility indices were affected in the mid-dose group. A complete crossover mating trial was conducted using control mice and the mid-dose mice, which indicated that the probable cause of the reduced fertility was a decrement in male fertility. A dose-related decrease in body, testicular and epididymal weights was observed in the mid- and high-dose F_0 males. Sperm count was significantly decreased in these dose groups, and percent motile sperm was decreased in all dose groups. Testicular histopathology showed seminiferous tubular atrophy in the high-dose males and partial atrophy of the seminiferous tubules in the mid-dose males. There were no histopathologic changes in the mid-dose females. No statistically significant decreases in mating index, fertility index, or live pups/litter in the mid-dose females, but the number of days to litter in this dose group was increased. Estrous cyclicity was unaffected. Reproductive organ weights were unaffected, but relative maternal liver and kidney/adrenal weights were reduced. An F_1 fertility trial was performed using offspring from the low-dose groups. There was no decreases in mating, fertility or reproductive performance. The F_2 adjusted live pup weight was slightly, but significantly, reduced from controls. A clear NOAEL for reproductive toxicity in males was not seen in this study. Decreased sperm motility was observed in the F_0 generation and sperm concentration was decreased in the F_1 generation in the low-dose males. Decreased F_2 pup relative body weight was statistically significant from controls. The NOAEL in females is 1,000 ppm boric acid (27 mg B/kg-day.

Male deer mice were fed a diet containing 0, 4,500 or 9000 ppm boric acid (0, 108 or 216 mg B/kg-day, respectively) for eight weeks (Fail *et al.* 1989; reviewed in Moore 1997). At the end of the 8-week exposure period, half of the male deer mice were mated with untreated adult female deer mice for one week. Following the mating trial, these males were killed and necropsied. The other groups of treated male deer mice were fed a diet containing no boric acid for an additional 9-week period to assess any recovery from the boron treatment. After the 9-week recovery period, the male deer mice were mated for one week with untreated adult female deer mice, then killed and necropsied. After each mating trial, the females were allowed to litter and the resulting pups were counted, sexed, and weighed at birth. Exposure of the male deer mice to 9,000 ppm boric acid for 8 weeks resulted in complete infertility. There was no decrease in fertility in the 4,500 ppm male deer mice. Decreased testicular and epididymal weights occurred in the 9,000 ppm male deer mice; and there was a reduction in the seminiferous index (a semi-quantitative rating of cell types present), which was thought to have resulted in the observed decrease in formation of mature sperm. There were no treatment-related changes in body and organ weights, seminiferous index and litter measurements in the 4,500 ppm mice. Following a 9-week "recovery" period, the fertility performance in the high-dose male mice, as well as the necropsy results and histopathologic examination of the testes, were similar to the controls.

Male Fischer rats were administered 0, 3,000, 4,500, 6,000 or 9,000 ppm boric acid [0, 17.3, 25.9, 37.8, 51.8 or 68 mg B/kg-day] in their feed for 9 weeks (Ku *et al.* 1993; reviewed in Moore 1997). After 9 weeks on the test diet, a group of rats were returned to a control diet and recovery was assessed at 8, 16, 24 and 32 weeks post-treatment. There as a strong relationship between boric acid exposure and testicular lesions. Inhibition of spermiation, which was characterized as the aberrant retention

of step 19 spermatids in stage IX-XI tubules, was seen in the 25.9 and 37.8 mg B/kg groups. The 51.8 and 63 mg B/kg rats developed severe inhibition of spermiation by week 2, which progressed to testicular atrophy (defined as complete absence of post-spermatogonial germ cells). There was no signs of recovery from the testicular atrophy in these two high-dose groups after 32 weeks of no exposure even though these tubules contained a normal complement of spermatogonia and Sertoli cells and the spermatogonia were seen to divide. These rats appeared to have an intact gonadotropin response since serum FSH and LH levels were increased. The authors referred to a preliminary study of the same size and duration, in which 2,000 ppm boric acid [17.3 mg B/kg-day B] was not observed to cause any testicular effects. Although the authors did not consider 25.9 mg B/kg-day to be an adverse effect because of the absence of changes in other testicular and reproductive indices, an Expert Committee (Moore 1997) considered this dose level to a LOAEL and 17.3 mg B/kg-day to be a NOAEL.

Developmental Toxicity

Pregnant SD rats were given 0, 0.1, 0.2 or 0.4% boric acid in their feed on gestational days (GD) 0 to 20 or 0.8% boric acid on GD 6 to 15 (Heindel *et al.* 1992). The average amounts of boric acid ingested were estimated to be 0, 78, 163, 330 or 539 mg/kg-day (0, 13.6, 28.5 or 57.7 mg B/kg-day), respectively. Effects on the dams were altered food and/or water intake at $\geq$0.2% boric acid, increased liver and kidney weights relative to body weights at $\geq$0.2%, reduced weight gain at $\geq$0.4%, and increased corrected weight gain at 0.4% boric acid. There was a reduction in fetal body weights in all treated groups (94, 87, 63, and 47% of control weight, respectively). Increased malformations occurred at $\geq$0.2% and prenatal mortality was increased at 0.8%. There was a dose-response for altered skeletal morphology in rats ($\geq$0.1%), and specific findings were significantly elevated above controls at $\geq$0.2%. Specifically, there was an increased incidence of short rib XIII (a malformation) and a decreased incidence or rudimentary or full rib(s) at lumbar I (an anatomical variation).

Pregnant SD rats were given 0, 0.025, 0.005, 0.075, 0.1 or 0.2% boric acid in their feed on GD 0 to 20 (Price *et al.* 1996a). Approximately half of the dams were terminated on GD 20, and the remaining dams delivered their litters. Pup growth and viability were monitored until postnatal day (PND) 21. The average amounts of boric acid ingested on GD 20 (PND 21) were: 0(0), 19(19), 36(37), 55(56), 76(74) or 143(145) mg/kg-day, [0, 3.3(3.2), 6.3(6.5), 9.6(9.7), 13.3(12.9), and 25(25.3) mg B/kg-day], respectively. Maternal toxicity consisted of increased relative kidney weights in the 0.2% group. There were no differences in the viability of the offspring between treated and controls. On GD 20, fetal body weight was 94% and 88% of controls in the 0.1% and 0.2% groups, respectively; recovery was complete at birth (~GD 22). The incidence of short rib XIII was increased in GD 20 in the $\geq$0.1% groups., but only in the 0.2% group at PND 21. The incidence of wavy rib was increased on GD 20 in the $\geq$0.1% group; the reversibility of this effect was confirmed on PND 21. There was a slight decrease in extra lumbar ribs in the 0.2% group on GD 20, and extra lumbar ribs were seen in the 0.2% group on PND 21. The developmental NOAEL was considered to be 0.075% boric acid (9.6 mg B/kg-day) on GD 20 and 0.1% boric acid (12.9 mg B/kg-day) on PND 21.

Pregnant Swiss mice were given 0, 0.1, 0.2 or 0.4% boric acid in their feed on gestational days (GD) 0 to 17 (Heindel *et al.* 1992). The average amounts of boric acid ingested were estimated to be 248, 452 or 1,003 mg/kg-day (0, 43.4, 79.0 or 175.3 mg/B/kg-day), respectively. Maternal toxicity consisted of mild kidney lesions ($\geq$0.1%), increased water intake and relative kidney weights (0.4%), and decreased water intake during treatment. Fetal body weights were reduced in the $\geq$0.2% groups, and there were increased incidences of resorptions and malformed fetuses per litter in the 0.4% group.

Pregnant New Zealand rabbits were dosed by oral gavage with 0, 62.5, 125 or 250 mg/kg boric acid (0, 10.9, 21.9 or 43.7 mg B/kg) during GD 6-19 (Price *et al.* 1996b). There was reduced food intake during treatment in the 250 mg/kg maternal animals, but it was increased in the $\geq$125 mg/kg dose groups. In the 250 mg/kg group, there were decreased maternal body weight (GD 9-30), weight gain during treatment, gravid uterine weight, and number of ovarian corpora lutea. In the $\geq$125 mg/kg groups, maternal corrected gestational weight gain was increased. Maternal liver weights were unaffected by treatment. In the 250 mg/kg group, relative, but not absolute, kidney weights were increased, although no effects in the kidney were noted in the histopathological examination. Prenatal mortality was increased in the 250 mg/kg group (90% resorptions/litter versus 6% for controls); the proportion of pregnant females with no live fetuses was increased (73% versus 0%), and live litter size was reduced (2.3 fetuses versus 8.8). Thus, there were only 14 live fetuses (6 live litters) available for evaluation in the 250 mg/kg group. The percentage malformed fetuses/litter was increased in the 250 mg/kg group, primarily due to cardiovascular defects (72% versus 3% of controls). There was no definitive maternal or developmental toxicity in the 62.5 or 125 mg/kg dose groups.

Key Study/Critical Effect for Screening Criteria

The U.S. Environmental Protection Agency (U.S. EPA) derived an Oral Reference Dose (RfD) for boron of 0.2 mg B/kg-day (U.S. EPA 2004) based on developmental effects in rats from two studies (Price *et al.* 1996a; Heindel *et al.* 1992). The RfD was derived using the benchmark dose (BMD) method ($BMDL_{05}$ from Allen *et al.* 1996) using a data derived uncertainty factor of 66. Decreased fetal body weight was considered by Allen *et al.* (1996) as the most suitable endpoint for developing a point of departure, because the benchmark doses calculated for the other endpoints (incidence of total malformations, enlarged lateral ventricles in the brain, shortening of rib XIII, and variations of the first lumbar rib) were higher.

Oral RfD = 0.2 mg B/kg-day

Drinking water guidance value = 0.7 ppm (boron)

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Toxicity Profile

Potassium hydroxide
(CAS No. 1310-58-3)

Potassium hydroxide (KOH) has been reviewed in the OECD-SIDS program (OECD, 2002a,b).

Potassium hydroxide (KOH) is present in the environment as potassium (K^+) and hydroxyl ions (OH^-). Potassium (K^+) is an essential ion of bodily fluids; it is critical for the nervous and muscular cell function, as well as for a number of metabolic activities. The normal plasma concentration is approximately 140 to 200 mg/L. The minimum toxicity level is under 250 mg/L. Regulation of potassium ions is controlled by excretion and reabsorption in the kidney. Exposure to KOH could potentially increase the pH of the blood from the hydroxyl anions (OH^-). However, the pH of the blood is regulated between narrow ranges to maintain homeostasis (pH of 7.4 to 7.5) by urinary excretion of bicarbonate and via exhalation of carbon dioxide.

Acute Toxicity

The oral LD_{50} values for KOH have been reported to be 365 mg/kg (Johnson *et al.*, 1975); 273 mg/kg (Bruce, 1987); and 1,230 mg/kg (Smyth *et al.*, 1969).

Irritation

Application of 0.5 ml of a 5% solution of KOH to the skin of rabbits with a Gauze covering resulted in moderate irritation, with a PII score of 4.8. A 10% solution was severely irritating (Nixon *et al.*, 1990). When a 19 mm diameter Hill Top Chamber pad covering was used and 0.2 ml of a 5 or 10% solution of KOH was applied for 1 or 4 hours, a severe irritation response was observed (Nixon *et al.*, 1990).

Application of 0.1 ml of a 5% solution of KOH to the skin of rabbits and covered by gauze for 24 hours resulted in mild irritation to intact skin and severely irritating to abraded skin (Johnson *et al.*, 1975). Application of 0.5 ml of a 10% solution of KOH for 4 hours under occluded conditions was corrosive to intact or abraded skin (Nixon *et al.*, 1990).

When 0.1 ml was instilled on the eyes of rabbits, a 5% KOH solution for 5 minutes was extremely irritating to corrosive; a 1% KOH solution for 5 minutes or 24 hours was considered irritating; 0.5% KOH solution for 24 hours was marginally irritating; and 0.1% KOH solution was 24 hours was negative (Johnson *et al.*, 1975).

Sensitization

Potassium hydroxide was not considered a skin sensitizer to guinea pigs when 0.1 ml of a 0.1% solution was injected in the induction phase and then challenged with another 0.1 ml (Johnson *et al.*, 1975).

Repeated Dose Toxicity

No animal data are available on repeated dose toxicity studies by oral, dermal, inhalation or by other routes for KOH. It is not useful to study the repeated dose toxicity of hydroxide via an oral study because at high concentrations the substance is corrosive or irritating, while at low concentrations the hydroxide will be neutralized in the stomach by gastric juice, which has a very low pH.

Genotoxicity

Potassium hydroxide was not considered mutagenic in an Ames test with or without metabolic activation (OECD 2002 a,b).

Carcinogenicity

No valid carcinogenicity studies on sodium hydroxide were identified.

Reproductive Toxicity

No valid studies were identified regarding toxicity to reproduction in animals after oral, dermal or inhalation exposure to KOH. It is not useful to study the reproduction/developmental toxicity of hydroxide via an oral study because at high concentrations the substance is corrosive or irritating, while at low concentrations the hydroxide will be neutralized in the stomach by gastric juice, which has a very low pH.

Developmental Toxicity

No valid studies were identified regarding developmental toxicity in animals after oral, dermal or inhalation exposure to KOH. It is not useful to study the reproduction/developmental toxicity of hydroxide via an oral study because at high concentrations the substance is corrosive or irritating, while at low concentrations the hydroxide will be neutralized in the stomach by gastric juice, which has a very low pH.

Key Study/Critical Effect for Screening Criteria

The Australian drinking water guideline value for pH may apply to sodium hydroxide.

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Toxicity Profile

Talc
(CAS No. 61789-40-0)

Talc refers to both mineral talc and industrial mineral products that are marketed under the name talc and contain proportions of mineral talc that range from about 35% to almost 100%. Industrial talc generally refers to products that contain abundant minerals other than talc; cosmetic talc now normally contains >98% talc but the content may have been lower in the past. Pharmaceutical talc contains >99% talc. Talcum powder is cosmetic-grade talc.

Talc is a mineral composed of hydrated magnesium silicate with the chemical formula $Mg_3Si4O_{10}(OH)_2$ or $H_2Mg_3(SiO_3)_4$. Talc is not soluble in water.

The U.S. Food and Drug Administration (FDA) regulates talc and states that it is generally recognized as safe for use in color additives in foods, drugs and cosmetics, and in paper, paper products, cotton and cotton fabrics that come into contact with food. The Food Chemical Codex (2003) provides specifications for food-grade talc, including the statement that "talc derived from deposits that are known to contain associated asbestos is not food grade." Under the voluntary guidelines initiated in 1976, the Cosmetic, Toiletry, and Fragrances Association stated that all cosmetic talc should contain at least 90% platy talc (hydrated magnesium silicate) that is free from detectable amounts (<0.5%) of fibrous, asbestos minerals.

Toxicokinetics (Oral)

The absorption and disposition of ^3H-labeled talc in rats, mice, and guinea pigs administered a single oral dose was studied by Phillips *et al.* (1978). The oral doses were 50 mg/kg for rats, 40 mg/kg for mice, and 25 mg/kg for guinea pigs. In rats, mice, and guinea pigs, more than 95% of the dose was excreted in the feces 3 to 4 days after dosing. Less than 2% of the radioactivity was recovered in the urine. This radioactivity probably reflected contamination of urine samples with feces. No radioactivity was found in the liver or kidneys of these animals. This information suggests that talc is not absorbed from the gastrointestinal tract following oral exposure.

Acute Toxicity

No data were located.

Repeated Dose Toxicity/Carcinogenicity

Male and female Wistar rats were given in their diet 0 or 50 mg/kg of commercial talc

[characteristics unspecified] for the life of the animals (average survival was 702 and 649 days, respectively). There was no significant difference in the talc-fed animals compared with control animals (Gibel *et al.*, 1976).

Male and female Wistar-derived rats were given in their diet 100 mg Italian talc (grade 00000; ready milled; mean particle size, 25 μm; containing 92% talc, 3% chlorite, 1% carbonate minerals and 0.5–1% quartz) per rat per day for 5 months (talc-containing diet was actually given for 101 days) and were then maintained on basal diet for life (average survival, 614 days). No differences in tumor incidence were noted between treated animals and control animals (eight/sex for an average survival of 641 days) (Wagner *et al.*, 1977).

In humans and experimental animals, the effects of talc are dependent on the route of exposure, and the dose and properties of the talc. Talc pneumoconiosis was somewhat more prevalent and severe among miners exposed to talc containing asbestiform minerals and/or asbestos than among those exposed to talc without such contaminants. However, the role of quartz and asbestos in the observed pneumoconiosis could not be ruled out. Among drug users, intravenous injection of talc present as a filler in the drugs resulted in microembolization in a variety of organs and alterations in pulmonary function. In animal studies, talc has been shown to cause granulomas and mild inflammation when inhaled. Observations of the effects that occurred in the lungs of rats exposed by inhalation to talc suggested that the operative mechanisms may be similar to those identified for carbon black, and talc is known to cause the release of cytokines, chemokines and growth factors from pleural mesothelial cells.

IARC: There is *inadequate evidence* in humans for the carcinogenicity of inhaled talc not containing asbestos or asbestiform fibres. There is *limited evidence* in experimental animals for the carcinogenicity of talc not containing asbestos or asbestiform fibres. Inhaled talc not containing asbestos or asbestiform fibres is *not classifiable as to its carcinogenicity (Group 3)*.

Genotoxicity

The IARC (1987) review of talc included unpublished results from a 1974 study conducted by Litton Bionetics that showed no mutagenic activity for talc *in vitro* or *in vivo.* Talc did not induce mutations in *Salmonella typhimurium* strains TA1530 or HisG46, or in the yeast, *Saccharomyces cerevisiae.* No chromosomal aberrations were observed in human fibroblasts treated with talc *in vitro. In vivo* tests conducted in rats gave negative results for induction of chromosomal aberrations in bone marrow cells and dominant lethal mutations in germinal cells.

Three samples of respirable talc failed to elicit significant unscheduled DNA synthesis (10, 20 and 50 μg/cm^2, 24 hours), sister chromatid exchange or aneuploidy (2, 5, 10 and 15 μg/cm^2, 48 hours) in rat pleural mesothelial cells, in contrast to various positive controls. The three samples, *i.e.* Spanish talc (No. 5725), Italian talc (No. 5726) and French talc (No. 7841), contained 90–95% talc; the remaining contents were chlorite and dolomite. Electron microscopy analysis revealed that talc

particles were taken up by the rat pleural mesothelial cells, but no aneuploidy was observed in metaphases (Endo-Capron *et al.*, 1993).

Reproductive Toxicity

No data are available.

Developmental Toxicity

No teratologic effects were observed in hamsters, rats, mice, or rabbits after oral administration of talc. The doses used were 1,600 mg/kg for rats and mice on days 6 through 15 of gestation; 1,200 mg/kg for hamsters on day 6 through 10 of gestation; and 900 mg/kg for rabbits on days 6 through 18 of gestation.

Key Study/Critical Effect for Screening Criteria

There are no adequate studies for which to derive a oral reference dose. Talc is poorly absorbed from the gastrointestinal tract, if at all, and the limited data available by the oral route indicate that talc is essentially non-toxic by the oral route of exposure.

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Toxicity Profile

Triethanolamine
[2,2′,2″-nitrilotriethanol]
(CAS No. 102-71-6)

Acute Toxicity

The oral LD_{50} in rats is 6,400 mg/kg (ECHA), and the dermal LD_{50} in rabbits is >2,000 mg/kg (ECHA). No deaths seen in rats following an 8-hour exposure to a saturated vapor atmosphere [approximately 1.8 mg/m^3] (ECHA).

Irritation

Triethanolamine is not a skin irritant to rabbits when applied for 4 hours under occluded conditions (ECHA). It is not irritating to the eyes of rabbits (Griffith *et al.*, 1980; ECHA).

Sensitization

Triethanolamine was not considered a skin sensitizer when tested in a guinea pig maximization test (ECHA).

Repeated Dose Toxicity (Oral only)

Male and female Cox CD rats were fed in their diet 0, 250, 500 or 1,000 mg/kg triethanolamine for 91 days (ECHA). There were no effects that were considered treatment-related. The NOAEL for this study is 1,000 mg/kg-day.

Genotoxicity

Triethanolamine was not mutagenic to *S. typhimurium* strains TA1535, TA1537, TA97, TA 98 or TA100 in the absence or presence of metabolic activation (Mortelsman *et al.*, 1986). Nor was triethanolamine mutagenic in mouse lymphoma L5178Y cells in the absence or presence of metabolic activation (ECHA). Triethanolamine did not increase sister chromatid exchanges (SCEs) or chromosomal aberrations in Chinese Hamster Ovary (CHO) cells in the absence or presence of metabolic activation (Galloway *et al.*, 1987).

Male and female $B6C3F_1$ mice were given dermal applications of triethanolamine, 5 days/week for 13 weeks (NTP, 2004). There were no increase in the frequency of micronucleated erythrocytes in the peripheral blood.

Triethanolamine did not induce sex-linked recessive lethal mutations in germ cells of adult male *Drosophila melanogaster* exposed by feeding or injection (Yoon *et al.*, 1985).

Carcinogenicity

Male and female B6C3F$_1$ mice were given in their drinking water 0, 1 or 2% triethanolamine (0 and approximately 1,600 and 3,200 mg/kg-day) for 82 weeks. (Konishi *et al.*, 1992). Mortality, organ weights and tumor incidences were similar between treated and control animals.

Male and female F344 rats were given dermal applications of triethanolamine, 5 days/week for two years (NTP, 1999). The doses were: 0, 32, 63 or 125 mg/kg-day for males, and 0, 63, 125 or 250 mg/kg-day for females. There were no treatment-related carcinogenic effects in either sexes.

Male and female B6C3F$_1$ mice were given dermal applications of triethanolamine, 5 days/week for two years (NTP, 2004). The doses were: 0, 200, 630 and 2,000 mg/kg-day for males, and 0, 100, 300 and 1,000 mg/kg-day for females. In females, there was some evidence of carcinogenicity activity based on increased incidences of hepatocellular adenomas. In males, there was equivocal evidence of carcinogenicity activity based on the incidence of liver hemangiosarcomas.

Reproductive/developmental Toxicity

In a reproductive and developmental toxicity screening (OECD 421) study, male and female Wistar rats were dosed by oral gavage with 0, 100, 300 or 1,000 mg/kg-day triethanolamine (ECHA). Most of the 1,000 mg/kg-day animals and one 100 mg/kg-day animals showed transient salivation for a few minutes immediately after each treatment. This effect was considered to be induced by the unpalatability of the test substance or from local irritation of the upper digestive tract. Body weight gain was slightly lower in the 1,000 mg/kg-day females during gestation and was considered to be caused by the increased postimplantation loss rather than by a systemic effect of the test substance. In the 1,000 mg/kg-day group, there were lower mean number of implantation sites, increased postimplantation loss, and lower average litter size. There were no treatment-related effects in the F_1 pups. The NOAEL for systemic toxicity is 1,000 mg/kg-day. The NOAEL for reproductive toxicity is 1,000 mg/kg-day. The NOAEL for developmental toxicity is 300 mg/kg-day.

Key Study/Critical Effect for Screening Criteria

There were no adverse effects in male or female rats given 1,000 mg/kg-day in the diet, the highest dose tested, for 91 days (ECHA). The NOAEL for this study is 1,000 mg/kg-day.

Oral RfD = 1,000/1,000 = 1.0 mg/kg/day

Drinking water guideline value = 3.5 ppm

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Santos

APPENDIX F.7 SCHLUMBERGER SAPPHIRE LF

Toxicity Profile

Reaction mass of 5-chloro-2-methyl-4-isothiazolin-3-one and 2-methyl-2H-isothiazolin-3-one [3:1]
(CAS No. 55965-84-9)

5-Chloro-2-methyl-4-isothiazol-3-one (CMI) and 2-methyl-2H-isothiazolin-3-one (MI) combined formulations are marketed under several trade names, such as Kathon CG, Kathon 886, Kathon WT, Kathon 886, Acticide LG, Acticide 14 L, Acticide 14P, Microcare IT, Microcare ITL etc.

Acute Toxicity

The oral LD_{50} of Kathon WT (1.5% a.i.) is >5,000 mg/kg (>75 mg a.i./kg) in male rats and >3,310 mg/kg (~49.6 mg a.i./kg) in female rats. The oral LD_{50} of Acticide 14 (14% a.i.) is 472-490 mg/kg (~66 to 69 mg a.i./kg) in rats (combined sexes); and 465 mg/kg (69 mg a.i./kg) in male rats and 393 mg/kg (59 mg a.i./kg) in female rats.

The dermal LD_{50} of Kathon CG is >5,000 mg/kg (>75 mg a.i./kg) in female rabbits. The dermal LD_{50} of Acticide 14 (14% a.i.) is 1,008 mg/kg (141 mg a.i./kg) in rats (combined sexes).

The inhalation LC_{50} of Kathon 886F (13.9% a.i.) in male and female rats is 2.36 mg/L (0.33 mg a.i./L).

Irritation

Undiluted Kathon MW (1.5% a.i.) and Acticide 14 (14% a.i.) were corrosive to rabbit skin. Undiluted Kathon CG was severely irritating to the eyes of rabbits. Kathon RH 886T at 100 ppm (0.01% a.i.) was non-irritating to the eyes of rabbits.

Sensitization

CMI/MI has been tested in the guinea pig Buehler and Magnusson-Kligman tests and has been shown to be a strong skin sensitizer. It is also a strong contact allergen in humans.

Repeat Dose Toxicity

Rats were exposed to CMI/MI in a powdered commercial diet. CMI/MI concentrations were increased over the 13-week period (initial concentration up to week 2, intermediate concentration week 3-4, final concentration week 5 to 13). Concentrations in the control and CMI/MI groups were: 0/0/0, 40/57/80, 132/187/260, 400/570/800 ppm. There were no mortalities and no effects on body weight or food consumption. In each group, some animals showed slight alopecia or reddened raw or

scabbed areas on the skin. There were no other differences in general behavior or appearance. There were no treatment-related changes in hematological, biochemical, urinary parameters nor any pathology. No systemic toxicity was observed up to and including the highest dose of either CMI/MI (800 ppm, equivalent 29.1 mg a.i./kg-day). The NOAEL in this study is 800 ppm (29.1 mg a.i. /kg-day).

Rats were exposed to CMI/MI via their drinking water at concentrations of 25, 75 or 225 ppm a.i. for three months (equivalent to an average intake of 2.38, 6.28 and 16.3 mg/kg/day in males and 4.06, 10.8, and 24.7 mg/kg-day in females). Two additional groups of rats were given tap water or tap water containing the inorganic ions present in the CMI/MI solution, at a concentration equal to that in the high dose group (225 ppm). This solution is referred to as the ion control solution. There were no mortalities in either sex at any dose level. There were no treatment-related effects on body weight up to the mid dose. A significant decrease in body weight was seen in males at the high dose during the first two weeks of the study. Food consumption was significantly decreased in males at all dose levels and in females mid and high dose groups during the first few weeks of dosing. Water consumption was significantly decreased at all concentrations. No overt clinical signs or ophthalmic were seen in any group throughout the 13 week toxicity or the reproductive phase. No adverse effects were seen in the examinations. No hematological treatment-related changes were seen in either sex at any dose level. There was a significant decrease in globulin and an increase in the albumin/globulin (A/G) ratio in males in both the high concentration and in the ion control groups, after 13 weeks of treatment. A significant decrease in total protein was also seen high concentration group, but was not seen in the ion control group. Females in the high concentration group showed a modest (40%) increase in SGOT (AST, aspartate aminotransferase) levels after 13 weeks of dosing. No changes were observed at any dose in mixed-function oxidase activities of the liver. At the end of 13 weeks of treatment, there was a significant increase in relative liver weight in males and in relative kidney weight in females at the high concentration but without any correlative changes in organ pathology. Histology revealed a local irritation of the glandular mucosa of the stomach in 7 of 15 males and 5 of 15 females at the high concentration. These subtle low level changes did not occur at the low or mid concentration nor were they present in either control group. No other compound related changes were seen. Reproductive organs at all doses were comparable to the control. The NOEL in this study was considered to be 75 ppm a.i. (equivalent to 6.28 and 10.8 mg/kg-day in males and females, respectively), based primarily on irritation of the glandular stomach at the high dose. The No Observed Adverse Effect Level (NOAEL) is 225 ppm a.i. (equivalent to 16.3 and 24.7 mg/kg-day in males and females, respectively), the highest dose tested, since no adverse effects were observed on the histopathology of any tissues or organs distant from the site of dosing.

Genotoxicity

The results of the *in vitro* mutagenicity tests were equivocal. In bacterial reverse mutation tests, CMI/MI was positive in *Salmonella* strain TA100 but was predominantly negative in other strains commonly tested strains. CMI/MI was

mutagenic in the mouse lymphoma assay with and without metabolic activation. Effects at the Tk locus was seen both with and without S-9, but were enhanced with S9 mix. CMI/MI was not genotoxic in the *in vitro* unscheduled DNA synthesis (UDS) assay with primary rat hepatocytes or in an *in vitro* chromosomal aberration test with Chinese hamster lung cells.

The *in vivo* studies indicated that CMI/MI does not have relevant mutagenic potential *in vivo*. The positive mutagenic effect of CMI/MI found in *in vitro* gene mutation assays was not confirmed in the sex-linked recessive lethal test in *Drosophila melanogaster* nor in two unscheduled DNA synthesis (UDS) studies in the rat. CMI/MI also did not show any increase in cells with micronuclei in mice nor did it induce chromosomal aberrations in rat bone marrow cells.

Carcinogenicity

In a two-year rat drinking water study, Kathon 886 is given as 14.2% active ingredient with a pH between 2-3. In the document with compiled batch information for Kathon, the active ingredient is 13.2, [10.13 % CMI/ 3.85% MI] with 15.4% magnesium nitrate and 9.0% magnesium chloride. The dose levels were 0, 30, 100 and 300 ppm (equivalent to: 0, 2.0, 6.6, 17.2 mg a.i./kg-day in males and 0, 3.1, 9.8, 25.7 mg a.i./kg-day in females. There were no deaths. There were no treatment-related effects on body weight or body weight gain at doses or food consumption up to and including the mid dose group. A treatment-related and concentration-dependent decrease in water consumption was seen in both sexes in all treated groups throughout the study. These decreases ranged from 0-22% at low dose 3-30% at mid dose and 15-40% at high dose. These decreases appear to be due to the unpalatability of the CMI/MI and not its inorganic stabilizer salts since the water consumption in the salt control was comparable to the tap water control throughout the study. Based on the average daily water consumption, the high dose was judged to be a maximum tolerated dose. The decreases in body weight and body weight gain were seen in high dose animals throughout the study and may be secondary to decreased water consumption. No treatment-related clinical effects were recorded. No treatment-related ophthalmic, hematological. biochemical or urinary changes were noted. Organ weights were comparable to the control. No effects on type or incidence of neoplasms were seen at up to and including the high dose (males: 17.2 a.i.; females 25.7 mg a.i./kg/day). Slight to moderate forestomach hyperplasia was seen at both mid and high dose groups. Gastric irritation was the primary effect observed. No adverse effects on the histopathology of any other tissues/organs were observed away from the site of dosing. No systemic effects were observed. The NOEL in this study was considered to be 30 ppm a.i. (2.0 to 3.1 mg a.i./kg-day), based primarily on gastric irritation of the stomach at 100 and 300 ppm a.i.. The NOAEL was considered to be 300 ppm a.i. (17.2 to 25.7 mg/a.i./kg-day), since no evidence of systemic toxicity was observed at any dose and there was no adverse effects on the histopathology of any tissues/organs distant from the site of dosing at any dose.

Reproductive/Developmental Toxicity

A one-generation reproductive toxicity study was combined with the 13-week

drinking water study reported above in the repeated dose toxicity section. Reproductive capability was similar in all groups. Litter size and survival at birth was also similar in all groups. One dam at the high concentration lost the entire litter by day 4 due to a lactation problem. This is not uncommon and was not considered treatment related. Pups of the other high concentration group dams, except one, survived and thrived to day 21. Thus, no adverse effects were observed on reproductive capability of male and female rats and no effects were observed on fetal health or pup survival (to day 21) up to and including the high dose (equivalent to 16.3 and 24.7 mg/kg-day in males and females, respectively].

In a two-generation reproductive toxicity study, rats were dosed with CMI/MI (Kathon 886F: 11.1% CMI, 3.7% MI a.i.) at concentrations of 0 (control), 0 (magnesium salt control), 30, 100 or 300 ppm a.i. For the P_1 generation, this was equivalent to 0, 2.8-4.4; 8.5-11.8, and 22.7-28.0 mg a.i./kg-day; and in the P_2 generation 0, 4.3-5.5, 13.4-16.0, and 35.7-39.1 mg a.i./kg-day. There were no treatment related effects on survival, food consumption or overt signs of toxicity. A decrease in bodyweight gain was noted initially in the P_1 generation. This was thought to be linked to reduced water consumption since significant dose-related reduction in water consumption was seen at all concentrations in both the P_1 and P_2 generations, during the premating, gestation and lactation stages. Treatment-related histopathological changes were seen in the stomach in the P_1 and P_2 generation. These included erosions of the glandular mucosa, edema and inflammation in the submucosa of the glandular and nonglandular stomach, with hyperplasia and hyperkeratosis of the nonglandular stomach at the 100 and 300 ppm a.i. Other histopathological changes were seen but were not dose dependent.The estrus cycle in P_1 or P_2 females at any treatment level was comparable with the controls, as was the sperm motility, morphology, testicular sperm count or caudal epididymal reserves of P_1 or P_2 males. All other endpoints (gestation index, gestation length, number of pups per litter or treatment-related gross findings in F_1 or F_2 pups) were similar to those in the controls in either generation. The study authors considered that rats exposed to CMI/MI in the drinking water through two generations had a NOAEL of 30 ppm a.i. (2.8-4.4 mg/kg-day in the P_1 animals; 4.3-5.5 mg/kg-day in the P_2 animals) for parental animal toxicity, based on the gastric irritation of stomach at higher doses. The NOEL for reproductive toxicity is 300 ppm a.i. (22.7-28.0 mg/kg-day in the P_1 animals; 35.7-39.1 mg/kg-day in the P_2 animals), the highest dose tested. There were no effects on fertility or fetal development at any dose level.

In a rat oral gavage developmental toxicity study on Kathon 886 (13.9% a.i.), the developmental NOEL for CMI/MI is >15 mg a.i./kg-day during organogenesis (highest dose tested). In a rat oral gavage developmental toxicity study on Acticide 14 (10.2% CMi/ 4% MI), the NOAEL for maternal toxicity is <3.95 mg a.i./kg-day; the NOAEL for teratogenicity is >19.6 mg a.i./kg-day; and the NOAEL for embryotoxicity is >19.6 mg a.i./kg-day. In a rabbit oral gavage developmental toxicity study on Acticide 14 (10.2% CMI/ 4% MI), the developmental NOAEL is >5.49 mg a.i./kg-day; the NOAELs for maternal toxicity and fetal toxicity are 1.41 mg a.i./kg-day. In a rabbit oral gavage developmental toxicity study on Kathon MW (13.9% a.i.), the NOEL for maternal toxicity is 2 mg a.i./kg-day; the developmental NOEL is 8 mg a.i./kg-day, the highest dose based on severe maternal toxicity at 20 mg a.i./kg.

Key Study/Critical Effect for Screening Criteria

A two-year drinking water study was conducted in rats with CMI/MI (13.2% active ingredient). No systemic effects were observed. There was, however, gastric irritation of the stomach at 100 and 300 ppm. The NOEL for this study is 30 ppm (equivalent to 2.0 and 3.1 mg a.i./kg-day for males and females, respectively). The NOEL of 2.0 mg/kg-day will be used to derive an oral RfD and a drinking water guidance value.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral Reference Dose = 2/100 = 0.02 mg/kg-day

Drinking water guidance value = 0.07 ppm

Reference

EU SCCS (2009). Opinion on the mixture of 5-chloro-2-methyl-4-isothiazolin-3-one and 2-methyl-2H-isothiazol-3-one [3:1], Colipa Nº P56, Scientific Committee on Consumer Safety, SCCS/1238/09.

Toxicity Profile

Choline chloride
Cholinium chloride
(CAS No. 67-48-1)

Choline chloride, also known as cholinium chloride, is a quaternary amine salt. It dissociates in water into the corresponding positively charged quaternary hydroxyl alkylammonium ion and the negatively charged chloride ion.

Choline chloride has been reviewed in the OECD-SIDS program (OECD, 2004).

Acute Toxicity

The oral LD_{50} in rats was reported to be between 3,150 and 5,000 mg/kg (BASF AG, 1963a, 1969).

Irritation

Application of a 70% aqueous solution to the skin of rabbits for 20 hours under occlusive conditions resulted in only minor skin irritation (BASF AG, 1963b). Slight eye irritation was seen in the eyes of rabbits after instillation of a 70% aqueous solution of choline chloride; no effects were seen one day after exposure (BASF AG, 1963c).

Sensitization

No data are available in animals. In a Human Repeated Insult Patch Test, there was no evidence of dermal sensitization in two hundred subjects given 0.5% (w/v) aqueous solution of choline chloride during the induction phase and 0.2% (w/v) aqueous solution during the challenge phase (Colgate-Palmolive, 2003).

Repeated Dose Toxicity

A 72-week feeding study was conducted to investigate the impact of choline chloride on the liver tumor promoting activity of phenobarbital and DDT in diethylnitroamine-initiated Fischer 344 rats (Shivapurkar *et al.*, 1986). Animals received approximately 500 mg/kg-day choline chloride. Following the end of the exposure period, the animals were kept on the same untreated diet as the control group until study termination at week 103. Histopathology was limited to the liver and organs that developed gross abnormalities. There were no significant differences between treated and control animals on survival rates, body weights, and relative liver weights. Neither was there any increased number of neoplastic liver nodules, hepatocellular carcinomas, lung tumors, leukemia or other tumors between treated and control animals. The NOAEL for choline chloride in this study is 500 mg/kg-day.

In humans, oral administration of 10,000 mg/day choline chloride in a pilot study treating a small number of patients with Alzheimer's disease resulted in a slight hypotensive effect (Boyd *et al.*, 1977). This dose was regarded as a LOAEL by the U.S. Institute of Medicine (IOM) Standing Committee on the Scientific Evaluation of Dietary Reference Intake (2000).

Genotoxicity

Choline chloride was not mutagenic to bacteria in reverse mutation assays (Haworth *et al.*, 1984; JETOC, 1997; Litton Bionetics, 1977).

A small, but statistically significant, and dose-related increase in sister chromatid exchanges (SCEs) in Chinese Hamster Ovary (CHO) cells was reported at 50 and 500 µg/ml choline chloride in the absence of S9 only (Bloom *et al.*, 1982). No higher concentrations were examined. These results could not be confirmed in another study using CHO cells at concentrations of choline chloride up to 5,000 µg/ml. (Galloway *et al.*, 1985).

In a gene conversion assay with *Saccharomyces cerevisiae* strain D4, choline chloride was negative in the presence and absence of metabolic activation (Litton Bionetics, 1977).

No *in vivo* genotoxicity studies are available.

Carcinogenicity

No studies were located.

Reproductive Toxicity

No reliable studies have been conducted that address female fertility or reproductive toxicity by a relevant route of exposure.

Developmental Toxicity

Pregnant female mice were given in their feed 1,250 to 20,000 mg/kg choline chloride during gestational days 1 to 18 (BASF AG, 1966). Maternal body weight gain was reduced in all treated groups except for the 1,250 mg/kg group. Determination of maternal weight gain of dams with embryonic/fetal absorptions showed that there was no net weight gain at $\geq$4,160 mg/kg, but there was net weight loss in the 20,000 mg/kg group. All fetuses were resorbed in the 20,000 mg/kg group. Embryonic/fetal lethality of 35% and 69% were seen in the 4,160 and 10,800 mg/kg groups, respectively. No resorptions occurred in the 1,250 mg/kg group. Developmental toxicity was seen in all but the 1,250 mg/kg group. No statistically significant

increases in malformations were observed in any dose group. The NOAELs for maternal and developmental toxicity is 1,250 mg/kg-day.

Key Study/Critical Effect for Screening Criteria

The Standing Committee on the Scientific Evaluation of Dietary Reference Intakes selected hypotension as the critical effect from the study by Boyd *et al*. (1977) when deriving a Tolerable Upper Intake Level. Boyd *et al*. (1977) reported a LOAEL of 10,000 mg/day choline chloride (7,500 mg/day choline). An uncertainty factor of 2 was chosen because of the limited data regarding hypotension and the inter-individual variation in response to cholinergic effects. Thus, the value for the Tolerable Upper Intake Value for repeated exposure of adults to choline is 3,500 mg/day choline.

The oral RfD for choline chloride is derived by using the LOAEL of 10,000 mg/day from the Boyd *et al*. (1977) study, which is divided by an uncertainty factor of 2, to obtain a value of 3,500 mg choline/day or 50 mg choline/kg-day for a 70 kg person.

Oral RfD = 50 mg/kg-day

Drinking water guideline value = 175 ppm

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Toxicity Profile

Crystalline Silica, Cristobalite
(CAS No 14464-46-1)

Crystalline Silica, Quartz
(CAS No. 14808-60-7)

Silica is an off-white granule that occurs naturally in various crystalline and amorphous or other non-crystalline forms. Crystalline silica is characterized by silicon dioxide (SiO_2) molecules oriented in fixed, periodic patterns to form stable crystals. The primary crystalline form of silica is quartz. Other crystalline forms of silica include cristobalite, tripoli and tridymite. Particle size is a key determinate of silica toxicity, since toxicity is restricted to particles that are small enough to be deposited into the target regions of the respiratory tract.

Oral Exposure

No oral studies were located; however, crystalline silica is not expected to exhibit toxicity by the oral route. Although absorption studies were not found for crystalline silica, kinetic studies on amorphous silica show no absorption from the gastrointestinal tract.

Dermal Exposure

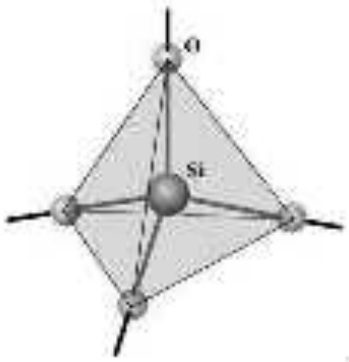
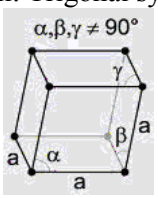
No dermal studies were located; however, crystalline silica is not expected to exhibit toxicity by the dermal route.

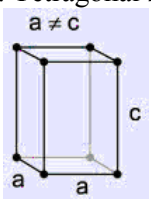
Inhalation Exposure

See attached OECD-SIDS Initial Targeted Assessment Profile on Quartz and Cristobalite, SIAM 32, 19-21 April 2011.

INITIAL TARGETED ASSESSMENT PROFILE (Human Health)

<table>
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Cristobalite: CAS RN 14464-46-1</td></tr>
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<tr><td rowspan="2">Structural Formula</td><td colspan="2">Molecular Formula: SiO_2

</td></tr>
<tr><td>Unit Cell: Trigonal symmetry


Quartz: CAS RN 14808-60-7</td><td>Unit Cell: Tetragonal symmetry


Cristobalite: CAS RN 14464-46-1</td></tr>
</table>

SUMMARY CONCLUSIONS OF THE TARGETED ASSESSMENT

NOTE: The present assessment is targeted to address the following human health endpoints: repeated dose toxicity and carcinogenicity via the inhalation route of exposure, and genotoxicity. It cannot be considered as a full SIDS Initial Assessment. Summary information on exposure is also reported here. Other endpoints for human health and the environment included in the Canadian screening assessment but have not been presented to OECD member countries, and thus are not included in this profile.

The final screening assessment will be published under the responsibility of the Government of Canada.

Rationale for Targeting the Assessment

The Government of Canada "categorized" or prioritized all 23,000 chemical substances on its Domestic Substances List (DSL) from 1999 to September 2006, as required by its *Canadian Environmental Protection Act, 1999* (CEPA 1999). Additional details may be found at http://www.chemicalsubstanceschimiques.gc.ca/about-apropos/categor/index-eng.php. Using information from Canadian industry, academic research and other countries, Government of Canada scientists applied a set of rigorous tools to the 23,000 chemical substances on the DSL. They were categorized to identify those that were: **inherently toxic** to humans or to the environment and that might be **persistent** and/or **bioaccumulative**; and substances to which people might have **greatest potential for exposure**. During this priority-setting exercise, distinct approaches were taken for identifying substances of likely concern for human health and the environment, and subsequent assessment activities may have focused on either human health or ecological endpoints. Through categorization, the Government of Canada has identified approximately 4,000 of the 23,000

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chemical substances on the DSL as priorities for further assessment, research and/or measures to control their use or release. Quartz and cristobalite were identified at that time, applying the categorization criteria, as high priorities for human health risk because they were considered to pose greatest potential for exposure and their respirable forms are classified by the International Agency for Research on Cancer as carcinogenic to humans (quartz and cristobalite) and by the National Toxicology Program as known human carcinogens (crystalline silica). These substances did not meet the ecological categorization criteria for bioaccumulation potential or inherent toxicity to aquatic organisms.

Under the Canadian legislation a determination of whether one or more of the criteria of the CANADIAN ENVIRONMENTAL PROTECTION ACT (CEPA) 1999, section 64 are met is based upon an assessment of potential risks to the environment and/or to human health associated with exposures in the general environment. For humans, this includes, but is not limited to, exposures from ambient and indoor air, drinking water, foodstuffs, and the use of consumer products. A conclusion under CEPA 1999 on the substances in the Chemicals Management Plan (CMP) Challenge is not relevant to, nor does it preclude, an assessment against the hazard criteria specified in the Controlled Products Regulations, which is part of the regulatory framework for the Workplace Hazardous Materials Information System [WHMIS] for products intended for workplace use.

Physical-chemical properties

The silicon dioxide group represents a polymorphic category containing a large number of forms identical in composition but with different atomic arrangements which afford different chemical properties. There are two sub-categories within this group: crystalline silica, to which the present substances quartz and cristobalite belong, and non-crystalline or amorphous silica. The key distinction between these sub-categories is that in crystalline substances, the building blocks are arranged in regular, repeating 3-dimensional pattern having long range order, whereas amorphous materials do not display long range order. In all forms of silica, (crystalline and non-crystalline), the silicon atom is tetrahedral and bound to four neighbouring oxygen atoms.

Quartz and cristobalite are solid at room temperature, existing normally as colourless or white crystals. The melting points for quartz and cristobalite are 1400-2000 ^{o}C and 1713-1728 ^{o}C, respectively and for both compounds, the boiling point is 2230^{o}C. Even though no experimental data were available, their vapour pressure and Henry's Law constant are likely negligible. Log K_{ow} (octanol-water partition coefficient) and log K_{oc} (organic carbon-water partition coefficient) are not applicable to these substances. The densities range from 2500-2700 kg/m^3 for quartz and 2300-2380 kg/m^3 for cristobalite.

The very similar physico-chemical properties of quartz and cristobalite reflect their closely related crystal forms. The solubility of crystalline silicates decreases as a function of silica tetrahedral packing density and long-range crystal order. For example, cristobalite has a more open framework structure than quartz and its density is lower, therefore, its solubility is higher. The water solubility of these minerals is also function of temperature, pH, particle size, and the presence of a disrupted surface layer. This may explain the variability of solubility values reported by many authors. The most probable solubility value for quartz is approximately 3.8 mg Si/L, or 6.4 mg/L expressed as the SiO_2 species, while the solubility of cristobalite is approximately 8.7 mg Si/L, or 18 mg SiO_2/L. The kinetics of dissolution of these substances is slow due to the high activation energy required to hydrolyse the Si-O-Si bond.

Human Health Targeted Endpoints

The majority of the studies described here have been reviewed by the International Agency for Research on Cancer (IARC 1997). However, additional data relevant to the screening assessment were identified up to August 2010.

Repeated dose toxicity/non-neoplastic effects (development of silicosis).

Studies on animals

Significant short-term and subchronic studies have demonstrated adverse effects in the lungs, while one of the 6 studies showed effects on the spleen in mice. Rats were exposed to 0, 10 or 100 mg/m^3 of cristobalite via inhalation for 6 hours/day during 3 days. Animals were observed 3 months after exposure. Elevated levels of granulocytes and elevated markers of cytotoxicity from the lung lavage fluid were noted in all exposed groups. Another study of similar duration (9 days) conducted in mice also identified a LOAEC of 10 mg/m^3. Effects observed included minimal interstitial thickening, accumulations of mononuclear cells and slight lymphoid tissue hypertrophy in the lungs.

In a 4-week inhalation study, female rats were exposed to 0, 0.1, 1 or 10 mg/m^3 of quartz 6 hours/day, 5 days/week. Bronchoalveolar lavage fluid was evaluated at 1, 8, and 24 weeks after exposure. Elevated levels of

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granulocytes and significant elevation of markers of cytotoxicity (Lactate dehydrogenase [LDH] and β-glucuronidase [β-glu]) were observed at 1 mg/m^3 and higher. The increased levels of LDH and β-glu were only significant at 24 weeks after exposure. A LOAEC of 1 mg/m^3 was identified at 24 weeks.

Male rats (4 animals per dose) were exposed to 0 or 3 mg/m^3 of cristobalite via inhalation for 6 hours/day, 5 days/week during 13 weeks. Pulmonary inflammation and fibrosis were observed in the exposed group at the end of treatment. When mice were similarly exposed to 5 mg/m^3 of quartz for 6 hours/day, 5 days/week for 15 or 27 weeks, the authors observed increased spleen weight and formation of plaque in the spleen.

In two separate studies, in which rats or hamsters were exposed to quartz via inhalation for at least 6 months, LOAECs of 2 and 3 mg/m^3 were identified, respectively. All the effects observed were related to inflammation and fibrosis of the lung tissue.

Several chronic studies investigated exposure of the respirable forms (i.e. accumulated via inhalation in the lung tissues) of quartz and cristobalite to rats, mice and hamsters. The following is a description of the study in which the lowest non-neoplastic LOAEC was determined. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz, containing 74% of respirable quartz, through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. The mean mass of particle at the end of the exposure period was 0.91 mg/lung. The LOAEC identified was 0.74 mg/m^3 (adjusted for 74% respirable quartz) based on lipoproteinosis, multifocal, inflammatory cell infiltrate and alveolar hyperplasia.

Human epidemiology data

In humans, the lowest observed adverse effect level was identified in a U.S. cohort study. The study was conducted on 3330 gold miners (all are males), who had an average of 9 years underground exposure during the period 1940 to 1965. The cohort was followed up through 1990. Silicosis[1] was identified through death certificates or chest X-rays. A job-exposure matrix together with work history was used to estimate individual exposure. The total silica content in the respirable dust in the mine was estimated at 13% and the median crystalline silica exposure was 0.05 mg/m^3. In this sub population of miners, 170 cases of silicosis were identified. The best predictor for risk of silicosis was cumulative exposure, which varied from less than 1% for a 0.5 mg/m^3-year exposure to 68-84% when exposed to more than 4 mg/m^3-year (based on the average daily dust exposure during the workday each year and summed over time for each miner). The main limitations identified by the authors include the limited number of radiographic surveys, the potential bias from death certificates

[1] Silicosis: Lung disease caused by inhalation of crystalline silica dust, and resulting in inflammation and scarring in forms of nodular lesions in the upper lobes of the lungs. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics). It does not follow that a history of exposure to silica necessarily results in silicosis (Nonsilicotics). The typical "Silicotic" lung nodule is shown in Figure 1.

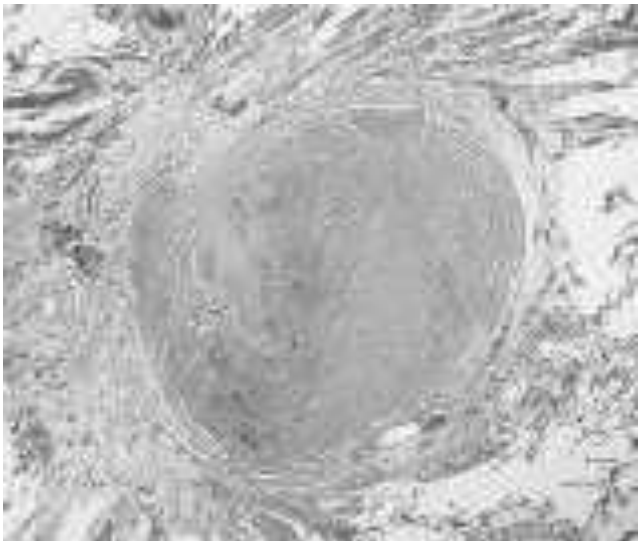


Figure 1. Silicotic nodule characterised by a central zone of hyalinised collagen with a whorled appearance and peripheral dust-containing macrophages (Rees and Murray, 2007).

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(relying on death certificates instead of relying on repeated x-rays, which were lacking for each miner, may have underestimated the number of cases) and the fact that the conversion of dust counts to

gravimetric measurements may not be accurate based on the estimation of 13% silica content in the respirable dust (although based on a relatively large number of samples (n = 82) collected in two different surveys, there was broad range of content in these samples (1% to 48%, SD = 9), and the percentage of respirable quartz may have differed in earlier years, but data were lacking for these years).

Two other human studies have identified similar LOAECs based on the critical endpoint of radiographic confirmed silicosis. A LOAEC of 0.053 mg/m^3 (mean exposure) was identified in a cross sectional study of South African gold miners and a LOAEC of 0.064 mg/m^3 (mean exposure) was derived in a mining community population-based random sample survey in Colorado.

Carcinogenicity studies

Studies on animals

Experimental studies conducted in rats have shown clear and consistent increases in lung tumours after chronic inhalation exposure. In the nine rat studies identified, five were inhalation studies and four were intratracheal instillation studies. All studies except one inhalation study showed increased incidence of lung tumours. For the inhalation studies with treatment related tumours, concentrations ranged from 1 to 50 mg/m^3 (1, 6, and 30 mg/m^3 of DQ-12 quartz; 12 and 50 mg/m^3 of Min-U-Sil 5 quartz) and duration of exposure ranged from 29 days to 2 years. In the inhalation study with no treatment-related tumours, exposure was 60 mg/m^3 of Sikron F300 quartz for 13 weeks. The following is a description of the neoplastic results in the study also identified as the critical study for non-neoplastic results. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. In the exposed group, 18 animals developed tumours (12 in females, 5 in males), as opposed to 3 and 2 for the control and positive control groups respectively. The majority (10/18) of the tumours observed were adenocarcinomas. The mean mass of particles in the lungs at the end of the exposure period was 0.91 mg/lung.

For the intratracheal instillation studies, doses ranged from 4 to 57 mg/kg-bw (based on 7, 12 or 20 mg/animal of Min-U-Sil (5) quartz or 20 mg/animal of novaculite quartz). Exposure regimes were diverse and included single instillation with observation for up to two years, to weekly instillation for 10 weeks. It is noteworthy that the single intratracheal administration of a 95% pure quartz particles (<5 μm) resulted in an increased incidence of silicotic granulomas after 3 weeks and lung tumours after 11 months. The most common tumours reported across the long term rat studies were adenocarcinomas, however other tumours such as squamous-cell carcinoma, alveolar carcinoma and bronchiole-alveolar adenoma were also reported, and all animals that developed tumours also showed some degree of fibrosis.

Of particular interest is the intratracheal instillation study, investigating the sequence of pathological events leading to lung tumors. An unspecified number of rats/sex/dose received a single intratracheal instillation of various crystalline silica dusts or ferric oxide, allowing direct administration into the bronchial tree. The doses were 12 or 20 mg of Min-U-Sil 5 quartz (MQZ), 12 mg of hydrofluoric-acid-etched Min-U-Sil 5 quartz (HFMQZ), 12 mg of cristobalite, 12 mg of tridymite and 12 mg of ferric oxide suspended in saline. All groups were observed until six months post exposure, except for both MQZ groups, the HFMQZ and the ferric oxide group which were observed up until 17 months post-exposure. Interim sacrifices were conducted at 6, 11 and 17 months. The rat lungs showed a clear progression of effects. The sequence of pathological events were, an initial inflammatory response leading to a marked hyperplasia and hypertrophy of alveolar cells after one month, and at six months hyperplasia was evident but no lung tumours were observed. In this study, lung tumours were observed starting at the 11 month sacrifice with a 17% and 42% incidence in males and females (based on 3/18 males and 8/19 females), respectively, and at 17 months incidences were 32% and 59% (based on 6/19 males and 10/17 females, respectively). No lung tumours were found in ferric oxide treated rats. Similar studies have also been conducted in hamsters and mice. Although treated mice and hamsters showed treatment related signs (inflammation or fibrosis), no tumours were observed in hamsters. No increase in the incidence of lung tumours was seen in mice treated with quartz; however silicotic granulomas and lymphoid cuffing around airways but no fibrosis were seen in the lungs of quartz-treated mice.

Human epidemiology data

There is an extensive dataset of human studies investigating the link between crystalline silica exposure and cancer. IARC (1997) identified over 50 epidemiological studies based on occupational exposure to dust containing respirable crystalline silica. Main industry sectors from which the human data is derived include gold mines, foundries, granite/stone industry, pottery workers and refractory brick workers. From the least confounded studies, it was noted that lung cancer tended to increase with the following parameters: cumulative

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exposure; duration of exposure; peak intensity of exposure; presence of radiographically defined silicosis; and length of follow-up time from date of silicosis diagnostic. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics).

Since the 1997 IARC report, a large number of epidemiological studies have been published, with the more recent studies being updates from supplementary follow-up of results from previously assessed case-control studies cohorts, new results based on refined exposure assessments or adjustment for confounders or meta-analyses of the pooled data from these epidemiology studies

In a meta-analysis of the data from 10 cohort studies of gold, tin and tungsten miners, granite workers, industrial sand, diatomaceous earth and pottery workers with quantitative exposure estimates for crystalline silica were pooled in order to analyse the risk related to lung cancer. The pooled cohort standardized mortality ratio (SMR, against national rates) [See Appendix 1 for definition] was 1.2 (Confidence Interval [CI] 1.1-1.3). The results from the case-control analyses show a statistically significant trend with duration of exposure (odds ratios (ORs) [See Appendix 1] by quintile of cumulative exposure increased from 1.0 to 1.6 [CIs of 0.85 to 2.1] and by quintile of average concentration increased from 1.0 to 1.7 [CIs of 1.1 to 2.3]), supporting the importance of the increasing lung burden of silica in the occurrence of cancer. Overall, the authors concluded that the results support the carcinogenicity conclusion presented by IARC (1997).

To investigate the link between crystalline silica, silicosis and lung cancer, epidemiological data published between 1966 and 2001 were gathered. Over 50 studies were selected and pooled according to type of study and the parameter being linked to lung cancer (i.e. silica exposure, presence of silicosis in subjects). The quality of study, adjustment for confounding factors, co-exposure to other carcinogens and availability of a more recent analysis of a same cohort were taken into consideration in the final selection of the studies. Analysis of the relationship between exposure to silica and lung cancer included 17 cohort and 13 case-control studies. For the analysis of lung cancer versus silicosis, 11 cohort and 5 case-control studies were selected. The third analysis included 6 cohort and 2 case-control studies to evaluate the risk of lung cancer in non-silicotics. A random effect model was used to conduct each meta-analysis. Pooled cancer risk ratios (RRs) were 1.32 (CI 1.23-1.41) for crystalline silica exposure, 2.37 (CI 1.98-2.84) for individuals exposed to silica with confirmed silicosis (Silicotics) and 0.96 (CI 0.81-1.15) for individuals with no evidence of silicosis (non-silicotics) with confirmed exposure to silica, supporting the general observation that silicosis has a stronger temporal relationship with crystalline silica exposure and furthermore support the view that a human silicotic response could be a preliminary stage in the development of cancer.

A more recent meta-analysis included 28 cohort, 15 case-control and two proportionate mortality ratio (PMR) [See Appendix 1] studies from a variety of occupational settings conducted between 1996 and 2005. Risk ratios (RRs) were calculated based on type of study and silicosis status using fixed and random effect models (results presented here are from the random model). RRs for all cohort studies was 1.34 (CI 1.25-1.45), and were 1.69 (CI 1.32-2.16) for silicotics, 1.25 (CI 1.18-1.33) for those with undefined silicosis status and 1.19 (CI 0.87-1.57) for non-silicotics. In the case-control studies, the general RR was 1.41 (CI1.18-1.67), and the same sub-groups as mentioned above resulted in RRs of 3.27 (CI 1.32-8.2), 1.41 (CI1.18-1.70) and 0.97 (CI 0.68-1.38), respectively. The proportionate mortality ratio for the last two studies was 1.24 (CI 1.05-1.47). The authors noted that the association between lung cancer and exposure to crystalline silica was more consistent for silicotics, i.e., those diagnosed with silicosis and RR values split into type of occupational settings in which participants worked.

Based upon the above three meta-analysis studies and the epidemiology studies discussed in IARC (1997), the following can be concluded. Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis. Cancer risk is often more significant in workers exposed to crystalline silica over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours. Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles.

There have been reports of tumours outside of the lungs in persons with high silica exposure; however, these reports are sparse and the data inconsistent and have not been unequivocally linked to exposure to either one of the crystalline forms (quartz or cristobalite). Some of the reported locations are: oesophagus, stomach, liver, skin and bone. Sufficient epidemiological or toxicological data do not currently exist for quantitative assessment of the exposure-response relationship on these other tissues or organs.

Genotoxicity

Potential genotoxicity has been assessed in multiple *in vitro* and *in vivo* assays. Table 1 below gives a brief summary of the positive results observed in each type of assay.

Table 1. Summary of positive results over total number of results for each assay and each category (all studies

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conducted with crystalline silica: quartz, except where indicated).

Assay	Animal data		Human data		Positives/Total	
	In vitro	In vivo	In vitro	In vivo[d]	In vitro	In vivo
Rec Assay	0/1				0/1	
DNA strand break	1/1	2/2	5/5[b]	1/1	6/6	3/3
Sister chromatid exchange	0/1		0/1[c]	1/1	0/2	1/1
Micronucleus	2/3	0/1	2/2[b]	1/1	4/5	1/2
Chromosome aberration	0/1			1/1	0/1	1/1
Aneuploidy/polyploidy	0/3				0/3	
Cell transformation	4/4				4/4	
Hprt mutation	1/2	2/2[a]	1/1[b]		2/3	2/2
Oxidative DNA damage		4/5	2/2		2/2	4/5
DNA binding		1/1				1/1
p53 activation		0/1				0/1

a. one assay conducted with crystalline silica: cristobalite
b. one assay conducted with "ultrafine crystalline silicon dioxide".
c. crystalline silica: tridymite
d. crystalline silica dust (subtypes not provided).

All the *in vivo* human genotoxicity studies are based on three independent studies that used blood samples from workers from diverse occupational settings with confirmed exposures to crystalline silica dust; however, quantification of exposure was not provided. After stratification by smoking status, sister chromatid exchange remained statistically significant in both smokers and non-smokers although the frequency was higher in smokers. For the chromosome aberration assay conducted as part of the same study (blood samples from workers in the stone crusher industry), the increased frequency was no longer significant after stratification. In the DNA damage study of foundry and pottery workers and the micronucleus assay of workers involved in sandblasting and related jobs, results were positive when compared to controls. However, in both studies, smoking status influenced the results, contributing to the increased DNA damage observed since results were greater in smokers versus non-smokers, and the frequency of micronuclei in nasal epithelial cells was higher in smokers (p=0.002) but when using peripheral blood lymphocytes did not differ statistically between smokers and non-smokers who were similarly exposed to silica dust,

The role of *in situ* generation of reactive oxygen species (ROS) and reactive nitrogen species (RNS) has been well established in the following types of DNA damage: small scale insertions, DNA base pair deletion, base modification, chromosomal change/loss, microsatellite instability, DNA strand break, 8-hydroxydeoxyguanosine (8-OHdG) mutation and point mutations. ROS and RNS generation is postulated to be (a part of) the DNA damage mechanism for crystalline silica. Studies are described below to support this hypothesis.

DNA was exposed *in vitro* to various crystalline silica dusts, to H_2O_2, or to both. Results show that DNA damage was limited when dust or H_2O_2 were administered alone but increased with the co-exposure. When the reactive oxygen scavenger, dimethylsulfoxide, was added to the test system, DNA strand break was inhibited, data supporting the viewpoint that it is the presence of radicals generated in response to quartz and cristobalite that causes the DNA damage and not quartz or cristobalite themselves.

Hprt mutation assays in rat alveolar epithelial cells, both *in vitro* and *in vivo,* were positive in response to quartz. The positive results *in vivo* were seen only in the presence of significant inflammatory responses in the treated animals. Also, in a parallel *in vitro* experiment, rat alveolar epithelial cells were incubated with the bronchoalveolar lavage fluid from the rats exposed to quartz. Both macrophage and neutrophil enriched lavage cells induced mutation in the exposed alveolar epithelial cells. Addition of catalase (an enzyme which inactivates H_2O_2) before incubation inhibited the increase in *hprt* mutation.

Rats were exposed to either crystalline or amorphous silica in a manner to induce the same level of

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inflammation in the lungs. The inflammatory response was assessed by measuring the proportion of neutrophils in the bronchiolar lavage fluid. The actual concentrations were 3 and 50 mg/m^3 for crystalline and amorphous silica respectively. The animals were exposed for 13 weeks. *Hprt* mutation frequency was measured in the alveolar epithelial cells at the end of the exposure period. Mutation frequency was greatly increased only in the crystalline silica treated rats; no treatment related increase was found in the rats treated with the amorphous form.

In an 8-OHdG assay conducted to monitor DNA damage by reactive oxygen species, female rats were exposed to 0, 0.3, 1.5 and 7.5 mg/animal of quartz via intratracheal instillation. Effects were observed 90 days post-exposure. A clear dose-response relationship was identified between quartz exposure and various inflammation markers (differential cell count, protein, lung surfactant lipids and tumour necrosis factor alpha). Inflammation was present starting at the lowest dose. However, 8-OHdG showed a statistically significant increase starting at 1.5 mg/animal only. Similarly, in another study, 8-OHdG and DNA strand breaks were observed at concentrations of or above 10 ug/m^3 in rat lung epithelial cells.

In the aim of investigating the role of ROS in lung carcinogenesis, rat lung epithelial cells were incubated with polymorphonuclear (PMN) leukocytes (involved in the inflammatory process and responsible for the release of certain ROS) or hydrogen peroxide. Statistically significant increases in 8-OHdG were observed in the presence of PMN or hydrogen peroxide in a dose-response manner.

In a series of experiments which used *in vitro* stimulation of macrophages with crystalline silica and *in vivo* intranasal instillation of crystalline silica in mice, it was demonstrated that that the chronic fibrosis seen in a murine model of silicosis *in vivo* is dependent on the presence of adaptor molecule ASC and Nalp3 inflammazome. These data support a potential mode of action whereby silica triggers cellular responses that in turn activate alveolar macrophages, resulting in an inflammatory response and silicosis. In mice deficient in Nalp3 inflammazome, the development of inflammation and collagen deposition was significantly reduced compared with normal mice 3 months after the initial intranasal instillation of silica.

Analysis of Lung Tumour Data

The weight of evidence for both rats and humans indicates that fibrotic and silicotic lesions in the lung result from inhalation exposure to crystalline silica and that lung cancer is secondary to those lesions in the lung. Although the mechanism of induction for the lung tumours has not been fully elucidated, there is sufficient supportive mode of action evidence from the data presented to demonstrate that a threshold approach to risk assessment is appropriate based on an understanding of the key events in the pathogenesis of crystalline silica induced lung tumours. The body of evidence include the following:

- In experimental studies, all rats that developed tumours also showed fibrosis.
- Adenocarcinomas, the most common type of tumour identified in rats, are commonly associated with fibrosis and deeply scarred lung tissue.
- Experimental rat studies showed a clear progression of the effects from initially mild inflammation, followed by fibrosis over-time, leading eventually to lung tumours.
- Tumours are not present in all treated species dosed in the same way.
- The tumours, both in rats and humans, are concentrated in the lungs only, although other organs are indirectly exposed.
- In human studies, cancer risk is often more significant in workers exposed over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours.
- Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles
- Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis.
- For genotoxicity, in vitro results were mostly mixed and in vivo results were mostly positive. However, the vast majority of the positive genotoxicity assay results can be explained by the generation of reactive oxygen species, as demonstrated experimentally, where ROS scavenging prevents the genotoxicity.
- *In vivo*, macrophage deficient mice (macrophages produce ROS in response to crystalline silica) do not develop silicosis nor do they develop tumours and the Nalp3 inflammazome, a key player in the macrophage initiated inflammatory response, is required for the development of pulmonary fibrosis after

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inhalation of silica.

- Though inhalation exposure to crystalline silica in multiple occupational settings is clear, the increase in risk, based on the several recent meta-analyses of the multiple human epidemiological studies, remains low.

It is worth noting that where aggressive engineering controls have been made to reduce silica dust levels in the workplace (Sweden), silicosis has been eliminated. By corollary, existing exposures outside of the workplace in such areas do not pose a risk for silicosis to the general population.

The respirable forms of quartz and cristobalite possess properties indicating a hazard for human health (repeated dose toxicity, carcinogenicity and genotoxicity). The mode of action in the lungs involves irritation, inflammation and reactive species formation, leading to silicosis, and eventually to tumour formation.

Exposure

Uses

Consistent with oxygen and silicon being the two most abundant elements in the Earth's crust, silicon-oxide minerals, including quartz are ubiquitous in the natural environment. In particular, as a component of sand, quartz may find use in a diverse array of applications. Several high volume uses include, but are not limited to, the use of sand as a filling material for the construction of roads and in general building activities, the use of sand and gravel aggregates as abrasives on roads in winter and the use of fly-ash, which may contain 4-14% quartz and 0.5-1% cristobalite, as a cement additive. These abrasives when used on winter roads are usually mixed with road salts and may be sand only, stone dust, sand and gravel aggregates, or pre-treated sand. They are used mainly by rural municipalities or in areas where cold temperatures diminish the efficiency of salts for de-icing. Quantities of abrasives used in Canada were 5.73×10^9 kg, 4.59×10^9 kg, and 4.93×10^9 kg for 2007, 2008 and 2009, respectively.

Industrial sand, high purity silica sand products with closely controlled sizing are expected to contain quartz and cristobalite, include lump silica (2-3mm up to 15 cm or more), silica sand (75µm to 2-3mm) and silica flour (less than 75µm). Lump silica may be used in the production of silicon alloys, silica bricks, and the linings of certain types of pulverizers (eg. ball mills and tube mills).

Silica sand may be used in the manufacture of glass and glass fibres, silicate chemicals and silicon carbide, the hydraulic fracturing of wells, foundry moulding, and for sandblasting. Silica flour may find use in the ceramics and cement industries, as a filler and extender in rubber and coatings, and as an abrasive in soaps.

Natural clays, such as bentonite and fuller's earth, are used in cat litters for their high water absorbance capacities. Quartz is a natural component of these clays, and consequently, it may be present in cat litter products. High purity α-quartz is a piezoelectric material, which means that application of a voltage induces a distortion in the crystal shape and vice versa. This ability to interconvert electrical and mechanical energy has led to the use of quartz crystals in electronic devices requiring precise timing control, for example telephones, radios, watches and computers.

According to a survey conducted in Canada, quartz and cristobalite are also used in abrasives, adsorbents, filter products (diatomaceous earth), grout and cement. These substances reportedly also find use as fillers, which add bulk and improve wear resistance, in paints and coatings, adhesives, sealants, polymer films, caulking, epoxy resins and silicones. Also, quartz is listed as an ingredient in 60 cosmetic products in Canada. The types of products include anti-wrinkle preparation, eye and face makeup, lipstick, hair dyes, shampoos and grooming products, as well as skin cleansers, moisturizers and tanning preparations.

Natural Sources

In Canada, quartz naturally occurs in many types of rock formations. Those with high silicon dioxide content (95% SiO_2 or more) include vein and massive intrusion bodies, quartz pebbles, silica sand, sandstone and quartzite. Sandstone is a sedimentary rock mostly composed of quartz grains cemented by a bonding material such as clay, calcite or iron oxide. Quartzite is a hard, compact, metamorphosed sandstone made of grains of quartz firmly bonded with a siliceous cement. Mineral aggregates (e.g., sand and gravel) have variable silicon dioxide content. Quartz is also found as crystals, aggregates or discrete particles in certain igneous rocks (e.g., granites and pegmatites), soils, sediments, air and surface water. This omnipresence is consistent with the fact that silicon is the second most abundant chemical element on Earth.

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Cristobalite is naturally produced in the ashes of volcanic eruptions, and by combustion metamorphism which is a local phenomenon of spontaneous combustion of naturally occurring substances such as bituminous rocks, coal or oil. It may be found in cavities in volcanic rocks and in thermally metamorphosed sandstones and may also be a transient stage in the diagenesis of diatomaceous shale with the result that soils made of these geologic formations may be rich in cristobalite. Unlike quartz, the natural occurrence of cristobalite is limited to specific geographic regions and mineral types.

Anthropogenic Sources

Natural quartz is isolated from ore via beneficiation, which involves milling or grinding the material into particles that are separated into desired mineral and waste. The materials obtained are either used directly or further purified. In Canada, in 2006, 2.146×10^{9} kg of pure quartz were mined, and 2.385×10^{11} kg of sand and gravel aggregates were produced. The proportion of quartz in silica sand deposits and gravel aggregates will vary from one site to another.

Cristobalite can form from silica melts during the preparation of silica glass; quartz is not obtained from melts but is manufactured at elevated temperature and pressure via a hydrothermal process. Cristobalite also forms during the calcination[2] of diatomaceous earth.

Human Exposure Estimate

Ambient air

The exposure assessment is focussed on respirable quartz and cristobalite, which in ambient air comprises a component of total particulate matter (PM). In Canada, data on the concentrations of silicon in PM was available and used as a surrogate for quartz and cristobalite. This approach is conservative because the measured silicon includes all silicon-containing substances and therefore represents the upper limit for quartz and cristobalite in ambient air.

The National Air Pollution Surveillance (NAPS) Program measured concentrations in $\mu g/m^3$ of silicon in PM with aerodynamic radii less than 2.5 µm ($PM_{2.5}$ (dichot)), and from 2.5 to 10 µm (PM_{10} (dichot)) (the total particulate matter with aerodynamic radii less than 10 µm (PM_{10}) is obtained by adding these values) in Canada. In 2009, as part of the NAPS Program, silicon concentrations were determined on over 1600 samples of $PM_{2.5}$(dichot) and over 1500 samples of PM_{10}(dichot) at 24 urban locations across Canada. An estimate of exposure to quartz and cristobalite can be obtained by assuming that all the silicon in the PM is represented stoichiometrically as SiO_2, and multiplying the reported concentration of silicon by 2.14 to obtain a value for silica.

The intake of respirable quartz and cristobalite by the general population of Canada is estimated using a range covering the lowest 50^{th} percentile SiO_2 concentration in PM_{10}, measured in Pt. Petre, ON, (0.12 $\mu g/m^3$) to the highest 50^{th} percentile concentration in PM_{10} measured in Calgary, AB (2.1 $\mu g/m^3$). The 50^{th} percentile SiO_2 concentrations ranged from 0.1 to 2.1 $\mu g/m^3$ across the survey sites; the top of this range is quite close to the average of the maximum values for the 24 sites (3.7 $\mu g/m^3$). The outdoor data were used to represent the indoor levels, because information on indoor silicon concentrations was not available, and the range of PM_{10} measured indoors is generally lower than the outdoor range. Thus, this approach conservatively overestimates indoor exposure in homes.

The highest exposure group based on these calculations is children ages 0.5 to 4 years with an estimated daily intake ranging from 0.07 to 5.26 µg/kg-bw per day; the estimated daily intake decreases with age due to changes in the ratio of inhalation rates to body weights; the daily intake of adults, 20-59 years old, is estimated to range from 0.03 to 2.00 µg/kg-bw per day.

Consumer Products

Exposure to respirable quartz from the use of cosmetic products, which contained quartz as an ingredient, was considered low because they are not formulated for spray application, the loose powders were reported to contain less than 0.1% quartz, and in these products the substance is not expected to be associated with other components of the formulation and not available in a free form.

For consumer Do It Yourself (DIY) activities around the home, the highest mean breathing zone concentration of particles from sanding dry wall (median cut-point of 10µm) of 6.31 mg/m^3, was used to derive an upper-

[2] Calcinations: Heat treating a substance, but without fusion, to bring about change in its physical or chemical constitution.

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bound exposure estimate ranging from 2 to10 µg/kg-bw per event.

Quartz is used to formulate a large number of paints and coatings. To estimate potential inhalation exposure to quartz from these products, the spray painting of wall paints with an airless spray gun was considered appropriate as a conservative scenario. Exposure to respirable paint particles was estimated using data from controlled a laboratory study in which walls of poorly ventilated test rooms were painted by professional painters using an airless sprayer to apply interior latex paint. The maximum concentration of 13% quartz in paint in Canada was used to estimate exposure. The upper-bound estimate of exposure to quartz, based on the maximum concentration of 13% quartz in paint in the Canadian market and the maximum concentration of respirable paint particles measured in these controlled studies when recommended personal protective equipment is used, is 0.954 µg/kg-bw per event.

Inhalation of ambient air containing quartz and cristobalite is the dominant pathway of chronic exposure (excluding that from DIY activities) for the general population. Because SiO_2 makes up only approximately 5% of PM_{10}, silicon concentrations (expressed as SiO_2) measured in the Canadian NAPS survey of 24 urban locations were considered most relevant to the estimation of exposure by the general population. Quartz and cristobalite comprise only a portion of the total SiO_2 in PM_{10}, therefore, the use of the total silicon concentration to represent the upper bound crystalline silica concentrations results in an overestimation of exposure.

Appendix 1: Definitions of Epidemiological Terms in the ITAP

SMR (Standardized Mortality Ratio): The ratio (x 100) of observed to expected deaths in a study population. Expected deaths are calculated by applying a set of standard age-specific mortality rates to the age distribution of the study population. Standardized ratios are only useful for comparisons. They have no intrinsic meaning.

OR (Odds Ratio): In epidemiological case-control studies, a relative measure of disease occurrence. The odds in favour of a particular disease occurring in an exposed group are divided by the odds in favour of its occurring in an unexposed group. If the condition being studied is rare, the odds ratio is a close approximation to the relative risk.

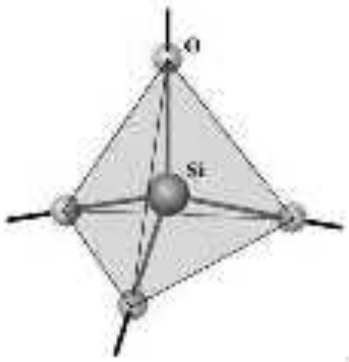
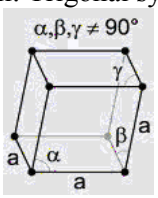
RR (Risk Ratio): The probability of the occurrence of a disease in a group that has been exposed to some environmental, medicinal, microbial, or toxic influence, relative to its probability in a randomly selected population.

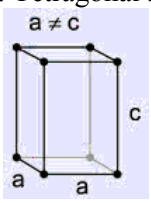
PMR (Proportionate Mortality Ratio): Proportionate mortality is the proportion of deaths in a specified population over a period of time attributable to different causes. Each cause is expressed as a percentage of all deaths, and the sum of the causes must add to 100%. These proportions are not mortality rates, since the denominator is all deaths, not the population in which the deaths occurred. Thus, proportionate mortality ratio is a measure of the frequency of occurrence of the proportionate mortality in a defined population during a specified interval of time.

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INITIAL TARGETED ASSESSMENT PROFILE (Human Health)

<table>
<tr><td>CAS No.</td><td colspan="2">Quartz: CAS RN 14808-60-7

Cristobalite: CAS RN 14464-46-1</td></tr>
<tr><td>Chemical Name</td><td colspan="2">Quartz and Cristobalite</td></tr>
<tr><td rowspan="2">Structural Formula</td><td colspan="2">Molecular Formula: SiO_2

</td></tr>
<tr><td>Unit Cell: Trigonal symmetry


Quartz: CAS RN 14808-60-7</td><td>Unit Cell: Tetragonal symmetry


Cristobalite: CAS RN 14464-46-1</td></tr>
</table>

SUMMARY CONCLUSIONS OF THE TARGETED ASSESSMENT

NOTE: The present assessment is targeted to address the following human health endpoints: repeated dose toxicity and carcinogenicity via the inhalation route of exposure, and genotoxicity. It cannot be considered as a full SIDS Initial Assessment. Summary information on exposure is also reported here. Other endpoints for human health and the environment included in the Canadian screening assessment but have not been presented to OECD member countries, and thus are not included in this profile.

The final screening assessment will be published under the responsibility of the Government of Canada.

Rationale for Targeting the Assessment

The Government of Canada "categorized" or prioritized all 23,000 chemical substances on its Domestic Substances List (DSL) from 1999 to September 2006, as required by its *Canadian Environmental Protection Act, 1999* (CEPA 1999). Additional details may be found at http://www.chemicalsubstanceschimiques.gc.ca/about-apropos/categor/index-eng.php. Using information from Canadian industry, academic research and other countries, Government of Canada scientists applied a set of rigorous tools to the 23,000 chemical substances on the DSL. They were categorized to identify those that were: **inherently toxic** to humans or to the environment and that might be **persistent** and/or **bioaccumulative**; and substances to which people might have **greatest potential for exposure**. During this priority-setting exercise, distinct approaches were taken for identifying substances of likely concern for human health and the environment, and subsequent assessment activities may have focused on either human health or ecological endpoints. Through categorization, the Government of Canada has identified approximately 4,000 of the 23,000

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chemical substances on the DSL as priorities for further assessment, research and/or measures to control their use or release. Quartz and cristobalite were identified at that time, applying the categorization criteria, as high priorities for human health risk because they were considered to pose greatest potential for exposure and their respirable forms are classified by the International Agency for Research on Cancer as carcinogenic to humans (quartz and cristobalite) and by the National Toxicology Program as known human carcinogens (crystalline silica). These substances did not meet the ecological categorization criteria for bioaccumulation potential or inherent toxicity to aquatic organisms.

Under the Canadian legislation a determination of whether one or more of the criteria of the CANADIAN ENVIRONMENTAL PROTECTION ACT (CEPA) 1999, section 64 are met is based upon an assessment of potential risks to the environment and/or to human health associated with exposures in the general environment. For humans, this includes, but is not limited to, exposures from ambient and indoor air, drinking water, foodstuffs, and the use of consumer products. A conclusion under CEPA 1999 on the substances in the Chemicals Management Plan (CMP) Challenge is not relevant to, nor does it preclude, an assessment against the hazard criteria specified in the Controlled Products Regulations, which is part of the regulatory framework for the Workplace Hazardous Materials Information System [WHMIS] for products intended for workplace use.

Physical-chemical properties

The silicon dioxide group represents a polymorphic category containing a large number of forms identical in composition but with different atomic arrangements which afford different chemical properties. There are two sub-categories within this group: crystalline silica, to which the present substances quartz and cristobalite belong, and non-crystalline or amorphous silica. The key distinction between these sub-categories is that in crystalline substances, the building blocks are arranged in regular, repeating 3-dimensional pattern having long range order, whereas amorphous materials do not display long range order. In all forms of silica, (crystalline and non-crystalline), the silicon atom is tetrahedral and bound to four neighbouring oxygen atoms.

Quartz and cristobalite are solid at room temperature, existing normally as colourless or white crystals. The melting points for quartz and cristobalite are 1400-2000 ^{o}C and 1713-1728 ^{o}C, respectively and for both compounds, the boiling point is 2230^{o}C. Even though no experimental data were available, their vapour pressure and Henry's Law constant are likely negligible. Log K_{ow} (octanol-water partition coefficient) and log K_{oc} (organic carbon-water partition coefficient) are not applicable to these substances. The densities range from 2500-2700 kg/m^3 for quartz and 2300-2380 kg/m^3 for cristobalite.

The very similar physico-chemical properties of quartz and cristobalite reflect their closely related crystal forms. The solubility of crystalline silicates decreases as a function of silica tetrahedral packing density and long-range crystal order. For example, cristobalite has a more open framework structure than quartz and its density is lower, therefore, its solubility is higher. The water solubility of these minerals is also function of temperature, pH, particle size, and the presence of a disrupted surface layer. This may explain the variability of solubility values reported by many authors. The most probable solubility value for quartz is approximately 3.8 mg Si/L, or 6.4 mg/L expressed as the SiO_2 species, while the solubility of cristobalite is approximately 8.7 mg Si/L, or 18 mg SiO_2/L. The kinetics of dissolution of these substances is slow due to the high activation energy required to hydrolyse the Si-O-Si bond.

Human Health Targeted Endpoints

The majority of the studies described here have been reviewed by the International Agency for Research on Cancer (IARC 1997). However, additional data relevant to the screening assessment were identified up to August 2010.

Repeated dose toxicity/non-neoplastic effects (development of silicosis).

Studies on animals

Significant short-term and subchronic studies have demonstrated adverse effects in the lungs, while one of the 6 studies showed effects on the spleen in mice. Rats were exposed to 0, 10 or 100 mg/m^3 of cristobalite via inhalation for 6 hours/day during 3 days. Animals were observed 3 months after exposure. Elevated levels of granulocytes and elevated markers of cytotoxicity from the lung lavage fluid were noted in all exposed groups. Another study of similar duration (9 days) conducted in mice also identified a LOAEC of 10 mg/m^3. Effects observed included minimal interstitial thickening, accumulations of mononuclear cells and slight lymphoid tissue hypertrophy in the lungs.

In a 4-week inhalation study, female rats were exposed to 0, 0.1, 1 or 10 mg/m^3 of quartz 6 hours/day, 5 days/week. Bronchoalveolar lavage fluid was evaluated at 1, 8, and 24 weeks after exposure. Elevated levels of

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granulocytes and significant elevation of markers of cytotoxicity (Lactate dehydrogenase [LDH] and β-glucuronidase [β-glu]) were observed at 1 mg/m^3 and higher. The increased levels of LDH and β-glu were only significant at 24 weeks after exposure. A LOAEC of 1 mg/m^3 was identified at 24 weeks.

Male rats (4 animals per dose) were exposed to 0 or 3 mg/m^3 of cristobalite via inhalation for 6 hours/day, 5 days/week during 13 weeks. Pulmonary inflammation and fibrosis were observed in the exposed group at the end of treatment. When mice were similarly exposed to 5 mg/m^3 of quartz for 6 hours/day, 5 days/week for 15 or 27 weeks, the authors observed increased spleen weight and formation of plaque in the spleen.

In two separate studies, in which rats or hamsters were exposed to quartz via inhalation for at least 6 months, LOAECs of 2 and 3 mg/m^3 were identified, respectively. All the effects observed were related to inflammation and fibrosis of the lung tissue.

Several chronic studies investigated exposure of the respirable forms (i.e. accumulated via inhalation in the lung tissues) of quartz and cristobalite to rats, mice and hamsters. The following is a description of the study in which the lowest non-neoplastic LOAEC was determined. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz, containing 74% of respirable quartz, through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. The mean mass of particle at the end of the exposure period was 0.91 mg/lung. The LOAEC identified was 0.74 mg/m^3 (adjusted for 74% respirable quartz) based on lipoproteinosis, multifocal, inflammatory cell infiltrate and alveolar hyperplasia.

Human epidemiology data

In humans, the lowest observed adverse effect level was identified in a U.S. cohort study. The study was conducted on 3330 gold miners (all are males), who had an average of 9 years underground exposure during the period 1940 to 1965. The cohort was followed up through 1990. Silicosis[1] was identified through death certificates or chest X-rays. A job-exposure matrix together with work history was used to estimate individual exposure. The total silica content in the respirable dust in the mine was estimated at 13% and the median crystalline silica exposure was 0.05 mg/m^3. In this sub population of miners, 170 cases of silicosis were identified. The best predictor for risk of silicosis was cumulative exposure, which varied from less than 1% for a 0.5 mg/m^3-year exposure to 68-84% when exposed to more than 4 mg/m^3-year (based on the average daily dust exposure during the workday each year and summed over time for each miner). The main limitations identified by the authors include the limited number of radiographic surveys, the potential bias from death certificates

[1] Silicosis: Lung disease caused by inhalation of crystalline silica dust, and resulting in inflammation and scarring in forms of nodular lesions in the upper lobes of the lungs. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics). It does not follow that a history of exposure to silica necessarily results in silicosis (Nonsilicotics). The typical "Silicotic" lung nodule is shown in Figure 1.

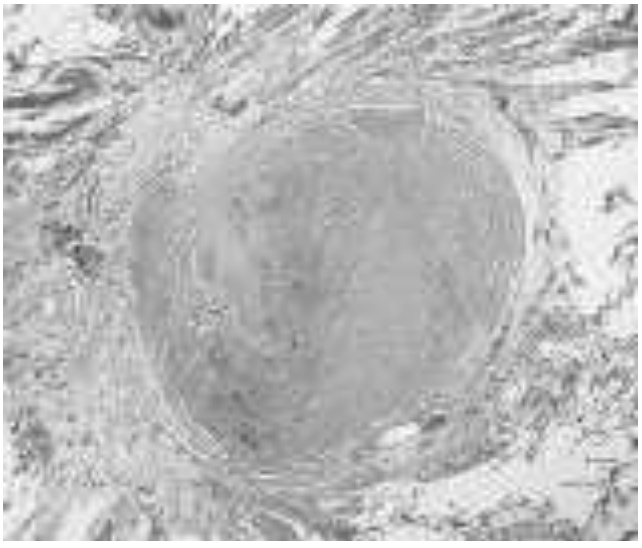


Figure 1. Silicotic nodule characterised by a central zone of hyalinised collagen with a whorled appearance and peripheral dust-containing macrophages (Rees and Murray, 2007).

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(relying on death certificates instead of relying on repeated x-rays, which were lacking for each miner, may have underestimated the number of cases) and the fact that the conversion of dust counts to

gravimetric measurements may not be accurate based on the estimation of 13% silica content in the respirable dust (although based on a relatively large number of samples (n = 82) collected in two different surveys, there was broad range of content in these samples (1% to 48%, SD = 9), and the percentage of respirable quartz may have differed in earlier years, but data were lacking for these years).

Two other human studies have identified similar LOAECs based on the critical endpoint of radiographic confirmed silicosis. A LOAEC of 0.053 mg/m^3 (mean exposure) was identified in a cross sectional study of South African gold miners and a LOAEC of 0.064 mg/m^3 (mean exposure) was derived in a mining community population-based random sample survey in Colorado.

Carcinogenicity studies

Studies on animals

Experimental studies conducted in rats have shown clear and consistent increases in lung tumours after chronic inhalation exposure. In the nine rat studies identified, five were inhalation studies and four were intratracheal instillation studies. All studies except one inhalation study showed increased incidence of lung tumours. For the inhalation studies with treatment related tumours, concentrations ranged from 1 to 50 mg/m^3 (1, 6, and 30 mg/m^3 of DQ-12 quartz; 12 and 50 mg/m^3 of Min-U-Sil 5 quartz) and duration of exposure ranged from 29 days to 2 years. In the inhalation study with no treatment-related tumours, exposure was 60 mg/m^3 of Sikron F300 quartz for 13 weeks. The following is a description of the neoplastic results in the study also identified as the critical study for non-neoplastic results. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. In the exposed group, 18 animals developed tumours (12 in females, 5 in males), as opposed to 3 and 2 for the control and positive control groups respectively. The majority (10/18) of the tumours observed were adenocarcinomas. The mean mass of particles in the lungs at the end of the exposure period was 0.91 mg/lung.

For the intratracheal instillation studies, doses ranged from 4 to 57 mg/kg-bw (based on 7, 12 or 20 mg/animal of Min-U-Sil (5) quartz or 20 mg/animal of novaculite quartz). Exposure regimes were diverse and included single instillation with observation for up to two years, to weekly instillation for 10 weeks. It is noteworthy that the single intratracheal administration of a 95% pure quartz particles (<5 μm) resulted in an increased incidence of silicotic granulomas after 3 weeks and lung tumours after 11 months. The most common tumours reported across the long term rat studies were adenocarcinomas, however other tumours such as squamous-cell carcinoma, alveolar carcinoma and bronchiole-alveolar adenoma were also reported, and all animals that developed tumours also showed some degree of fibrosis.

Of particular interest is the intratracheal instillation study, investigating the sequence of pathological events leading to lung tumors. An unspecified number of rats/sex/dose received a single intratracheal instillation of various crystalline silica dusts or ferric oxide, allowing direct administration into the bronchial tree. The doses were 12 or 20 mg of Min-U-Sil 5 quartz (MQZ), 12 mg of hydrofluoric-acid-etched Min-U-Sil 5 quartz (HFMQZ), 12 mg of cristobalite, 12 mg of tridymite and 12 mg of ferric oxide suspended in saline. All groups were observed until six months post exposure, except for both MQZ groups, the HFMQZ and the ferric oxide group which were observed up until 17 months post-exposure. Interim sacrifices were conducted at 6, 11 and 17 months. The rat lungs showed a clear progression of effects. The sequence of pathological events were, an initial inflammatory response leading to a marked hyperplasia and hypertrophy of alveolar cells after one month, and at six months hyperplasia was evident but no lung tumours were observed. In this study, lung tumours were observed starting at the 11 month sacrifice with a 17% and 42% incidence in males and females (based on 3/18 males and 8/19 females), respectively, and at 17 months incidences were 32% and 59% (based on 6/19 males and 10/17 females, respectively). No lung tumours were found in ferric oxide treated rats. Similar studies have also been conducted in hamsters and mice. Although treated mice and hamsters showed treatment related signs (inflammation or fibrosis), no tumours were observed in hamsters. No increase in the incidence of lung tumours was seen in mice treated with quartz; however silicotic granulomas and lymphoid cuffing around airways but no fibrosis were seen in the lungs of quartz-treated mice.

Human epidemiology data

There is an extensive dataset of human studies investigating the link between crystalline silica exposure and cancer. IARC (1997) identified over 50 epidemiological studies based on occupational exposure to dust containing respirable crystalline silica. Main industry sectors from which the human data is derived include gold mines, foundries, granite/stone industry, pottery workers and refractory brick workers. From the least confounded studies, it was noted that lung cancer tended to increase with the following parameters: cumulative

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exposure; duration of exposure; peak intensity of exposure; presence of radiographically defined silicosis; and length of follow-up time from date of silicosis diagnostic. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics).

Since the 1997 IARC report, a large number of epidemiological studies have been published, with the more recent studies being updates from supplementary follow-up of results from previously assessed case-control studies cohorts, new results based on refined exposure assessments or adjustment for confounders or meta-analyses of the pooled data from these epidemiology studies

In a meta-analysis of the data from 10 cohort studies of gold, tin and tungsten miners, granite workers, industrial sand, diatomaceous earth and pottery workers with quantitative exposure estimates for crystalline silica were pooled in order to analyse the risk related to lung cancer. The pooled cohort standardized mortality ratio (SMR, against national rates) [See Appendix 1 for definition] was 1.2 (Confidence Interval [CI] 1.1-1.3). The results from the case-control analyses show a statistically significant trend with duration of exposure (odds ratios (ORs) [See Appendix 1] by quintile of cumulative exposure increased from 1.0 to 1.6 [CIs of 0.85 to 2.1] and by quintile of average concentration increased from 1.0 to 1.7 [CIs of 1.1 to 2.3]), supporting the importance of the increasing lung burden of silica in the occurrence of cancer. Overall, the authors concluded that the results support the carcinogenicity conclusion presented by IARC (1997).

To investigate the link between crystalline silica, silicosis and lung cancer, epidemiological data published between 1966 and 2001 were gathered. Over 50 studies were selected and pooled according to type of study and the parameter being linked to lung cancer (i.e. silica exposure, presence of silicosis in subjects). The quality of study, adjustment for confounding factors, co-exposure to other carcinogens and availability of a more recent analysis of a same cohort were taken into consideration in the final selection of the studies. Analysis of the relationship between exposure to silica and lung cancer included 17 cohort and 13 case-control studies. For the analysis of lung cancer versus silicosis, 11 cohort and 5 case-control studies were selected. The third analysis included 6 cohort and 2 case-control studies to evaluate the risk of lung cancer in non-silicotics. A random effect model was used to conduct each meta-analysis. Pooled cancer risk ratios (RRs) were 1.32 (CI 1.23-1.41) for crystalline silica exposure, 2.37 (CI 1.98-2.84) for individuals exposed to silica with confirmed silicosis (Silicotics) and 0.96 (CI 0.81-1.15) for individuals with no evidence of silicosis (non-silicotics) with confirmed exposure to silica, supporting the general observation that silicosis has a stronger temporal relationship with crystalline silica exposure and furthermore support the view that a human silicotic response could be a preliminary stage in the development of cancer.

A more recent meta-analysis included 28 cohort, 15 case-control and two proportionate mortality ratio (PMR) [See Appendix 1] studies from a variety of occupational settings conducted between 1996 and 2005. Risk ratios (RRs) were calculated based on type of study and silicosis status using fixed and random effect models (results presented here are from the random model). RRs for all cohort studies was 1.34 (CI 1.25-1.45), and were 1.69 (CI 1.32-2.16) for silicotics, 1.25 (CI 1.18-1.33) for those with undefined silicosis status and 1.19 (CI 0.87-1.57) for non-silicotics. In the case-control studies, the general RR was 1.41 (CI1.18-1.67), and the same sub-groups as mentioned above resulted in RRs of 3.27 (CI 1.32-8.2), 1.41 (CI1.18-1.70) and 0.97 (CI 0.68-1.38), respectively. The proportionate mortality ratio for the last two studies was 1.24 (CI 1.05-1.47). The authors noted that the association between lung cancer and exposure to crystalline silica was more consistent for silicotics, i.e., those diagnosed with silicosis and RR values split into type of occupational settings in which participants worked.

Based upon the above three meta-analysis studies and the epidemiology studies discussed in IARC (1997), the following can be concluded. Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis. Cancer risk is often more significant in workers exposed to crystalline silica over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours. Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles.

There have been reports of tumours outside of the lungs in persons with high silica exposure; however, these reports are sparse and the data inconsistent and have not been unequivocally linked to exposure to either one of the crystalline forms (quartz or cristobalite). Some of the reported locations are: oesophagus, stomach, liver, skin and bone. Sufficient epidemiological or toxicological data do not currently exist for quantitative assessment of the exposure-response relationship on these other tissues or organs.

Genotoxicity

Potential genotoxicity has been assessed in multiple *in vitro* and *in vivo* assays. Table 1 below gives a brief summary of the positive results observed in each type of assay.

Table 1. Summary of positive results over total number of results for each assay and each category (all studies

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conducted with crystalline silica: quartz, except where indicated).

Assay	Animal data		Human data		Positives/Total	
	In vitro	In vivo	In vitro	In vivo[d]	In vitro	In vivo
Rec Assay	0/1				0/1	
DNA strand break	1/1	2/2	5/5[b]	1/1	6/6	3/3
Sister chromatid exchange	0/1		0/1[c]	1/1	0/2	1/1
Micronucleus	2/3	0/1	2/2[b]	1/1	4/5	1/2
Chromosome aberration	0/1			1/1	0/1	1/1
Aneuploidy/polyploidy	0/3				0/3	
Cell transformation	4/4				4/4	
Hprt mutation	1/2	2/2[a]	1/1[b]		2/3	2/2
Oxidative DNA damage		4/5	2/2		2/2	4/5
DNA binding		1/1				1/1
p53 activation		0/1				0/1

a. one assay conducted with crystalline silica: cristobalite
b. one assay conducted with "ultrafine crystalline silicon dioxide".
c. crystalline silica: tridymite
d. crystalline silica dust (subtypes not provided).

All the *in vivo* human genotoxicity studies are based on three independent studies that used blood samples from workers from diverse occupational settings with confirmed exposures to crystalline silica dust; however, quantification of exposure was not provided. After stratification by smoking status, sister chromatid exchange remained statistically significant in both smokers and non-smokers although the frequency was higher in smokers. For the chromosome aberration assay conducted as part of the same study (blood samples from workers in the stone crusher industry), the increased frequency was no longer significant after stratification. In the DNA damage study of foundry and pottery workers and the micronucleus assay of workers involved in sandblasting and related jobs, results were positive when compared to controls. However, in both studies, smoking status influenced the results, contributing to the increased DNA damage observed since results were greater in smokers versus non-smokers, and the frequency of micronuclei in nasal epithelial cells was higher in smokers (p=0.002) but when using peripheral blood lymphocytes did not differ statistically between smokers and non-smokers who were similarly exposed to silica dust,

The role of *in situ* generation of reactive oxygen species (ROS) and reactive nitrogen species (RNS) has been well established in the following types of DNA damage: small scale insertions, DNA base pair deletion, base modification, chromosomal change/loss, microsatellite instability, DNA strand break, 8-hydroxydeoxyguanosine (8-OHdG) mutation and point mutations. ROS and RNS generation is postulated to be (a part of) the DNA damage mechanism for crystalline silica. Studies are described below to support this hypothesis.

DNA was exposed *in vitro* to various crystalline silica dusts, to H_2O_2, or to both. Results show that DNA damage was limited when dust or H_2O_2 were administered alone but increased with the co-exposure. When the reactive oxygen scavenger, dimethylsulfoxide, was added to the test system, DNA strand break was inhibited, data supporting the viewpoint that it is the presence of radicals generated in response to quartz and cristobalite that causes the DNA damage and not quartz or cristobalite themselves.

Hprt mutation assays in rat alveolar epithelial cells, both *in vitro* and *in vivo,* were positive in response to quartz. The positive results *in vivo* were seen only in the presence of significant inflammatory responses in the treated animals. Also, in a parallel *in vitro* experiment, rat alveolar epithelial cells were incubated with the bronchoalveolar lavage fluid from the rats exposed to quartz. Both macrophage and neutrophil enriched lavage cells induced mutation in the exposed alveolar epithelial cells. Addition of catalase (an enzyme which inactivates H_2O_2) before incubation inhibited the increase in *hprt* mutation.

Rats were exposed to either crystalline or amorphous silica in a manner to induce the same level of

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inflammation in the lungs. The inflammatory response was assessed by measuring the proportion of neutrophils in the bronchiolar lavage fluid. The actual concentrations were 3 and 50 mg/m^3 for crystalline and amorphous silica respectively. The animals were exposed for 13 weeks. *Hprt* mutation frequency was measured in the alveolar epithelial cells at the end of the exposure period. Mutation frequency was greatly increased only in the crystalline silica treated rats; no treatment related increase was found in the rats treated with the amorphous form.

In an 8-OHdG assay conducted to monitor DNA damage by reactive oxygen species, female rats were exposed to 0, 0.3, 1.5 and 7.5 mg/animal of quartz via intratracheal instillation. Effects were observed 90 days post-exposure. A clear dose-response relationship was identified between quartz exposure and various inflammation markers (differential cell count, protein, lung surfactant lipids and tumour necrosis factor alpha). Inflammation was present starting at the lowest dose. However, 8-OHdG showed a statistically significant increase starting at 1.5 mg/animal only. Similarly, in another study, 8-OHdG and DNA strand breaks were observed at concentrations of or above 10 ug/m^3 in rat lung epithelial cells.

In the aim of investigating the role of ROS in lung carcinogenesis, rat lung epithelial cells were incubated with polymorphonuclear (PMN) leukocytes (involved in the inflammatory process and responsible for the release of certain ROS) or hydrogen peroxide. Statistically significant increases in 8-OHdG were observed in the presence of PMN or hydrogen peroxide in a dose-response manner.

In a series of experiments which used *in vitro* stimulation of macrophages with crystalline silica and *in vivo* intranasal instillation of crystalline silica in mice, it was demonstrated that that the chronic fibrosis seen in a murine model of silicosis *in vivo* is dependent on the presence of adaptor molecule ASC and Nalp3 inflammazome. These data support a potential mode of action whereby silica triggers cellular responses that in turn activate alveolar macrophages, resulting in an inflammatory response and silicosis. In mice deficient in Nalp3 inflammazome, the development of inflammation and collagen deposition was significantly reduced compared with normal mice 3 months after the initial intranasal instillation of silica.

Analysis of Lung Tumour Data

The weight of evidence for both rats and humans indicates that fibrotic and silicotic lesions in the lung result from inhalation exposure to crystalline silica and that lung cancer is secondary to those lesions in the lung. Although the mechanism of induction for the lung tumours has not been fully elucidated, there is sufficient supportive mode of action evidence from the data presented to demonstrate that a threshold approach to risk assessment is appropriate based on an understanding of the key events in the pathogenesis of crystalline silica induced lung tumours. The body of evidence include the following:

- In experimental studies, all rats that developed tumours also showed fibrosis.
- Adenocarcinomas, the most common type of tumour identified in rats, are commonly associated with fibrosis and deeply scarred lung tissue.
- Experimental rat studies showed a clear progression of the effects from initially mild inflammation, followed by fibrosis over-time, leading eventually to lung tumours.
- Tumours are not present in all treated species dosed in the same way.
- The tumours, both in rats and humans, are concentrated in the lungs only, although other organs are indirectly exposed.
- In human studies, cancer risk is often more significant in workers exposed over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours.
- Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles
- Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis.
- For genotoxicity, in vitro results were mostly mixed and in vivo results were mostly positive. However, the vast majority of the positive genotoxicity assay results can be explained by the generation of reactive oxygen species, as demonstrated experimentally, where ROS scavenging prevents the genotoxicity.
- *In vivo*, macrophage deficient mice (macrophages produce ROS in response to crystalline silica) do not develop silicosis nor do they develop tumours and the Nalp3 inflammazome, a key player in the macrophage initiated inflammatory response, is required for the development of pulmonary fibrosis after

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inhalation of silica.

- Though inhalation exposure to crystalline silica in multiple occupational settings is clear, the increase in risk, based on the several recent meta-analyses of the multiple human epidemiological studies, remains low.

It is worth noting that where aggressive engineering controls have been made to reduce silica dust levels in the workplace (Sweden), silicosis has been eliminated. By corollary, existing exposures outside of the workplace in such areas do not pose a risk for silicosis to the general population.

The respirable forms of quartz and cristobalite possess properties indicating a hazard for human health (repeated dose toxicity, carcinogenicity and genotoxicity). The mode of action in the lungs involves irritation, inflammation and reactive species formation, leading to silicosis, and eventually to tumour formation.

Exposure

Uses

Consistent with oxygen and silicon being the two most abundant elements in the Earth's crust, silicon-oxide minerals, including quartz are ubiquitous in the natural environment. In particular, as a component of sand, quartz may find use in a diverse array of applications. Several high volume uses include, but are not limited to, the use of sand as a filling material for the construction of roads and in general building activities, the use of sand and gravel aggregates as abrasives on roads in winter and the use of fly-ash, which may contain 4-14% quartz and 0.5-1% cristobalite, as a cement additive. These abrasives when used on winter roads are usually mixed with road salts and may be sand only, stone dust, sand and gravel aggregates, or pre-treated sand. They are used mainly by rural municipalities or in areas where cold temperatures diminish the efficiency of salts for de-icing. Quantities of abrasives used in Canada were 5.73×10^9 kg, 4.59×10^9 kg, and 4.93×10^9 kg for 2007, 2008 and 2009, respectively.

Industrial sand, high purity silica sand products with closely controlled sizing are expected to contain quartz and cristobalite, include lump silica (2-3mm up to 15 cm or more), silica sand (75µm to 2-3mm) and silica flour (less than 75µm). Lump silica may be used in the production of silicon alloys, silica bricks, and the linings of certain types of pulverizers (eg. ball mills and tube mills).

Silica sand may be used in the manufacture of glass and glass fibres, silicate chemicals and silicon carbide, the hydraulic fracturing of wells, foundry moulding, and for sandblasting. Silica flour may find use in the ceramics and cement industries, as a filler and extender in rubber and coatings, and as an abrasive in soaps.

Natural clays, such as bentonite and fuller's earth, are used in cat litters for their high water absorbance capacities. Quartz is a natural component of these clays, and consequently, it may be present in cat litter products. High purity α-quartz is a piezoelectric material, which means that application of a voltage induces a distortion in the crystal shape and vice versa. This ability to interconvert electrical and mechanical energy has led to the use of quartz crystals in electronic devices requiring precise timing control, for example telephones, radios, watches and computers.

According to a survey conducted in Canada, quartz and cristobalite are also used in abrasives, adsorbents, filter products (diatomaceous earth), grout and cement. These substances reportedly also find use as fillers, which add bulk and improve wear resistance, in paints and coatings, adhesives, sealants, polymer films, caulking, epoxy resins and silicones. Also, quartz is listed as an ingredient in 60 cosmetic products in Canada. The types of products include anti-wrinkle preparation, eye and face makeup, lipstick, hair dyes, shampoos and grooming products, as well as skin cleansers, moisturizers and tanning preparations.

Natural Sources

In Canada, quartz naturally occurs in many types of rock formations. Those with high silicon dioxide content (95% SiO_2 or more) include vein and massive intrusion bodies, quartz pebbles, silica sand, sandstone and quartzite. Sandstone is a sedimentary rock mostly composed of quartz grains cemented by a bonding material such as clay, calcite or iron oxide. Quartzite is a hard, compact, metamorphosed sandstone made of grains of quartz firmly bonded with a siliceous cement. Mineral aggregates (e.g., sand and gravel) have variable silicon dioxide content. Quartz is also found as crystals, aggregates or discrete particles in certain igneous rocks (e.g., granites and pegmatites), soils, sediments, air and surface water. This omnipresence is consistent with the fact that silicon is the second most abundant chemical element on Earth.

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Cristobalite is naturally produced in the ashes of volcanic eruptions, and by combustion metamorphism which is a local phenomenon of spontaneous combustion of naturally occurring substances such as bituminous rocks, coal or oil. It may be found in cavities in volcanic rocks and in thermally metamorphosed sandstones and may also be a transient stage in the diagenesis of diatomaceous shale with the result that soils made of these geologic formations may be rich in cristobalite. Unlike quartz, the natural occurrence of cristobalite is limited to specific geographic regions and mineral types.

Anthropogenic Sources

Natural quartz is isolated from ore via beneficiation, which involves milling or grinding the material into particles that are separated into desired mineral and waste. The materials obtained are either used directly or further purified. In Canada, in 2006, 2.146×10^{9} kg of pure quartz were mined, and 2.385×10^{11} kg of sand and gravel aggregates were produced. The proportion of quartz in silica sand deposits and gravel aggregates will vary from one site to another.

Cristobalite can form from silica melts during the preparation of silica glass; quartz is not obtained from melts but is manufactured at elevated temperature and pressure via a hydrothermal process. Cristobalite also forms during the calcination[2] of diatomaceous earth.

Human Exposure Estimate

Ambient air

The exposure assessment is focussed on respirable quartz and cristobalite, which in ambient air comprises a component of total particulate matter (PM). In Canada, data on the concentrations of silicon in PM was available and used as a surrogate for quartz and cristobalite. This approach is conservative because the measured silicon includes all silicon-containing substances and therefore represents the upper limit for quartz and cristobalite in ambient air.

The National Air Pollution Surveillance (NAPS) Program measured concentrations in $\mu g/m^3$ of silicon in PM with aerodynamic radii less than 2.5 µm ($PM_{2.5}$ (dichot)), and from 2.5 to 10 µm (PM_{10} (dichot)) (the total particulate matter with aerodynamic radii less than 10 µm (PM_{10}) is obtained by adding these values) in Canada. In 2009, as part of the NAPS Program, silicon concentrations were determined on over 1600 samples of $PM_{2.5}$(dichot) and over 1500 samples of PM_{10}(dichot) at 24 urban locations across Canada. An estimate of exposure to quartz and cristobalite can be obtained by assuming that all the silicon in the PM is represented stoichiometrically as SiO_2, and multiplying the reported concentration of silicon by 2.14 to obtain a value for silica.

The intake of respirable quartz and cristobalite by the general population of Canada is estimated using a range covering the lowest 50^{th} percentile SiO_2 concentration in PM_{10}, measured in Pt. Petre, ON, (0.12 $\mu g/m^3$) to the highest 50^{th} percentile concentration in PM_{10} measured in Calgary, AB (2.1 $\mu g/m^3$). The 50^{th} percentile SiO_2 concentrations ranged from 0.1 to 2.1 $\mu g/m^3$ across the survey sites; the top of this range is quite close to the average of the maximum values for the 24 sites (3.7 $\mu g/m^3$). The outdoor data were used to represent the indoor levels, because information on indoor silicon concentrations was not available, and the range of PM_{10} measured indoors is generally lower than the outdoor range. Thus, this approach conservatively overestimates indoor exposure in homes.

The highest exposure group based on these calculations is children ages 0.5 to 4 years with an estimated daily intake ranging from 0.07 to 5.26 µg/kg-bw per day; the estimated daily intake decreases with age due to changes in the ratio of inhalation rates to body weights; the daily intake of adults, 20-59 years old, is estimated to range from 0.03 to 2.00 µg/kg-bw per day.

Consumer Products

Exposure to respirable quartz from the use of cosmetic products, which contained quartz as an ingredient, was considered low because they are not formulated for spray application, the loose powders were reported to contain less than 0.1% quartz, and in these products the substance is not expected to be associated with other components of the formulation and not available in a free form.

For consumer Do It Yourself (DIY) activities around the home, the highest mean breathing zone concentration of particles from sanding dry wall (median cut-point of 10µm) of 6.31 mg/m^3, was used to derive an upper-

[2] Calcinations: Heat treating a substance, but without fusion, to bring about change in its physical or chemical constitution.

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bound exposure estimate ranging from 2 to10 µg/kg-bw per event.

Quartz is used to formulate a large number of paints and coatings. To estimate potential inhalation exposure to quartz from these products, the spray painting of wall paints with an airless spray gun was considered appropriate as a conservative scenario. Exposure to respirable paint particles was estimated using data from controlled a laboratory study in which walls of poorly ventilated test rooms were painted by professional painters using an airless sprayer to apply interior latex paint. The maximum concentration of 13% quartz in paint in Canada was used to estimate exposure. The upper-bound estimate of exposure to quartz, based on the maximum concentration of 13% quartz in paint in the Canadian market and the maximum concentration of respirable paint particles measured in these controlled studies when recommended personal protective equipment is used, is 0.954 µg/kg-bw per event.

Inhalation of ambient air containing quartz and cristobalite is the dominant pathway of chronic exposure (excluding that from DIY activities) for the general population. Because SiO_2 makes up only approximately 5% of PM_{10}, silicon concentrations (expressed as SiO_2) measured in the Canadian NAPS survey of 24 urban locations were considered most relevant to the estimation of exposure by the general population. Quartz and cristobalite comprise only a portion of the total SiO_2 in PM_{10}, therefore, the use of the total silicon concentration to represent the upper bound crystalline silica concentrations results in an overestimation of exposure.

Appendix 1: Definitions of Epidemiological Terms in the ITAP

SMR (Standardized Mortality Ratio): The ratio (x 100) of observed to expected deaths in a study population. Expected deaths are calculated by applying a set of standard age-specific mortality rates to the age distribution of the study population. Standardized ratios are only useful for comparisons. They have no intrinsic meaning.

OR (Odds Ratio): In epidemiological case-control studies, a relative measure of disease occurrence. The odds in favour of a particular disease occurring in an exposed group are divided by the odds in favour of its occurring in an unexposed group. If the condition being studied is rare, the odds ratio is a close approximation to the relative risk.

RR (Risk Ratio): The probability of the occurrence of a disease in a group that has been exposed to some environmental, medicinal, microbial, or toxic influence, relative to its probability in a randomly selected population.

PMR (Proportionate Mortality Ratio): Proportionate mortality is the proportion of deaths in a specified population over a period of time attributable to different causes. Each cause is expressed as a percentage of all deaths, and the sum of the causes must add to 100%. These proportions are not mortality rates, since the denominator is all deaths, not the population in which the deaths occurred. Thus, proportionate mortality ratio is a measure of the frequency of occurrence of the proportionate mortality in a defined population during a specified interval of time.

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Toxicity Profile

Diammonium peroxidisulfate
Ammonium persulfate
(CAS No. 7727-54-0)

Diammonium peroxisulfate or ammonium persulfate has been reviewed in the OECD-SIDS program (OECD, 2005a,b).

Ammonium persulfate is distributed into the water compartment in the ionic form of the ammonium cation and persulfate ion. The persulfate anion will readily hydrolyze (decompose) into sulfate ions.

Acute Toxicity

The acute oral LD_{50} in rats is 495 mg/kg, and the acute dermal LD_{50}s in rats and rabbits are >5,000 mg/kg. In acute inhalation studies in rats, the 4-hour LC_{50} was generally greater than the maximum attainable concentration (>2,950 mg/m^3 for ammonium persulfate).

Irritation

Ammonium persulfate is slightly irritating to the eye and skin of rabbits. Studies in humans indicate that aqueous solutions of 5% persulfate or higher can cause skin irritation.

Sensitization

Results of animal skin sensitization tests (Buehler Test and Maximization Test) were negative when persulfate was applied topically, but was positive when persulfate was injected intradermally in induction and challenge phases in a non-standard Maximization Test. Numerous dermal challenge tests indicate that all persulfates are dermal and respiratory sensitizers in humans occupationally exposed to persulfates in hairdressing salons and, in one case, in a production facility. In controlled clinical trials with non-occupationally exposed-subjects (ammonium and sodium salts), no sensitization reactions were observed.

Repeated Dose Toxicity

Rats were fed in their diet 0, 300, 1,000 or 3,000 ppm sodium persulfate (0, 23, 100 and 225 mg/kg/day) for 90 days. On day 48 of the study, the concentration of the group receiving 1,000 ppm was increased to 5,000 ppm for the remainder of the study. Body weights was decreased in the two highest dose groups during the last six weeks of treatment. There were no treatment-related effects on urinalysis, clinical chemistry or hematology parameters. Pathological findings were limited to the 3,000

ppm group only and consisted of necrosis and atrophy of the gastrointestinal tract epithelial lining. The absence of the gastrointestional lesions in the group receiving 1,000 ppm for 8 weeks, followed by 5000 ppm for 5 weeks, indicates that the lesions are related both to concentration in diet (dose) and length of exposure. There were no treatment-related pathological findings in reproductive organs or any other organ system or tissue.

Genotoxicity

Sodium persulfate was not genotoxic in a bacterial reverse mutation (Ames) assay or in an unscheduled DNA synthesis (UDS) assay with rat hepatocytes. It was also not active in a rat bone marrow micronucleus assay and when tested *in vivo* in a rat hepatocyte UDS assay.

Carcinogenicity

A 51-week dermal study in female SENCAR mice exposed to 0.2 ml of a 200 mg/ml solution of ammonium persulfate showed that it is neither a tumor promoter nor a complete carcinogen when applied to the skin.

Reproductive/Developmental Toxicity

In a developmental/reproduction study with ammonium persulfate in rats (OECD 421), no effects on reproductive performance, fertility, fetal anomalies, fetal viability, spermatogenesis, spermatogenic cycle were reported up to 250 mg/kg/day. Dose levels were chosen based on the acute lethality studies for the ammonium salt and on a 90-day repeat-dose study in rats with the sodium salt (high dose: 225 mg/kg/day). In the developmental/reproduction study, animals were dosed prior to and during mating through gestation until lactation day 4. There was a transient depression in pup body weight at the 250 mg/kg dose level on lactation day 0 which resolved by day 4. This effect was not considered adverse. Based on the available data, the persulfates do not show evidence of reproductive or developmental toxicity. The NOAEL is 250 mg/kg/day.

Key Study/Critical Effect for Screening Criteria

The Australian drinking water guideline value for sulfate may apply to sulfate (500 ppm, health; 250 ppm, aesthetic). There are no existing drinking water guideline values for ammonium ions.

References

OECD (2005a). IUCLID Data Set for Ammonium persulfate (CAS No. 7727-54-0); Potassium persulfate (CAS No. 7727- 27-1); Sodium persulfate (CAS No. 7775-27-1), UNEP Publications.

OECD (2005b). Screening Information Dataset (SIDS) Initial Assessment Report for Ammonium persulfate (CAS No. 7727-54-0); Potassium persulfate (CAS No. 7727-27-1); Sodium persulfate (CAS No. 7775-27-1), UNEP Publications.

Toxicity Profile

Diatomaceous Earth, Calcined
(CAS No. 91053-39-3)

Silica is an off-white granule that occurs naturally in various crystalline and amorphous or other non-crystalline forms. Crystalline silica is characterized by silicon dioxide (SiO_2) molecules oriented in fixed, periodic patterns to form stable crystals. The primary crystalline form of silica is quartz. Other crystalline forms of silica include cristobalite, tripoli and tridymite. Particle size is a key determinate of silica toxicity, since toxicity is restricted to particles that are small enough to be deposited into the target regions of the respiratory tract.

Uncalcined diatomaceous earth (CAS No. 61790-53-2) typically contains around 1% crystalline silica. When diatomaceous earth is subjected to pressure or is processed ("calcined") at temperatures above 1000°C some of the amorphous silica is converted to crystalline silica in the form of cristobalite. Calcined diatomaceous earth can contain anywhere from 1% to 75% cristobalite.

Oral Exposure

No oral studies were located; however, crystalline silica is not expected to exhibit toxicity by the oral route. Although absorption studies were not found for crystalline silica, kinetic studies on amorphous silica show no absorption from the gastrointestinal tract.

Dermal Exposure

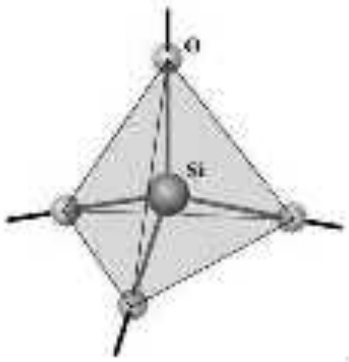
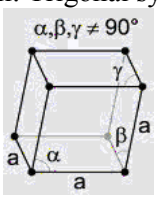
No dermal studies were located; however, crystalline silica is not expected to exhibit toxicity by the dermal route.

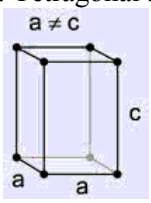
Inhalation Exposure

See attached OECD-SIDS Initial Targeted Assessment Profile on Quartz and Cristobalite, SIAM 32, 19-21 April 2011.

INITIAL TARGETED ASSESSMENT PROFILE (Human Health)

<table>
<tr><td>CAS No.</td><td colspan="2">Quartz: CAS RN 14808-60-7

Cristobalite: CAS RN 14464-46-1</td></tr>
<tr><td>Chemical Name</td><td colspan="2">Quartz and Cristobalite</td></tr>
<tr><td rowspan="2">Structural Formula</td><td colspan="2">Molecular Formula: SiO_2

</td></tr>
<tr><td>Unit Cell: Trigonal symmetry


Quartz: CAS RN 14808-60-7</td><td>Unit Cell: Tetragonal symmetry


Cristobalite: CAS RN 14464-46-1</td></tr>
</table>

SUMMARY CONCLUSIONS OF THE TARGETED ASSESSMENT

NOTE: The present assessment is targeted to address the following human health endpoints: repeated dose toxicity and carcinogenicity via the inhalation route of exposure, and genotoxicity. It cannot be considered as a full SIDS Initial Assessment. Summary information on exposure is also reported here. Other endpoints for human health and the environment included in the Canadian screening assessment but have not been presented to OECD member countries, and thus are not included in this profile.

The final screening assessment will be published under the responsibility of the Government of Canada.

Rationale for Targeting the Assessment

The Government of Canada "categorized" or prioritized all 23,000 chemical substances on its Domestic Substances List (DSL) from 1999 to September 2006, as required by its *Canadian Environmental Protection Act, 1999* (CEPA 1999). Additional details may be found at http://www.chemicalsubstanceschimiques.gc.ca/about-apropos/categor/index-eng.php. Using information from Canadian industry, academic research and other countries, Government of Canada scientists applied a set of rigorous tools to the 23,000 chemical substances on the DSL. They were categorized to identify those that were: **inherently toxic** to humans or to the environment and that might be **persistent** and/or **bioaccumulative**; and substances to which people might have **greatest potential for exposure**. During this priority-setting exercise, distinct approaches were taken for identifying substances of likely concern for human health and the environment, and subsequent assessment activities may have focused on either human health or ecological endpoints. Through categorization, the Government of Canada has identified approximately 4,000 of the 23,000

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chemical substances on the DSL as priorities for further assessment, research and/or measures to control their use or release. Quartz and cristobalite were identified at that time, applying the categorization criteria, as high priorities for human health risk because they were considered to pose greatest potential for exposure and their respirable forms are classified by the International Agency for Research on Cancer as carcinogenic to humans (quartz and cristobalite) and by the National Toxicology Program as known human carcinogens (crystalline silica). These substances did not meet the ecological categorization criteria for bioaccumulation potential or inherent toxicity to aquatic organisms.

Under the Canadian legislation a determination of whether one or more of the criteria of the CANADIAN ENVIRONMENTAL PROTECTION ACT (CEPA) 1999, section 64 are met is based upon an assessment of potential risks to the environment and/or to human health associated with exposures in the general environment. For humans, this includes, but is not limited to, exposures from ambient and indoor air, drinking water, foodstuffs, and the use of consumer products. A conclusion under CEPA 1999 on the substances in the Chemicals Management Plan (CMP) Challenge is not relevant to, nor does it preclude, an assessment against the hazard criteria specified in the Controlled Products Regulations, which is part of the regulatory framework for the Workplace Hazardous Materials Information System [WHMIS] for products intended for workplace use.

Physical-chemical properties

The silicon dioxide group represents a polymorphic category containing a large number of forms identical in composition but with different atomic arrangements which afford different chemical properties. There are two sub-categories within this group: crystalline silica, to which the present substances quartz and cristobalite belong, and non-crystalline or amorphous silica. The key distinction between these sub-categories is that in crystalline substances, the building blocks are arranged in regular, repeating 3-dimensional pattern having long range order, whereas amorphous materials do not display long range order. In all forms of silica, (crystalline and non-crystalline), the silicon atom is tetrahedral and bound to four neighbouring oxygen atoms.

Quartz and cristobalite are solid at room temperature, existing normally as colourless or white crystals. The melting points for quartz and cristobalite are 1400-2000 ^{o}C and 1713-1728 ^{o}C, respectively and for both compounds, the boiling point is 2230^{o}C. Even though no experimental data were available, their vapour pressure and Henry's Law constant are likely negligible. Log K_{ow} (octanol-water partition coefficient) and log K_{oc} (organic carbon-water partition coefficient) are not applicable to these substances. The densities range from 2500-2700 kg/m^3 for quartz and 2300-2380 kg/m^3 for cristobalite.

The very similar physico-chemical properties of quartz and cristobalite reflect their closely related crystal forms. The solubility of crystalline silicates decreases as a function of silica tetrahedral packing density and long-range crystal order. For example, cristobalite has a more open framework structure than quartz and its density is lower, therefore, its solubility is higher. The water solubility of these minerals is also function of temperature, pH, particle size, and the presence of a disrupted surface layer. This may explain the variability of solubility values reported by many authors. The most probable solubility value for quartz is approximately 3.8 mg Si/L, or 6.4 mg/L expressed as the SiO_2 species, while the solubility of cristobalite is approximately 8.7 mg Si/L, or 18 mg SiO_2/L. The kinetics of dissolution of these substances is slow due to the high activation energy required to hydrolyse the Si-O-Si bond.

Human Health Targeted Endpoints

The majority of the studies described here have been reviewed by the International Agency for Research on Cancer (IARC 1997). However, additional data relevant to the screening assessment were identified up to August 2010.

Repeated dose toxicity/non-neoplastic effects (development of silicosis).

Studies on animals

Significant short-term and subchronic studies have demonstrated adverse effects in the lungs, while one of the 6 studies showed effects on the spleen in mice. Rats were exposed to 0, 10 or 100 mg/m^3 of cristobalite via inhalation for 6 hours/day during 3 days. Animals were observed 3 months after exposure. Elevated levels of granulocytes and elevated markers of cytotoxicity from the lung lavage fluid were noted in all exposed groups. Another study of similar duration (9 days) conducted in mice also identified a LOAEC of 10 mg/m^3. Effects observed included minimal interstitial thickening, accumulations of mononuclear cells and slight lymphoid tissue hypertrophy in the lungs.

In a 4-week inhalation study, female rats were exposed to 0, 0.1, 1 or 10 mg/m^3 of quartz 6 hours/day, 5 days/week. Bronchoalveolar lavage fluid was evaluated at 1, 8, and 24 weeks after exposure. Elevated levels of

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granulocytes and significant elevation of markers of cytotoxicity (Lactate dehydrogenase [LDH] and β-glucuronidase [β-glu]) were observed at 1 mg/m^3 and higher. The increased levels of LDH and β-glu were only significant at 24 weeks after exposure. A LOAEC of 1 mg/m^3 was identified at 24 weeks.

Male rats (4 animals per dose) were exposed to 0 or 3 mg/m^3 of cristobalite via inhalation for 6 hours/day, 5 days/week during 13 weeks. Pulmonary inflammation and fibrosis were observed in the exposed group at the end of treatment. When mice were similarly exposed to 5 mg/m^3 of quartz for 6 hours/day, 5 days/week for 15 or 27 weeks, the authors observed increased spleen weight and formation of plaque in the spleen.

In two separate studies, in which rats or hamsters were exposed to quartz via inhalation for at least 6 months, LOAECs of 2 and 3 mg/m^3 were identified, respectively. All the effects observed were related to inflammation and fibrosis of the lung tissue.

Several chronic studies investigated exposure of the respirable forms (i.e. accumulated via inhalation in the lung tissues) of quartz and cristobalite to rats, mice and hamsters. The following is a description of the study in which the lowest non-neoplastic LOAEC was determined. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz, containing 74% of respirable quartz, through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. The mean mass of particle at the end of the exposure period was 0.91 mg/lung. The LOAEC identified was 0.74 mg/m^3 (adjusted for 74% respirable quartz) based on lipoproteinosis, multifocal, inflammatory cell infiltrate and alveolar hyperplasia.

Human epidemiology data

In humans, the lowest observed adverse effect level was identified in a U.S. cohort study. The study was conducted on 3330 gold miners (all are males), who had an average of 9 years underground exposure during the period 1940 to 1965. The cohort was followed up through 1990. Silicosis[1] was identified through death certificates or chest X-rays. A job-exposure matrix together with work history was used to estimate individual exposure. The total silica content in the respirable dust in the mine was estimated at 13% and the median crystalline silica exposure was 0.05 mg/m^3. In this sub population of miners, 170 cases of silicosis were identified. The best predictor for risk of silicosis was cumulative exposure, which varied from less than 1% for a 0.5 mg/m^3-year exposure to 68-84% when exposed to more than 4 mg/m^3-year (based on the average daily dust exposure during the workday each year and summed over time for each miner). The main limitations identified by the authors include the limited number of radiographic surveys, the potential bias from death certificates

[1] Silicosis: Lung disease caused by inhalation of crystalline silica dust, and resulting in inflammation and scarring in forms of nodular lesions in the upper lobes of the lungs. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics). It does not follow that a history of exposure to silica necessarily results in silicosis (Nonsilicotics). The typical "Silicotic" lung nodule is shown in Figure 1.

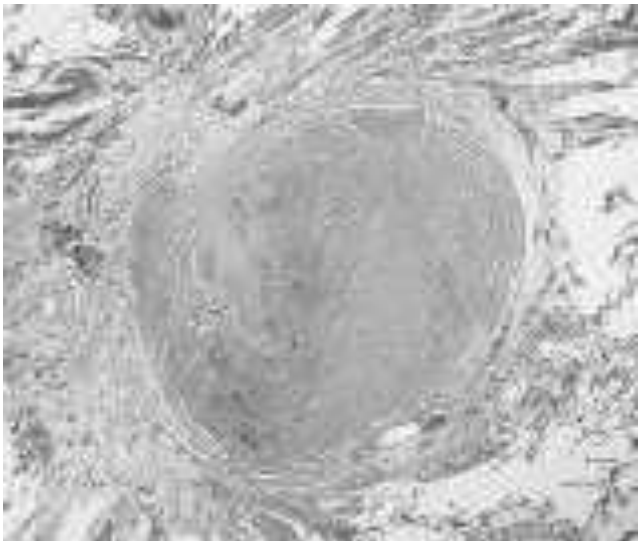


Figure 1. Silicotic nodule characterised by a central zone of hyalinised collagen with a whorled appearance and peripheral dust-containing macrophages (Rees and Murray, 2007).

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(relying on death certificates instead of relying on repeated x-rays, which were lacking for each miner, may have underestimated the number of cases) and the fact that the conversion of dust counts to

gravimetric measurements may not be accurate based on the estimation of 13% silica content in the respirable dust (although based on a relatively large number of samples (n = 82) collected in two different surveys, there was broad range of content in these samples (1% to 48%, SD = 9), and the percentage of respirable quartz may have differed in earlier years, but data were lacking for these years).

Two other human studies have identified similar LOAECs based on the critical endpoint of radiographic confirmed silicosis. A LOAEC of 0.053 mg/m^3 (mean exposure) was identified in a cross sectional study of South African gold miners and a LOAEC of 0.064 mg/m^3 (mean exposure) was derived in a mining community population-based random sample survey in Colorado.

Carcinogenicity studies

Studies on animals

Experimental studies conducted in rats have shown clear and consistent increases in lung tumours after chronic inhalation exposure. In the nine rat studies identified, five were inhalation studies and four were intratracheal instillation studies. All studies except one inhalation study showed increased incidence of lung tumours. For the inhalation studies with treatment related tumours, concentrations ranged from 1 to 50 mg/m^3 (1, 6, and 30 mg/m^3 of DQ-12 quartz; 12 and 50 mg/m^3 of Min-U-Sil 5 quartz) and duration of exposure ranged from 29 days to 2 years. In the inhalation study with no treatment-related tumours, exposure was 60 mg/m^3 of Sikron F300 quartz for 13 weeks. The following is a description of the neoplastic results in the study also identified as the critical study for non-neoplastic results. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. In the exposed group, 18 animals developed tumours (12 in females, 5 in males), as opposed to 3 and 2 for the control and positive control groups respectively. The majority (10/18) of the tumours observed were adenocarcinomas. The mean mass of particles in the lungs at the end of the exposure period was 0.91 mg/lung.

For the intratracheal instillation studies, doses ranged from 4 to 57 mg/kg-bw (based on 7, 12 or 20 mg/animal of Min-U-Sil (5) quartz or 20 mg/animal of novaculite quartz). Exposure regimes were diverse and included single instillation with observation for up to two years, to weekly instillation for 10 weeks. It is noteworthy that the single intratracheal administration of a 95% pure quartz particles (<5 μm) resulted in an increased incidence of silicotic granulomas after 3 weeks and lung tumours after 11 months. The most common tumours reported across the long term rat studies were adenocarcinomas, however other tumours such as squamous-cell carcinoma, alveolar carcinoma and bronchiole-alveolar adenoma were also reported, and all animals that developed tumours also showed some degree of fibrosis.

Of particular interest is the intratracheal instillation study, investigating the sequence of pathological events leading to lung tumors. An unspecified number of rats/sex/dose received a single intratracheal instillation of various crystalline silica dusts or ferric oxide, allowing direct administration into the bronchial tree. The doses were 12 or 20 mg of Min-U-Sil 5 quartz (MQZ), 12 mg of hydrofluoric-acid-etched Min-U-Sil 5 quartz (HFMQZ), 12 mg of cristobalite, 12 mg of tridymite and 12 mg of ferric oxide suspended in saline. All groups were observed until six months post exposure, except for both MQZ groups, the HFMQZ and the ferric oxide group which were observed up until 17 months post-exposure. Interim sacrifices were conducted at 6, 11 and 17 months. The rat lungs showed a clear progression of effects. The sequence of pathological events were, an initial inflammatory response leading to a marked hyperplasia and hypertrophy of alveolar cells after one month, and at six months hyperplasia was evident but no lung tumours were observed. In this study, lung tumours were observed starting at the 11 month sacrifice with a 17% and 42% incidence in males and females (based on 3/18 males and 8/19 females), respectively, and at 17 months incidences were 32% and 59% (based on 6/19 males and 10/17 females, respectively). No lung tumours were found in ferric oxide treated rats. Similar studies have also been conducted in hamsters and mice. Although treated mice and hamsters showed treatment related signs (inflammation or fibrosis), no tumours were observed in hamsters. No increase in the incidence of lung tumours was seen in mice treated with quartz; however silicotic granulomas and lymphoid cuffing around airways but no fibrosis were seen in the lungs of quartz-treated mice.

Human epidemiology data

There is an extensive dataset of human studies investigating the link between crystalline silica exposure and cancer. IARC (1997) identified over 50 epidemiological studies based on occupational exposure to dust containing respirable crystalline silica. Main industry sectors from which the human data is derived include gold mines, foundries, granite/stone industry, pottery workers and refractory brick workers. From the least confounded studies, it was noted that lung cancer tended to increase with the following parameters: cumulative

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exposure; duration of exposure; peak intensity of exposure; presence of radiographically defined silicosis; and length of follow-up time from date of silicosis diagnostic. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics).

Since the 1997 IARC report, a large number of epidemiological studies have been published, with the more recent studies being updates from supplementary follow-up of results from previously assessed case-control studies cohorts, new results based on refined exposure assessments or adjustment for confounders or meta-analyses of the pooled data from these epidemiology studies

In a meta-analysis of the data from 10 cohort studies of gold, tin and tungsten miners, granite workers, industrial sand, diatomaceous earth and pottery workers with quantitative exposure estimates for crystalline silica were pooled in order to analyse the risk related to lung cancer. The pooled cohort standardized mortality ratio (SMR, against national rates) [See Appendix 1 for definition] was 1.2 (Confidence Interval [CI] 1.1-1.3). The results from the case-control analyses show a statistically significant trend with duration of exposure (odds ratios (ORs) [See Appendix 1] by quintile of cumulative exposure increased from 1.0 to 1.6 [CIs of 0.85 to 2.1] and by quintile of average concentration increased from 1.0 to 1.7 [CIs of 1.1 to 2.3]), supporting the importance of the increasing lung burden of silica in the occurrence of cancer. Overall, the authors concluded that the results support the carcinogenicity conclusion presented by IARC (1997).

To investigate the link between crystalline silica, silicosis and lung cancer, epidemiological data published between 1966 and 2001 were gathered. Over 50 studies were selected and pooled according to type of study and the parameter being linked to lung cancer (i.e. silica exposure, presence of silicosis in subjects). The quality of study, adjustment for confounding factors, co-exposure to other carcinogens and availability of a more recent analysis of a same cohort were taken into consideration in the final selection of the studies. Analysis of the relationship between exposure to silica and lung cancer included 17 cohort and 13 case-control studies. For the analysis of lung cancer versus silicosis, 11 cohort and 5 case-control studies were selected. The third analysis included 6 cohort and 2 case-control studies to evaluate the risk of lung cancer in non-silicotics. A random effect model was used to conduct each meta-analysis. Pooled cancer risk ratios (RRs) were 1.32 (CI 1.23-1.41) for crystalline silica exposure, 2.37 (CI 1.98-2.84) for individuals exposed to silica with confirmed silicosis (Silicotics) and 0.96 (CI 0.81-1.15) for individuals with no evidence of silicosis (non-silicotics) with confirmed exposure to silica, supporting the general observation that silicosis has a stronger temporal relationship with crystalline silica exposure and furthermore support the view that a human silicotic response could be a preliminary stage in the development of cancer.

A more recent meta-analysis included 28 cohort, 15 case-control and two proportionate mortality ratio (PMR) [See Appendix 1] studies from a variety of occupational settings conducted between 1996 and 2005. Risk ratios (RRs) were calculated based on type of study and silicosis status using fixed and random effect models (results presented here are from the random model). RRs for all cohort studies was 1.34 (CI 1.25-1.45), and were 1.69 (CI 1.32-2.16) for silicotics, 1.25 (CI 1.18-1.33) for those with undefined silicosis status and 1.19 (CI 0.87-1.57) for non-silicotics. In the case-control studies, the general RR was 1.41 (CI1.18-1.67), and the same sub-groups as mentioned above resulted in RRs of 3.27 (CI 1.32-8.2), 1.41 (CI1.18-1.70) and 0.97 (CI 0.68-1.38), respectively. The proportionate mortality ratio for the last two studies was 1.24 (CI 1.05-1.47). The authors noted that the association between lung cancer and exposure to crystalline silica was more consistent for silicotics, i.e., those diagnosed with silicosis and RR values split into type of occupational settings in which participants worked.

Based upon the above three meta-analysis studies and the epidemiology studies discussed in IARC (1997), the following can be concluded. Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis. Cancer risk is often more significant in workers exposed to crystalline silica over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours. Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles.

There have been reports of tumours outside of the lungs in persons with high silica exposure; however, these reports are sparse and the data inconsistent and have not been unequivocally linked to exposure to either one of the crystalline forms (quartz or cristobalite). Some of the reported locations are: oesophagus, stomach, liver, skin and bone. Sufficient epidemiological or toxicological data do not currently exist for quantitative assessment of the exposure-response relationship on these other tissues or organs.

Genotoxicity

Potential genotoxicity has been assessed in multiple *in vitro* and *in vivo* assays. Table 1 below gives a brief summary of the positive results observed in each type of assay.

Table 1. Summary of positive results over total number of results for each assay and each category (all studies

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conducted with crystalline silica: quartz, except where indicated).

Assay	Animal data		Human data		Positives/Total	
	In vitro	In vivo	In vitro	In vivo[d]	In vitro	In vivo
Rec Assay	0/1				0/1	
DNA strand break	1/1	2/2	5/5[b]	1/1	6/6	3/3
Sister chromatid exchange	0/1		0/1[c]	1/1	0/2	1/1
Micronucleus	2/3	0/1	2/2[b]	1/1	4/5	1/2
Chromosome aberration	0/1			1/1	0/1	1/1
Aneuploidy/polyploidy	0/3				0/3	
Cell transformation	4/4				4/4	
Hprt mutation	1/2	2/2[a]	1/1[b]		2/3	2/2
Oxidative DNA damage		4/5	2/2		2/2	4/5
DNA binding		1/1				1/1
p53 activation		0/1				0/1

a. one assay conducted with crystalline silica: cristobalite
b. one assay conducted with "ultrafine crystalline silicon dioxide".
c. crystalline silica: tridymite
d. crystalline silica dust (subtypes not provided).

All the *in vivo* human genotoxicity studies are based on three independent studies that used blood samples from workers from diverse occupational settings with confirmed exposures to crystalline silica dust; however, quantification of exposure was not provided. After stratification by smoking status, sister chromatid exchange remained statistically significant in both smokers and non-smokers although the frequency was higher in smokers. For the chromosome aberration assay conducted as part of the same study (blood samples from workers in the stone crusher industry), the increased frequency was no longer significant after stratification. In the DNA damage study of foundry and pottery workers and the micronucleus assay of workers involved in sandblasting and related jobs, results were positive when compared to controls. However, in both studies, smoking status influenced the results, contributing to the increased DNA damage observed since results were greater in smokers versus non-smokers, and the frequency of micronuclei in nasal epithelial cells was higher in smokers (p=0.002) but when using peripheral blood lymphocytes did not differ statistically between smokers and non-smokers who were similarly exposed to silica dust,

The role of *in situ* generation of reactive oxygen species (ROS) and reactive nitrogen species (RNS) has been well established in the following types of DNA damage: small scale insertions, DNA base pair deletion, base modification, chromosomal change/loss, microsatellite instability, DNA strand break, 8-hydroxydeoxyguanosine (8-OHdG) mutation and point mutations. ROS and RNS generation is postulated to be (a part of) the DNA damage mechanism for crystalline silica. Studies are described below to support this hypothesis.

DNA was exposed *in vitro* to various crystalline silica dusts, to H_2O_2, or to both. Results show that DNA damage was limited when dust or H_2O_2 were administered alone but increased with the co-exposure. When the reactive oxygen scavenger, dimethylsulfoxide, was added to the test system, DNA strand break was inhibited, data supporting the viewpoint that it is the presence of radicals generated in response to quartz and cristobalite that causes the DNA damage and not quartz or cristobalite themselves.

Hprt mutation assays in rat alveolar epithelial cells, both *in vitro* and *in vivo,* were positive in response to quartz. The positive results *in vivo* were seen only in the presence of significant inflammatory responses in the treated animals. Also, in a parallel *in vitro* experiment, rat alveolar epithelial cells were incubated with the bronchoalveolar lavage fluid from the rats exposed to quartz. Both macrophage and neutrophil enriched lavage cells induced mutation in the exposed alveolar epithelial cells. Addition of catalase (an enzyme which inactivates H_2O_2) before incubation inhibited the increase in *hprt* mutation.

Rats were exposed to either crystalline or amorphous silica in a manner to induce the same level of

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inflammation in the lungs. The inflammatory response was assessed by measuring the proportion of neutrophils in the bronchiolar lavage fluid. The actual concentrations were 3 and 50 mg/m^3 for crystalline and amorphous silica respectively. The animals were exposed for 13 weeks. *Hprt* mutation frequency was measured in the alveolar epithelial cells at the end of the exposure period. Mutation frequency was greatly increased only in the crystalline silica treated rats; no treatment related increase was found in the rats treated with the amorphous form.

In an 8-OHdG assay conducted to monitor DNA damage by reactive oxygen species, female rats were exposed to 0, 0.3, 1.5 and 7.5 mg/animal of quartz via intratracheal instillation. Effects were observed 90 days post-exposure. A clear dose-response relationship was identified between quartz exposure and various inflammation markers (differential cell count, protein, lung surfactant lipids and tumour necrosis factor alpha). Inflammation was present starting at the lowest dose. However, 8-OHdG showed a statistically significant increase starting at 1.5 mg/animal only. Similarly, in another study, 8-OHdG and DNA strand breaks were observed at concentrations of or above 10 ug/m^3 in rat lung epithelial cells.

In the aim of investigating the role of ROS in lung carcinogenesis, rat lung epithelial cells were incubated with polymorphonuclear (PMN) leukocytes (involved in the inflammatory process and responsible for the release of certain ROS) or hydrogen peroxide. Statistically significant increases in 8-OHdG were observed in the presence of PMN or hydrogen peroxide in a dose-response manner.

In a series of experiments which used *in vitro* stimulation of macrophages with crystalline silica and *in vivo* intranasal instillation of crystalline silica in mice, it was demonstrated that that the chronic fibrosis seen in a murine model of silicosis *in vivo* is dependent on the presence of adaptor molecule ASC and Nalp3 inflammazome. These data support a potential mode of action whereby silica triggers cellular responses that in turn activate alveolar macrophages, resulting in an inflammatory response and silicosis. In mice deficient in Nalp3 inflammazome, the development of inflammation and collagen deposition was significantly reduced compared with normal mice 3 months after the initial intranasal instillation of silica.

Analysis of Lung Tumour Data

The weight of evidence for both rats and humans indicates that fibrotic and silicotic lesions in the lung result from inhalation exposure to crystalline silica and that lung cancer is secondary to those lesions in the lung. Although the mechanism of induction for the lung tumours has not been fully elucidated, there is sufficient supportive mode of action evidence from the data presented to demonstrate that a threshold approach to risk assessment is appropriate based on an understanding of the key events in the pathogenesis of crystalline silica induced lung tumours. The body of evidence include the following:

- In experimental studies, all rats that developed tumours also showed fibrosis.
- Adenocarcinomas, the most common type of tumour identified in rats, are commonly associated with fibrosis and deeply scarred lung tissue.
- Experimental rat studies showed a clear progression of the effects from initially mild inflammation, followed by fibrosis over-time, leading eventually to lung tumours.
- Tumours are not present in all treated species dosed in the same way.
- The tumours, both in rats and humans, are concentrated in the lungs only, although other organs are indirectly exposed.
- In human studies, cancer risk is often more significant in workers exposed over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours.
- Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles
- Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis.
- For genotoxicity, in vitro results were mostly mixed and in vivo results were mostly positive. However, the vast majority of the positive genotoxicity assay results can be explained by the generation of reactive oxygen species, as demonstrated experimentally, where ROS scavenging prevents the genotoxicity.
- *In vivo*, macrophage deficient mice (macrophages produce ROS in response to crystalline silica) do not develop silicosis nor do they develop tumours and the Nalp3 inflammazome, a key player in the macrophage initiated inflammatory response, is required for the development of pulmonary fibrosis after

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inhalation of silica.

- Though inhalation exposure to crystalline silica in multiple occupational settings is clear, the increase in risk, based on the several recent meta-analyses of the multiple human epidemiological studies, remains low.

It is worth noting that where aggressive engineering controls have been made to reduce silica dust levels in the workplace (Sweden), silicosis has been eliminated. By corollary, existing exposures outside of the workplace in such areas do not pose a risk for silicosis to the general population.

The respirable forms of quartz and cristobalite possess properties indicating a hazard for human health (repeated dose toxicity, carcinogenicity and genotoxicity). The mode of action in the lungs involves irritation, inflammation and reactive species formation, leading to silicosis, and eventually to tumour formation.

Exposure

Uses

Consistent with oxygen and silicon being the two most abundant elements in the Earth's crust, silicon-oxide minerals, including quartz are ubiquitous in the natural environment. In particular, as a component of sand, quartz may find use in a diverse array of applications. Several high volume uses include, but are not limited to, the use of sand as a filling material for the construction of roads and in general building activities, the use of sand and gravel aggregates as abrasives on roads in winter and the use of fly-ash, which may contain 4-14% quartz and 0.5-1% cristobalite, as a cement additive. These abrasives when used on winter roads are usually mixed with road salts and may be sand only, stone dust, sand and gravel aggregates, or pre-treated sand. They are used mainly by rural municipalities or in areas where cold temperatures diminish the efficiency of salts for de-icing. Quantities of abrasives used in Canada were 5.73×10^9 kg, 4.59×10^9 kg, and 4.93×10^9 kg for 2007, 2008 and 2009, respectively.

Industrial sand, high purity silica sand products with closely controlled sizing are expected to contain quartz and cristobalite, include lump silica (2-3mm up to 15 cm or more), silica sand (75µm to 2-3mm) and silica flour (less than 75µm). Lump silica may be used in the production of silicon alloys, silica bricks, and the linings of certain types of pulverizers (eg. ball mills and tube mills).

Silica sand may be used in the manufacture of glass and glass fibres, silicate chemicals and silicon carbide, the hydraulic fracturing of wells, foundry moulding, and for sandblasting. Silica flour may find use in the ceramics and cement industries, as a filler and extender in rubber and coatings, and as an abrasive in soaps.

Natural clays, such as bentonite and fuller's earth, are used in cat litters for their high water absorbance capacities. Quartz is a natural component of these clays, and consequently, it may be present in cat litter products. High purity α-quartz is a piezoelectric material, which means that application of a voltage induces a distortion in the crystal shape and vice versa. This ability to interconvert electrical and mechanical energy has led to the use of quartz crystals in electronic devices requiring precise timing control, for example telephones, radios, watches and computers.

According to a survey conducted in Canada, quartz and cristobalite are also used in abrasives, adsorbents, filter products (diatomaceous earth), grout and cement. These substances reportedly also find use as fillers, which add bulk and improve wear resistance, in paints and coatings, adhesives, sealants, polymer films, caulking, epoxy resins and silicones. Also, quartz is listed as an ingredient in 60 cosmetic products in Canada. The types of products include anti-wrinkle preparation, eye and face makeup, lipstick, hair dyes, shampoos and grooming products, as well as skin cleansers, moisturizers and tanning preparations.

Natural Sources

In Canada, quartz naturally occurs in many types of rock formations. Those with high silicon dioxide content (95% SiO_2 or more) include vein and massive intrusion bodies, quartz pebbles, silica sand, sandstone and quartzite. Sandstone is a sedimentary rock mostly composed of quartz grains cemented by a bonding material such as clay, calcite or iron oxide. Quartzite is a hard, compact, metamorphosed sandstone made of grains of quartz firmly bonded with a siliceous cement. Mineral aggregates (e.g., sand and gravel) have variable silicon dioxide content. Quartz is also found as crystals, aggregates or discrete particles in certain igneous rocks (e.g., granites and pegmatites), soils, sediments, air and surface water. This omnipresence is consistent with the fact that silicon is the second most abundant chemical element on Earth.

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Cristobalite is naturally produced in the ashes of volcanic eruptions, and by combustion metamorphism which is a local phenomenon of spontaneous combustion of naturally occurring substances such as bituminous rocks, coal or oil. It may be found in cavities in volcanic rocks and in thermally metamorphosed sandstones and may also be a transient stage in the diagenesis of diatomaceous shale with the result that soils made of these geologic formations may be rich in cristobalite. Unlike quartz, the natural occurrence of cristobalite is limited to specific geographic regions and mineral types.

Anthropogenic Sources

Natural quartz is isolated from ore via beneficiation, which involves milling or grinding the material into particles that are separated into desired mineral and waste. The materials obtained are either used directly or further purified. In Canada, in 2006, 2.146×10^{9} kg of pure quartz were mined, and 2.385×10^{11} kg of sand and gravel aggregates were produced. The proportion of quartz in silica sand deposits and gravel aggregates will vary from one site to another.

Cristobalite can form from silica melts during the preparation of silica glass; quartz is not obtained from melts but is manufactured at elevated temperature and pressure via a hydrothermal process. Cristobalite also forms during the calcination[2] of diatomaceous earth.

Human Exposure Estimate

Ambient air

The exposure assessment is focussed on respirable quartz and cristobalite, which in ambient air comprises a component of total particulate matter (PM). In Canada, data on the concentrations of silicon in PM was available and used as a surrogate for quartz and cristobalite. This approach is conservative because the measured silicon includes all silicon-containing substances and therefore represents the upper limit for quartz and cristobalite in ambient air.

The National Air Pollution Surveillance (NAPS) Program measured concentrations in $\mu g/m^3$ of silicon in PM with aerodynamic radii less than 2.5 µm ($PM_{2.5}$ (dichot)), and from 2.5 to 10 µm (PM_{10} (dichot)) (the total particulate matter with aerodynamic radii less than 10 µm (PM_{10}) is obtained by adding these values) in Canada. In 2009, as part of the NAPS Program, silicon concentrations were determined on over 1600 samples of $PM_{2.5}$(dichot) and over 1500 samples of PM_{10}(dichot) at 24 urban locations across Canada. An estimate of exposure to quartz and cristobalite can be obtained by assuming that all the silicon in the PM is represented stoichiometrically as SiO_2, and multiplying the reported concentration of silicon by 2.14 to obtain a value for silica.

The intake of respirable quartz and cristobalite by the general population of Canada is estimated using a range covering the lowest 50^{th} percentile SiO_2 concentration in PM_{10}, measured in Pt. Petre, ON, (0.12 $\mu g/m^3$) to the highest 50^{th} percentile concentration in PM_{10} measured in Calgary, AB (2.1 $\mu g/m^3$). The 50^{th} percentile SiO_2 concentrations ranged from 0.1 to 2.1 $\mu g/m^3$ across the survey sites; the top of this range is quite close to the average of the maximum values for the 24 sites (3.7 $\mu g/m^3$). The outdoor data were used to represent the indoor levels, because information on indoor silicon concentrations was not available, and the range of PM_{10} measured indoors is generally lower than the outdoor range. Thus, this approach conservatively overestimates indoor exposure in homes.

The highest exposure group based on these calculations is children ages 0.5 to 4 years with an estimated daily intake ranging from 0.07 to 5.26 µg/kg-bw per day; the estimated daily intake decreases with age due to changes in the ratio of inhalation rates to body weights; the daily intake of adults, 20-59 years old, is estimated to range from 0.03 to 2.00 µg/kg-bw per day.

Consumer Products

Exposure to respirable quartz from the use of cosmetic products, which contained quartz as an ingredient, was considered low because they are not formulated for spray application, the loose powders were reported to contain less than 0.1% quartz, and in these products the substance is not expected to be associated with other components of the formulation and not available in a free form.

For consumer Do It Yourself (DIY) activities around the home, the highest mean breathing zone concentration of particles from sanding dry wall (median cut-point of 10µm) of 6.31 mg/m^3, was used to derive an upper-

[2] Calcinations: Heat treating a substance, but without fusion, to bring about change in its physical or chemical constitution.

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bound exposure estimate ranging from 2 to10 µg/kg-bw per event.

Quartz is used to formulate a large number of paints and coatings. To estimate potential inhalation exposure to quartz from these products, the spray painting of wall paints with an airless spray gun was considered appropriate as a conservative scenario. Exposure to respirable paint particles was estimated using data from controlled a laboratory study in which walls of poorly ventilated test rooms were painted by professional painters using an airless sprayer to apply interior latex paint. The maximum concentration of 13% quartz in paint in Canada was used to estimate exposure. The upper-bound estimate of exposure to quartz, based on the maximum concentration of 13% quartz in paint in the Canadian market and the maximum concentration of respirable paint particles measured in these controlled studies when recommended personal protective equipment is used, is 0.954 µg/kg-bw per event.

Inhalation of ambient air containing quartz and cristobalite is the dominant pathway of chronic exposure (excluding that from DIY activities) for the general population. Because SiO_2 makes up only approximately 5% of PM_{10}, silicon concentrations (expressed as SiO_2) measured in the Canadian NAPS survey of 24 urban locations were considered most relevant to the estimation of exposure by the general population. Quartz and cristobalite comprise only a portion of the total SiO_2 in PM_{10}, therefore, the use of the total silicon concentration to represent the upper bound crystalline silica concentrations results in an overestimation of exposure.

Appendix 1: Definitions of Epidemiological Terms in the ITAP

SMR (Standardized Mortality Ratio): The ratio (x 100) of observed to expected deaths in a study population. Expected deaths are calculated by applying a set of standard age-specific mortality rates to the age distribution of the study population. Standardized ratios are only useful for comparisons. They have no intrinsic meaning.

OR (Odds Ratio): In epidemiological case-control studies, a relative measure of disease occurrence. The odds in favour of a particular disease occurring in an exposed group are divided by the odds in favour of its occurring in an unexposed group. If the condition being studied is rare, the odds ratio is a close approximation to the relative risk.

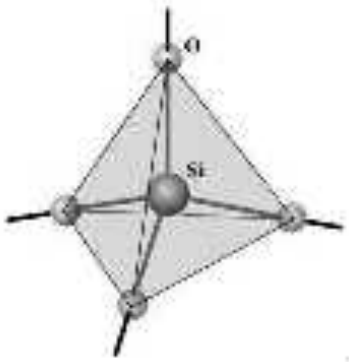
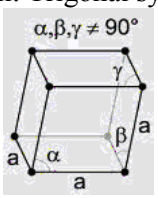
RR (Risk Ratio): The probability of the occurrence of a disease in a group that has been exposed to some environmental, medicinal, microbial, or toxic influence, relative to its probability in a randomly selected population.

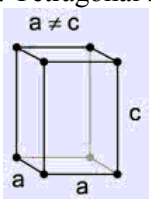
PMR (Proportionate Mortality Ratio): Proportionate mortality is the proportion of deaths in a specified population over a period of time attributable to different causes. Each cause is expressed as a percentage of all deaths, and the sum of the causes must add to 100%. These proportions are not mortality rates, since the denominator is all deaths, not the population in which the deaths occurred. Thus, proportionate mortality ratio is a measure of the frequency of occurrence of the proportionate mortality in a defined population during a specified interval of time.

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INITIAL TARGETED ASSESSMENT PROFILE (Human Health)

<table>
<tr><td>CAS No.</td><td colspan="2">Quartz: CAS RN 14808-60-7

Cristobalite: CAS RN 14464-46-1</td></tr>
<tr><td>Chemical Name</td><td colspan="2">Quartz and Cristobalite</td></tr>
<tr><td rowspan="2">Structural Formula</td><td colspan="2">Molecular Formula: SiO_2

</td></tr>
<tr><td>Unit Cell: Trigonal symmetry


Quartz: CAS RN 14808-60-7</td><td>Unit Cell: Tetragonal symmetry


Cristobalite: CAS RN 14464-46-1</td></tr>
</table>

SUMMARY CONCLUSIONS OF THE TARGETED ASSESSMENT

NOTE: The present assessment is targeted to address the following human health endpoints: repeated dose toxicity and carcinogenicity via the inhalation route of exposure, and genotoxicity. It cannot be considered as a full SIDS Initial Assessment. Summary information on exposure is also reported here. Other endpoints for human health and the environment included in the Canadian screening assessment but have not been presented to OECD member countries, and thus are not included in this profile.

The final screening assessment will be published under the responsibility of the Government of Canada.

Rationale for Targeting the Assessment

The Government of Canada "categorized" or prioritized all 23,000 chemical substances on its Domestic Substances List (DSL) from 1999 to September 2006, as required by its *Canadian Environmental Protection Act, 1999* (CEPA 1999). Additional details may be found at http://www.chemicalsubstanceschimiques.gc.ca/about-apropos/categor/index-eng.php. Using information from Canadian industry, academic research and other countries, Government of Canada scientists applied a set of rigorous tools to the 23,000 chemical substances on the DSL. They were categorized to identify those that were: **inherently toxic** to humans or to the environment and that might be **persistent** and/or **bioaccumulative**; and substances to which people might have **greatest potential for exposure**. During this priority-setting exercise, distinct approaches were taken for identifying substances of likely concern for human health and the environment, and subsequent assessment activities may have focused on either human health or ecological endpoints. Through categorization, the Government of Canada has identified approximately 4,000 of the 23,000

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chemical substances on the DSL as priorities for further assessment, research and/or measures to control their use or release. Quartz and cristobalite were identified at that time, applying the categorization criteria, as high priorities for human health risk because they were considered to pose greatest potential for exposure and their respirable forms are classified by the International Agency for Research on Cancer as carcinogenic to humans (quartz and cristobalite) and by the National Toxicology Program as known human carcinogens (crystalline silica). These substances did not meet the ecological categorization criteria for bioaccumulation potential or inherent toxicity to aquatic organisms.

Under the Canadian legislation a determination of whether one or more of the criteria of the CANADIAN ENVIRONMENTAL PROTECTION ACT (CEPA) 1999, section 64 are met is based upon an assessment of potential risks to the environment and/or to human health associated with exposures in the general environment. For humans, this includes, but is not limited to, exposures from ambient and indoor air, drinking water, foodstuffs, and the use of consumer products. A conclusion under CEPA 1999 on the substances in the Chemicals Management Plan (CMP) Challenge is not relevant to, nor does it preclude, an assessment against the hazard criteria specified in the Controlled Products Regulations, which is part of the regulatory framework for the Workplace Hazardous Materials Information System [WHMIS] for products intended for workplace use.

Physical-chemical properties

The silicon dioxide group represents a polymorphic category containing a large number of forms identical in composition but with different atomic arrangements which afford different chemical properties. There are two sub-categories within this group: crystalline silica, to which the present substances quartz and cristobalite belong, and non-crystalline or amorphous silica. The key distinction between these sub-categories is that in crystalline substances, the building blocks are arranged in regular, repeating 3-dimensional pattern having long range order, whereas amorphous materials do not display long range order. In all forms of silica, (crystalline and non-crystalline), the silicon atom is tetrahedral and bound to four neighbouring oxygen atoms.

Quartz and cristobalite are solid at room temperature, existing normally as colourless or white crystals. The melting points for quartz and cristobalite are 1400-2000 ^{o}C and 1713-1728 ^{o}C, respectively and for both compounds, the boiling point is 2230^{o}C. Even though no experimental data were available, their vapour pressure and Henry's Law constant are likely negligible. Log K_{ow} (octanol-water partition coefficient) and log K_{oc} (organic carbon-water partition coefficient) are not applicable to these substances. The densities range from 2500-2700 kg/m^3 for quartz and 2300-2380 kg/m^3 for cristobalite.

The very similar physico-chemical properties of quartz and cristobalite reflect their closely related crystal forms. The solubility of crystalline silicates decreases as a function of silica tetrahedral packing density and long-range crystal order. For example, cristobalite has a more open framework structure than quartz and its density is lower, therefore, its solubility is higher. The water solubility of these minerals is also function of temperature, pH, particle size, and the presence of a disrupted surface layer. This may explain the variability of solubility values reported by many authors. The most probable solubility value for quartz is approximately 3.8 mg Si/L, or 6.4 mg/L expressed as the SiO_2 species, while the solubility of cristobalite is approximately 8.7 mg Si/L, or 18 mg SiO_2/L. The kinetics of dissolution of these substances is slow due to the high activation energy required to hydrolyse the Si-O-Si bond.

Human Health Targeted Endpoints

The majority of the studies described here have been reviewed by the International Agency for Research on Cancer (IARC 1997). However, additional data relevant to the screening assessment were identified up to August 2010.

Repeated dose toxicity/non-neoplastic effects (development of silicosis).

Studies on animals

Significant short-term and subchronic studies have demonstrated adverse effects in the lungs, while one of the 6 studies showed effects on the spleen in mice. Rats were exposed to 0, 10 or 100 mg/m^3 of cristobalite via inhalation for 6 hours/day during 3 days. Animals were observed 3 months after exposure. Elevated levels of granulocytes and elevated markers of cytotoxicity from the lung lavage fluid were noted in all exposed groups. Another study of similar duration (9 days) conducted in mice also identified a LOAEC of 10 mg/m^3. Effects observed included minimal interstitial thickening, accumulations of mononuclear cells and slight lymphoid tissue hypertrophy in the lungs.

In a 4-week inhalation study, female rats were exposed to 0, 0.1, 1 or 10 mg/m^3 of quartz 6 hours/day, 5 days/week. Bronchoalveolar lavage fluid was evaluated at 1, 8, and 24 weeks after exposure. Elevated levels of

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granulocytes and significant elevation of markers of cytotoxicity (Lactate dehydrogenase [LDH] and β-glucuronidase [β-glu]) were observed at 1 mg/m^3 and higher. The increased levels of LDH and β-glu were only significant at 24 weeks after exposure. A LOAEC of 1 mg/m^3 was identified at 24 weeks.

Male rats (4 animals per dose) were exposed to 0 or 3 mg/m^3 of cristobalite via inhalation for 6 hours/day, 5 days/week during 13 weeks. Pulmonary inflammation and fibrosis were observed in the exposed group at the end of treatment. When mice were similarly exposed to 5 mg/m^3 of quartz for 6 hours/day, 5 days/week for 15 or 27 weeks, the authors observed increased spleen weight and formation of plaque in the spleen.

In two separate studies, in which rats or hamsters were exposed to quartz via inhalation for at least 6 months, LOAECs of 2 and 3 mg/m^3 were identified, respectively. All the effects observed were related to inflammation and fibrosis of the lung tissue.

Several chronic studies investigated exposure of the respirable forms (i.e. accumulated via inhalation in the lung tissues) of quartz and cristobalite to rats, mice and hamsters. The following is a description of the study in which the lowest non-neoplastic LOAEC was determined. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz, containing 74% of respirable quartz, through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. The mean mass of particle at the end of the exposure period was 0.91 mg/lung. The LOAEC identified was 0.74 mg/m^3 (adjusted for 74% respirable quartz) based on lipoproteinosis, multifocal, inflammatory cell infiltrate and alveolar hyperplasia.

Human epidemiology data

In humans, the lowest observed adverse effect level was identified in a U.S. cohort study. The study was conducted on 3330 gold miners (all are males), who had an average of 9 years underground exposure during the period 1940 to 1965. The cohort was followed up through 1990. Silicosis[1] was identified through death certificates or chest X-rays. A job-exposure matrix together with work history was used to estimate individual exposure. The total silica content in the respirable dust in the mine was estimated at 13% and the median crystalline silica exposure was 0.05 mg/m^3. In this sub population of miners, 170 cases of silicosis were identified. The best predictor for risk of silicosis was cumulative exposure, which varied from less than 1% for a 0.5 mg/m^3-year exposure to 68-84% when exposed to more than 4 mg/m^3-year (based on the average daily dust exposure during the workday each year and summed over time for each miner). The main limitations identified by the authors include the limited number of radiographic surveys, the potential bias from death certificates

[1] Silicosis: Lung disease caused by inhalation of crystalline silica dust, and resulting in inflammation and scarring in forms of nodular lesions in the upper lobes of the lungs. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics). It does not follow that a history of exposure to silica necessarily results in silicosis (Nonsilicotics). The typical "Silicotic" lung nodule is shown in Figure 1.

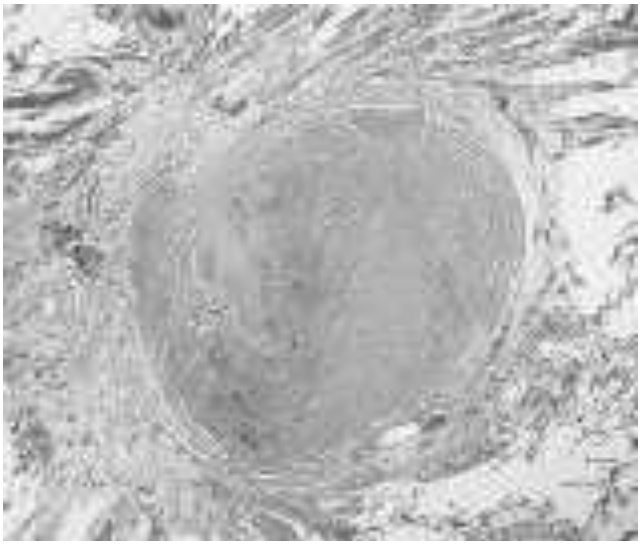


Figure 1. Silicotic nodule characterised by a central zone of hyalinised collagen with a whorled appearance and peripheral dust-containing macrophages (Rees and Murray, 2007).

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(relying on death certificates instead of relying on repeated x-rays, which were lacking for each miner, may have underestimated the number of cases) and the fact that the conversion of dust counts to

gravimetric measurements may not be accurate based on the estimation of 13% silica content in the respirable dust (although based on a relatively large number of samples (n = 82) collected in two different surveys, there was broad range of content in these samples (1% to 48%, SD = 9), and the percentage of respirable quartz may have differed in earlier years, but data were lacking for these years).

Two other human studies have identified similar LOAECs based on the critical endpoint of radiographic confirmed silicosis. A LOAEC of 0.053 mg/m^3 (mean exposure) was identified in a cross sectional study of South African gold miners and a LOAEC of 0.064 mg/m^3 (mean exposure) was derived in a mining community population-based random sample survey in Colorado.

Carcinogenicity studies

Studies on animals

Experimental studies conducted in rats have shown clear and consistent increases in lung tumours after chronic inhalation exposure. In the nine rat studies identified, five were inhalation studies and four were intratracheal instillation studies. All studies except one inhalation study showed increased incidence of lung tumours. For the inhalation studies with treatment related tumours, concentrations ranged from 1 to 50 mg/m^3 (1, 6, and 30 mg/m^3 of DQ-12 quartz; 12 and 50 mg/m^3 of Min-U-Sil 5 quartz) and duration of exposure ranged from 29 days to 2 years. In the inhalation study with no treatment-related tumours, exposure was 60 mg/m^3 of Sikron F300 quartz for 13 weeks. The following is a description of the neoplastic results in the study also identified as the critical study for non-neoplastic results. Groups of 50 rats/sex were exposed 6 hr/day, 5 days/week for 24 months to filtered air or 1 mg/m^3 of DQ-12 quartz through whole-body inhalation. An additional 50 rats/sex were exposed to 5 mg/m^3 of titanium dioxide as positive controls. In the exposed group, 18 animals developed tumours (12 in females, 5 in males), as opposed to 3 and 2 for the control and positive control groups respectively. The majority (10/18) of the tumours observed were adenocarcinomas. The mean mass of particles in the lungs at the end of the exposure period was 0.91 mg/lung.

For the intratracheal instillation studies, doses ranged from 4 to 57 mg/kg-bw (based on 7, 12 or 20 mg/animal of Min-U-Sil (5) quartz or 20 mg/animal of novaculite quartz). Exposure regimes were diverse and included single instillation with observation for up to two years, to weekly instillation for 10 weeks. It is noteworthy that the single intratracheal administration of a 95% pure quartz particles (<5 μm) resulted in an increased incidence of silicotic granulomas after 3 weeks and lung tumours after 11 months. The most common tumours reported across the long term rat studies were adenocarcinomas, however other tumours such as squamous-cell carcinoma, alveolar carcinoma and bronchiole-alveolar adenoma were also reported, and all animals that developed tumours also showed some degree of fibrosis.

Of particular interest is the intratracheal instillation study, investigating the sequence of pathological events leading to lung tumors. An unspecified number of rats/sex/dose received a single intratracheal instillation of various crystalline silica dusts or ferric oxide, allowing direct administration into the bronchial tree. The doses were 12 or 20 mg of Min-U-Sil 5 quartz (MQZ), 12 mg of hydrofluoric-acid-etched Min-U-Sil 5 quartz (HFMQZ), 12 mg of cristobalite, 12 mg of tridymite and 12 mg of ferric oxide suspended in saline. All groups were observed until six months post exposure, except for both MQZ groups, the HFMQZ and the ferric oxide group which were observed up until 17 months post-exposure. Interim sacrifices were conducted at 6, 11 and 17 months. The rat lungs showed a clear progression of effects. The sequence of pathological events were, an initial inflammatory response leading to a marked hyperplasia and hypertrophy of alveolar cells after one month, and at six months hyperplasia was evident but no lung tumours were observed. In this study, lung tumours were observed starting at the 11 month sacrifice with a 17% and 42% incidence in males and females (based on 3/18 males and 8/19 females), respectively, and at 17 months incidences were 32% and 59% (based on 6/19 males and 10/17 females, respectively). No lung tumours were found in ferric oxide treated rats. Similar studies have also been conducted in hamsters and mice. Although treated mice and hamsters showed treatment related signs (inflammation or fibrosis), no tumours were observed in hamsters. No increase in the incidence of lung tumours was seen in mice treated with quartz; however silicotic granulomas and lymphoid cuffing around airways but no fibrosis were seen in the lungs of quartz-treated mice.

Human epidemiology data

There is an extensive dataset of human studies investigating the link between crystalline silica exposure and cancer. IARC (1997) identified over 50 epidemiological studies based on occupational exposure to dust containing respirable crystalline silica. Main industry sectors from which the human data is derived include gold mines, foundries, granite/stone industry, pottery workers and refractory brick workers. From the least confounded studies, it was noted that lung cancer tended to increase with the following parameters: cumulative

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exposure; duration of exposure; peak intensity of exposure; presence of radiographically defined silicosis; and length of follow-up time from date of silicosis diagnostic. By definition, clinically or pathologically diagnosed silicosis implies prior exposure to silica (Silicotics).

Since the 1997 IARC report, a large number of epidemiological studies have been published, with the more recent studies being updates from supplementary follow-up of results from previously assessed case-control studies cohorts, new results based on refined exposure assessments or adjustment for confounders or meta-analyses of the pooled data from these epidemiology studies

In a meta-analysis of the data from 10 cohort studies of gold, tin and tungsten miners, granite workers, industrial sand, diatomaceous earth and pottery workers with quantitative exposure estimates for crystalline silica were pooled in order to analyse the risk related to lung cancer. The pooled cohort standardized mortality ratio (SMR, against national rates) [See Appendix 1 for definition] was 1.2 (Confidence Interval [CI] 1.1-1.3). The results from the case-control analyses show a statistically significant trend with duration of exposure (odds ratios (ORs) [See Appendix 1] by quintile of cumulative exposure increased from 1.0 to 1.6 [CIs of 0.85 to 2.1] and by quintile of average concentration increased from 1.0 to 1.7 [CIs of 1.1 to 2.3]), supporting the importance of the increasing lung burden of silica in the occurrence of cancer. Overall, the authors concluded that the results support the carcinogenicity conclusion presented by IARC (1997).

To investigate the link between crystalline silica, silicosis and lung cancer, epidemiological data published between 1966 and 2001 were gathered. Over 50 studies were selected and pooled according to type of study and the parameter being linked to lung cancer (i.e. silica exposure, presence of silicosis in subjects). The quality of study, adjustment for confounding factors, co-exposure to other carcinogens and availability of a more recent analysis of a same cohort were taken into consideration in the final selection of the studies. Analysis of the relationship between exposure to silica and lung cancer included 17 cohort and 13 case-control studies. For the analysis of lung cancer versus silicosis, 11 cohort and 5 case-control studies were selected. The third analysis included 6 cohort and 2 case-control studies to evaluate the risk of lung cancer in non-silicotics. A random effect model was used to conduct each meta-analysis. Pooled cancer risk ratios (RRs) were 1.32 (CI 1.23-1.41) for crystalline silica exposure, 2.37 (CI 1.98-2.84) for individuals exposed to silica with confirmed silicosis (Silicotics) and 0.96 (CI 0.81-1.15) for individuals with no evidence of silicosis (non-silicotics) with confirmed exposure to silica, supporting the general observation that silicosis has a stronger temporal relationship with crystalline silica exposure and furthermore support the view that a human silicotic response could be a preliminary stage in the development of cancer.

A more recent meta-analysis included 28 cohort, 15 case-control and two proportionate mortality ratio (PMR) [See Appendix 1] studies from a variety of occupational settings conducted between 1996 and 2005. Risk ratios (RRs) were calculated based on type of study and silicosis status using fixed and random effect models (results presented here are from the random model). RRs for all cohort studies was 1.34 (CI 1.25-1.45), and were 1.69 (CI 1.32-2.16) for silicotics, 1.25 (CI 1.18-1.33) for those with undefined silicosis status and 1.19 (CI 0.87-1.57) for non-silicotics. In the case-control studies, the general RR was 1.41 (CI1.18-1.67), and the same sub-groups as mentioned above resulted in RRs of 3.27 (CI 1.32-8.2), 1.41 (CI1.18-1.70) and 0.97 (CI 0.68-1.38), respectively. The proportionate mortality ratio for the last two studies was 1.24 (CI 1.05-1.47). The authors noted that the association between lung cancer and exposure to crystalline silica was more consistent for silicotics, i.e., those diagnosed with silicosis and RR values split into type of occupational settings in which participants worked.

Based upon the above three meta-analysis studies and the epidemiology studies discussed in IARC (1997), the following can be concluded. Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis. Cancer risk is often more significant in workers exposed to crystalline silica over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours. Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles.

There have been reports of tumours outside of the lungs in persons with high silica exposure; however, these reports are sparse and the data inconsistent and have not been unequivocally linked to exposure to either one of the crystalline forms (quartz or cristobalite). Some of the reported locations are: oesophagus, stomach, liver, skin and bone. Sufficient epidemiological or toxicological data do not currently exist for quantitative assessment of the exposure-response relationship on these other tissues or organs.

Genotoxicity

Potential genotoxicity has been assessed in multiple *in vitro* and *in vivo* assays. Table 1 below gives a brief summary of the positive results observed in each type of assay.

Table 1. Summary of positive results over total number of results for each assay and each category (all studies

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conducted with crystalline silica: quartz, except where indicated).

Assay	Animal data		Human data		Positives/Total	
	In vitro	In vivo	In vitro	In vivo[d]	In vitro	In vivo
Rec Assay	0/1				0/1	
DNA strand break	1/1	2/2	5/5[b]	1/1	6/6	3/3
Sister chromatid exchange	0/1		0/1[c]	1/1	0/2	1/1
Micronucleus	2/3	0/1	2/2[b]	1/1	4/5	1/2
Chromosome aberration	0/1			1/1	0/1	1/1
Aneuploidy/polyploidy	0/3				0/3	
Cell transformation	4/4				4/4	
Hprt mutation	1/2	2/2[a]	1/1[b]		2/3	2/2
Oxidative DNA damage		4/5	2/2		2/2	4/5
DNA binding		1/1				1/1
p53 activation		0/1				0/1

a. one assay conducted with crystalline silica: cristobalite
b. one assay conducted with "ultrafine crystalline silicon dioxide".
c. crystalline silica: tridymite
d. crystalline silica dust (subtypes not provided).

All the *in vivo* human genotoxicity studies are based on three independent studies that used blood samples from workers from diverse occupational settings with confirmed exposures to crystalline silica dust; however, quantification of exposure was not provided. After stratification by smoking status, sister chromatid exchange remained statistically significant in both smokers and non-smokers although the frequency was higher in smokers. For the chromosome aberration assay conducted as part of the same study (blood samples from workers in the stone crusher industry), the increased frequency was no longer significant after stratification. In the DNA damage study of foundry and pottery workers and the micronucleus assay of workers involved in sandblasting and related jobs, results were positive when compared to controls. However, in both studies, smoking status influenced the results, contributing to the increased DNA damage observed since results were greater in smokers versus non-smokers, and the frequency of micronuclei in nasal epithelial cells was higher in smokers (p=0.002) but when using peripheral blood lymphocytes did not differ statistically between smokers and non-smokers who were similarly exposed to silica dust,

The role of *in situ* generation of reactive oxygen species (ROS) and reactive nitrogen species (RNS) has been well established in the following types of DNA damage: small scale insertions, DNA base pair deletion, base modification, chromosomal change/loss, microsatellite instability, DNA strand break, 8-hydroxydeoxyguanosine (8-OHdG) mutation and point mutations. ROS and RNS generation is postulated to be (a part of) the DNA damage mechanism for crystalline silica. Studies are described below to support this hypothesis.

DNA was exposed *in vitro* to various crystalline silica dusts, to H_2O_2, or to both. Results show that DNA damage was limited when dust or H_2O_2 were administered alone but increased with the co-exposure. When the reactive oxygen scavenger, dimethylsulfoxide, was added to the test system, DNA strand break was inhibited, data supporting the viewpoint that it is the presence of radicals generated in response to quartz and cristobalite that causes the DNA damage and not quartz or cristobalite themselves.

Hprt mutation assays in rat alveolar epithelial cells, both *in vitro* and *in vivo,* were positive in response to quartz. The positive results *in vivo* were seen only in the presence of significant inflammatory responses in the treated animals. Also, in a parallel *in vitro* experiment, rat alveolar epithelial cells were incubated with the bronchoalveolar lavage fluid from the rats exposed to quartz. Both macrophage and neutrophil enriched lavage cells induced mutation in the exposed alveolar epithelial cells. Addition of catalase (an enzyme which inactivates H_2O_2) before incubation inhibited the increase in *hprt* mutation.

Rats were exposed to either crystalline or amorphous silica in a manner to induce the same level of

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inflammation in the lungs. The inflammatory response was assessed by measuring the proportion of neutrophils in the bronchiolar lavage fluid. The actual concentrations were 3 and 50 mg/m^3 for crystalline and amorphous silica respectively. The animals were exposed for 13 weeks. *Hprt* mutation frequency was measured in the alveolar epithelial cells at the end of the exposure period. Mutation frequency was greatly increased only in the crystalline silica treated rats; no treatment related increase was found in the rats treated with the amorphous form.

In an 8-OHdG assay conducted to monitor DNA damage by reactive oxygen species, female rats were exposed to 0, 0.3, 1.5 and 7.5 mg/animal of quartz via intratracheal instillation. Effects were observed 90 days post-exposure. A clear dose-response relationship was identified between quartz exposure and various inflammation markers (differential cell count, protein, lung surfactant lipids and tumour necrosis factor alpha). Inflammation was present starting at the lowest dose. However, 8-OHdG showed a statistically significant increase starting at 1.5 mg/animal only. Similarly, in another study, 8-OHdG and DNA strand breaks were observed at concentrations of or above 10 ug/m^3 in rat lung epithelial cells.

In the aim of investigating the role of ROS in lung carcinogenesis, rat lung epithelial cells were incubated with polymorphonuclear (PMN) leukocytes (involved in the inflammatory process and responsible for the release of certain ROS) or hydrogen peroxide. Statistically significant increases in 8-OHdG were observed in the presence of PMN or hydrogen peroxide in a dose-response manner.

In a series of experiments which used *in vitro* stimulation of macrophages with crystalline silica and *in vivo* intranasal instillation of crystalline silica in mice, it was demonstrated that that the chronic fibrosis seen in a murine model of silicosis *in vivo* is dependent on the presence of adaptor molecule ASC and Nalp3 inflammazome. These data support a potential mode of action whereby silica triggers cellular responses that in turn activate alveolar macrophages, resulting in an inflammatory response and silicosis. In mice deficient in Nalp3 inflammazome, the development of inflammation and collagen deposition was significantly reduced compared with normal mice 3 months after the initial intranasal instillation of silica.

Analysis of Lung Tumour Data

The weight of evidence for both rats and humans indicates that fibrotic and silicotic lesions in the lung result from inhalation exposure to crystalline silica and that lung cancer is secondary to those lesions in the lung. Although the mechanism of induction for the lung tumours has not been fully elucidated, there is sufficient supportive mode of action evidence from the data presented to demonstrate that a threshold approach to risk assessment is appropriate based on an understanding of the key events in the pathogenesis of crystalline silica induced lung tumours. The body of evidence include the following:

- In experimental studies, all rats that developed tumours also showed fibrosis.
- Adenocarcinomas, the most common type of tumour identified in rats, are commonly associated with fibrosis and deeply scarred lung tissue.
- Experimental rat studies showed a clear progression of the effects from initially mild inflammation, followed by fibrosis over-time, leading eventually to lung tumours.
- Tumours are not present in all treated species dosed in the same way.
- The tumours, both in rats and humans, are concentrated in the lungs only, although other organs are indirectly exposed.
- In human studies, cancer risk is often more significant in workers exposed over a 20 year period or to higher cumulative exposure levels; however a consistent finding is that the onset of silicosis, requires a smaller lag period than that for the appearance of tumours.
- Similarly, cancer risk is often more significantly associated at higher quintiles of exposure compared to the lower quintiles
- Lung cancer rates are higher in workers confirmed to have silicosis versus similarly exposed workers that do not have silicosis.
- For genotoxicity, in vitro results were mostly mixed and in vivo results were mostly positive. However, the vast majority of the positive genotoxicity assay results can be explained by the generation of reactive oxygen species, as demonstrated experimentally, where ROS scavenging prevents the genotoxicity.
- *In vivo*, macrophage deficient mice (macrophages produce ROS in response to crystalline silica) do not develop silicosis nor do they develop tumours and the Nalp3 inflammazome, a key player in the macrophage initiated inflammatory response, is required for the development of pulmonary fibrosis after

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inhalation of silica.

- Though inhalation exposure to crystalline silica in multiple occupational settings is clear, the increase in risk, based on the several recent meta-analyses of the multiple human epidemiological studies, remains low.

It is worth noting that where aggressive engineering controls have been made to reduce silica dust levels in the workplace (Sweden), silicosis has been eliminated. By corollary, existing exposures outside of the workplace in such areas do not pose a risk for silicosis to the general population.

The respirable forms of quartz and cristobalite possess properties indicating a hazard for human health (repeated dose toxicity, carcinogenicity and genotoxicity). The mode of action in the lungs involves irritation, inflammation and reactive species formation, leading to silicosis, and eventually to tumour formation.

Exposure

Uses

Consistent with oxygen and silicon being the two most abundant elements in the Earth's crust, silicon-oxide minerals, including quartz are ubiquitous in the natural environment. In particular, as a component of sand, quartz may find use in a diverse array of applications. Several high volume uses include, but are not limited to, the use of sand as a filling material for the construction of roads and in general building activities, the use of sand and gravel aggregates as abrasives on roads in winter and the use of fly-ash, which may contain 4-14% quartz and 0.5-1% cristobalite, as a cement additive. These abrasives when used on winter roads are usually mixed with road salts and may be sand only, stone dust, sand and gravel aggregates, or pre-treated sand. They are used mainly by rural municipalities or in areas where cold temperatures diminish the efficiency of salts for de-icing. Quantities of abrasives used in Canada were 5.73×10^9 kg, 4.59×10^9 kg, and 4.93×10^9 kg for 2007, 2008 and 2009, respectively.

Industrial sand, high purity silica sand products with closely controlled sizing are expected to contain quartz and cristobalite, include lump silica (2-3mm up to 15 cm or more), silica sand (75µm to 2-3mm) and silica flour (less than 75µm). Lump silica may be used in the production of silicon alloys, silica bricks, and the linings of certain types of pulverizers (eg. ball mills and tube mills).

Silica sand may be used in the manufacture of glass and glass fibres, silicate chemicals and silicon carbide, the hydraulic fracturing of wells, foundry moulding, and for sandblasting. Silica flour may find use in the ceramics and cement industries, as a filler and extender in rubber and coatings, and as an abrasive in soaps.

Natural clays, such as bentonite and fuller's earth, are used in cat litters for their high water absorbance capacities. Quartz is a natural component of these clays, and consequently, it may be present in cat litter products. High purity α-quartz is a piezoelectric material, which means that application of a voltage induces a distortion in the crystal shape and vice versa. This ability to interconvert electrical and mechanical energy has led to the use of quartz crystals in electronic devices requiring precise timing control, for example telephones, radios, watches and computers.

According to a survey conducted in Canada, quartz and cristobalite are also used in abrasives, adsorbents, filter products (diatomaceous earth), grout and cement. These substances reportedly also find use as fillers, which add bulk and improve wear resistance, in paints and coatings, adhesives, sealants, polymer films, caulking, epoxy resins and silicones. Also, quartz is listed as an ingredient in 60 cosmetic products in Canada. The types of products include anti-wrinkle preparation, eye and face makeup, lipstick, hair dyes, shampoos and grooming products, as well as skin cleansers, moisturizers and tanning preparations.

Natural Sources

In Canada, quartz naturally occurs in many types of rock formations. Those with high silicon dioxide content (95% SiO_2 or more) include vein and massive intrusion bodies, quartz pebbles, silica sand, sandstone and quartzite. Sandstone is a sedimentary rock mostly composed of quartz grains cemented by a bonding material such as clay, calcite or iron oxide. Quartzite is a hard, compact, metamorphosed sandstone made of grains of quartz firmly bonded with a siliceous cement. Mineral aggregates (e.g., sand and gravel) have variable silicon dioxide content. Quartz is also found as crystals, aggregates or discrete particles in certain igneous rocks (e.g., granites and pegmatites), soils, sediments, air and surface water. This omnipresence is consistent with the fact that silicon is the second most abundant chemical element on Earth.

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Cristobalite is naturally produced in the ashes of volcanic eruptions, and by combustion metamorphism which is a local phenomenon of spontaneous combustion of naturally occurring substances such as bituminous rocks, coal or oil. It may be found in cavities in volcanic rocks and in thermally metamorphosed sandstones and may also be a transient stage in the diagenesis of diatomaceous shale with the result that soils made of these geologic formations may be rich in cristobalite. Unlike quartz, the natural occurrence of cristobalite is limited to specific geographic regions and mineral types.

Anthropogenic Sources

Natural quartz is isolated from ore via beneficiation, which involves milling or grinding the material into particles that are separated into desired mineral and waste. The materials obtained are either used directly or further purified. In Canada, in 2006, 2.146×10^{9} kg of pure quartz were mined, and 2.385×10^{11} kg of sand and gravel aggregates were produced. The proportion of quartz in silica sand deposits and gravel aggregates will vary from one site to another.

Cristobalite can form from silica melts during the preparation of silica glass; quartz is not obtained from melts but is manufactured at elevated temperature and pressure via a hydrothermal process. Cristobalite also forms during the calcination[2] of diatomaceous earth.

Human Exposure Estimate

Ambient air

The exposure assessment is focussed on respirable quartz and cristobalite, which in ambient air comprises a component of total particulate matter (PM). In Canada, data on the concentrations of silicon in PM was available and used as a surrogate for quartz and cristobalite. This approach is conservative because the measured silicon includes all silicon-containing substances and therefore represents the upper limit for quartz and cristobalite in ambient air.

The National Air Pollution Surveillance (NAPS) Program measured concentrations in $\mu g/m^3$ of silicon in PM with aerodynamic radii less than 2.5 µm ($PM_{2.5}$ (dichot)), and from 2.5 to 10 µm (PM_{10} (dichot)) (the total particulate matter with aerodynamic radii less than 10 µm (PM_{10}) is obtained by adding these values) in Canada. In 2009, as part of the NAPS Program, silicon concentrations were determined on over 1600 samples of $PM_{2.5}$(dichot) and over 1500 samples of PM_{10}(dichot) at 24 urban locations across Canada. An estimate of exposure to quartz and cristobalite can be obtained by assuming that all the silicon in the PM is represented stoichiometrically as SiO_2, and multiplying the reported concentration of silicon by 2.14 to obtain a value for silica.

The intake of respirable quartz and cristobalite by the general population of Canada is estimated using a range covering the lowest 50^{th} percentile SiO_2 concentration in PM_{10}, measured in Pt. Petre, ON, (0.12 $\mu g/m^3$) to the highest 50^{th} percentile concentration in PM_{10} measured in Calgary, AB (2.1 $\mu g/m^3$). The 50^{th} percentile SiO_2 concentrations ranged from 0.1 to 2.1 $\mu g/m^3$ across the survey sites; the top of this range is quite close to the average of the maximum values for the 24 sites (3.7 $\mu g/m^3$). The outdoor data were used to represent the indoor levels, because information on indoor silicon concentrations was not available, and the range of PM_{10} measured indoors is generally lower than the outdoor range. Thus, this approach conservatively overestimates indoor exposure in homes.

The highest exposure group based on these calculations is children ages 0.5 to 4 years with an estimated daily intake ranging from 0.07 to 5.26 µg/kg-bw per day; the estimated daily intake decreases with age due to changes in the ratio of inhalation rates to body weights; the daily intake of adults, 20-59 years old, is estimated to range from 0.03 to 2.00 µg/kg-bw per day.

Consumer Products

Exposure to respirable quartz from the use of cosmetic products, which contained quartz as an ingredient, was considered low because they are not formulated for spray application, the loose powders were reported to contain less than 0.1% quartz, and in these products the substance is not expected to be associated with other components of the formulation and not available in a free form.

For consumer Do It Yourself (DIY) activities around the home, the highest mean breathing zone concentration of particles from sanding dry wall (median cut-point of 10µm) of 6.31 mg/m^3, was used to derive an upper-

[2] Calcinations: Heat treating a substance, but without fusion, to bring about change in its physical or chemical constitution.

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bound exposure estimate ranging from 2 to10 µg/kg-bw per event.

Quartz is used to formulate a large number of paints and coatings. To estimate potential inhalation exposure to quartz from these products, the spray painting of wall paints with an airless spray gun was considered appropriate as a conservative scenario. Exposure to respirable paint particles was estimated using data from controlled a laboratory study in which walls of poorly ventilated test rooms were painted by professional painters using an airless sprayer to apply interior latex paint. The maximum concentration of 13% quartz in paint in Canada was used to estimate exposure. The upper-bound estimate of exposure to quartz, based on the maximum concentration of 13% quartz in paint in the Canadian market and the maximum concentration of respirable paint particles measured in these controlled studies when recommended personal protective equipment is used, is 0.954 µg/kg-bw per event.

Inhalation of ambient air containing quartz and cristobalite is the dominant pathway of chronic exposure (excluding that from DIY activities) for the general population. Because SiO_2 makes up only approximately 5% of PM_{10}, silicon concentrations (expressed as SiO_2) measured in the Canadian NAPS survey of 24 urban locations were considered most relevant to the estimation of exposure by the general population. Quartz and cristobalite comprise only a portion of the total SiO_2 in PM_{10}, therefore, the use of the total silicon concentration to represent the upper bound crystalline silica concentrations results in an overestimation of exposure.

Appendix 1: Definitions of Epidemiological Terms in the ITAP

SMR (Standardized Mortality Ratio): The ratio (x 100) of observed to expected deaths in a study population. Expected deaths are calculated by applying a set of standard age-specific mortality rates to the age distribution of the study population. Standardized ratios are only useful for comparisons. They have no intrinsic meaning.

OR (Odds Ratio): In epidemiological case-control studies, a relative measure of disease occurrence. The odds in favour of a particular disease occurring in an exposed group are divided by the odds in favour of its occurring in an unexposed group. If the condition being studied is rare, the odds ratio is a close approximation to the relative risk.

RR (Risk Ratio): The probability of the occurrence of a disease in a group that has been exposed to some environmental, medicinal, microbial, or toxic influence, relative to its probability in a randomly selected population.

PMR (Proportionate Mortality Ratio): Proportionate mortality is the proportion of deaths in a specified population over a period of time attributable to different causes. Each cause is expressed as a percentage of all deaths, and the sum of the causes must add to 100%. These proportions are not mortality rates, since the denominator is all deaths, not the population in which the deaths occurred. Thus, proportionate mortality ratio is a measure of the frequency of occurrence of the proportionate mortality in a defined population during a specified interval of time.

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Toxicity Profile

Magnesium chloride
(CAS No. 7786-30-3)

Acute Toxicity

The oral LD_{50} of magnesium chloride hexahydrate in rats is >2,000 mg/kg. The dermal LD_{50} of magnesium chloride hexahydrate in rats is >2,000 mg/kg.

Irritation

Magnesium chloride hexahydrate was applied topically to the EPISKIN-SM™ for 15 min followed by a 42 hour post-incubation period and immediate determination of cytotoxic effects via MTT reduction assay. The test item showed no irritant effects.

Single ocular instillation of magnesium chloride hexahydrate to rabbits at a dose of 0.1 g produced irritant effects, which were fully reversible within 6, 4 and 2 days post-instillation in animal no. 1, 2 and 3, respectively. Based on these findings, magnesium chloride hexahydrate is not an eye irritant.

Sensitization

Magnesium chloride hexahydrate was not a skin sensitizer when tested in guinea pigs.

Repeated Dose Toxicity

In an OECD 422 study, Wistar rats at dosages of 250, 500 and 1,000 mg/kg magnesium chloride hexahydrate revealed no major toxicological findings. The cause of death of animals during the conduct of the study could not be determined (a plausible cause may be gavage error or regurgitation). The NOAEL for this study is 1,000 mg/kg/day.

Groups of 50 male and 50 female B6C3F_1 mice were given magnesium hexahydrate at dose levels of 0, 0.5% and 2% in the diet for 96 weeks, after which all animals received the control diet for 8 weeks and were then necropsied. In the 2% females, a decrease in body weight was observed. However, survival rates did not differ between the treatment and control groups for males or females and clinical signs and urinary, hematological or serum clinical chemistry parameters showed no treatment-related effects. Therefore, this change was considered not to be of biological significance. The NOAEL for female and male mice was 2% in feed, which corresponded to 3,930 and 2,810 mg/kg/day, respectively.

Genotoxicity

Magnesium chloride was not genotoxic in the *in vitro* mouse lymphoma assay and in the *in vitro* chromosomal aberration assay using human lymphocytes.

Carcinogenicity

Male and female $B6C3F_1$ mice were given in their fed 0, 0.5% or 2% magnesium chloride hexahydrate for 96 weeks, after which all animals received the control diet for 8 weeks and were then necropsied. Tumors were mainly found in the skin/subcutis, liver and lymphatic system. With the exception of a significant decrease in the incidence of liver tumors among the 2% males, there were no differences in the tumor incidences between the treated and control animals.

Reproductive/Developmental Toxicity

In an OECD 422 study, Wistar rats at dosages of 0, 250, 500 or 1,000 mg/kg showed no treatment-related reproductive or developmental effects. The NOAEL for this study is 1,000 mg/kg/day.

Key Study/Critical Effect for Screening Criteria

The Australian drinking water guideline value for chloride may apply to magnesium chloride.

Reference

ECHA REACH database: http://apps.echa.europa.eu/registered/registered-sub.aspx

Toxicity Profile

Magnesium nitrate
(CAS No. 10377-60-3)

Acute Toxicity

The acute oral LD_{50} in rats is >5,000 mg/kg.

Irritation

No studies are available.

Sensitization

Magnesium nitrate is not a skin sensitizer based on results of a Local Lymph Node Assay (LLNA).

Repeat Dose Toxicity Studies

No studies are available.

Genotoxicity

Magnesium nitrate hexahydrate is not mutagenic in the *Salmonella typhimurium* reverse mutation assay and in the *Escherichia coli* reverse mutation assay.

Carcinogenicity

No data are available.

Reproductive Toxicity

No data are available.

Developmental Toxicity

No data are available.

Key Study/Critical Effect for Screening Criteria

The Australian drinking water guidance value for nitrates may apply to magnesium nitrate.

Reference

ECHA REACH database: http://apps.echa.europa.eu/registered/registered-sub.aspx

Toxicity Profile

Vinylidene chloride/methacrylate copolymer (CAS No. 25038-72-6)

No toxicity information exists for this substance.

As a polymer, vinylidene chloride/methacrylate copolymer is not expected to be absorbed by the oral, dermal or inhalation routes of exposure due to its large molecular weight. It is also expected to be stable in biological media and resistant to metabolism.

This polymers are expected to be essentially acutely non-toxic by the oral, dermal and inhalation routes of exposure. Under certain conditions, dusts may be formed, which is to be considered as a nuisance dust. The polymers are expected to be non-irritating and not dermal sensitizers.

Toxicity Profile

Sodium Carboxymethyl Cellulose
(CAS No. 9004-32-4)

Sodium carboxycellulose is the sodium salt of carboxymethylcellulose. Carboxymethyl cellulose is a cellulose derivative with carboxymethyl groups (-CH_2COOH) bound to some of the hydroxyl groups of the glucopyranose monomers that make up the cellulose backbone.

Sodium carboxycellulase is a listed as GRAS (Generally Regarded as Safe) by the U.S. Food and Drug Administration (FDA GRAS database).

It is an approved food additive in the EU (EC, 1995) and may be added to all foodstuffs following *quantum satis* principle, except in products for the dietary management of metabolic disorders, where the limit of use is 10 g/L or kg (EC, 1999).

The Joint FAO/WHO Expert Committee on Food Additives has determined an Acceptable Daily Intake (ADI) for sodium carboxymethyl cellulose of "Not Specified" (no upper limit) (JECFA, 1989).

References

EC (1995). European Parliament and Council Directive No 95/2/EC of 20 February 1995 on food additives other than colours and sweeteners, OJ L 61, 18.3.1995, p. 1-63.

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FDA GRAS Database:
http://www.fda.gov/Food/IngredientsPackagingLabeling/GRAS/SCOGS/ucm260737.htm

JECFA (1989).
http://apps.who.int/ipsc/database/evaluations/chemical.aspx?chemID=3773

Toxicity Profile

Talc
(CAS No. 61789-40-0)

Talc refers to both mineral talc and industrial mineral products that are marketed under the name talc and contain proportions of mineral talc that range from about 35% to almost 100%. Industrial talc generally refers to products that contain abundant minerals other than talc; cosmetic talc now normally contains >98% talc but the content may have been lower in the past. Pharmaceutical talc contains >99% talc. Talcum powder is cosmetic-grade talc.

Talc is a mineral composed of hydrated magnesium silicate with the chemical formula $Mg_3Si4O_{10}(OH)_2$ or $H_2Mg_3(SiO_3)_4$. Talc is not soluble in water.

The U.S. Food and Drug Administration (FDA) regulates talc and states that it is generally recognized as safe for use in color additives in foods, drugs and cosmetics, and in paper, paper products, cotton and cotton fabrics that come into contact with food. The Food Chemical Codex (2003) provides specifications for food-grade talc, including the statement that "talc derived from deposits that are known to contain associated asbestos is not food grade." Under the voluntary guidelines initiated in 1976, the Cosmetic, Toiletry, and Fragrances Association stated that all cosmetic talc should contain at least 90% platy talc (hydrated magnesium silicate) that is free from detectable amounts (<0.5%) of fibrous, asbestos minerals.

Toxicokinetics (Oral)

The absorption and disposition of ^{3}H-labeled talc in rats, mice, and guinea pigs administered a single oral dose was studied by Phillips *et al*. (1978). The oral doses were 50 mg/kg for rats, 40 mg/kg for mice, and 25 mg/kg for guinea pigs. In rats, mice, and guinea pigs, more than 95% of the dose was excreted in the feces 3 to 4 days after dosing. Less than 2% of the radioactivity was recovered in the urine. This radioactivity probably reflected contamination of urine samples with feces. No radioactivity was found in the liver or kidneys of these animals. This information suggests that talc is not absorbed from the gastrointestinal tract following oral exposure.

Acute Toxicity

No data were located.

Repeated Dose Toxicity/Carcinogenicity

Male and female Wistar rats were given in their diet 0 or 50 mg/kg of commercial talc

[characteristics unspecified] for the life of the animals (average survival was 702 and 649 days, respectively). There was no significant difference in the talc-fed animals compared with control animals (Gibel *et al.*, 1976).

Male and female Wistar-derived rats were given in their diet 100 mg Italian talc (grade 00000; ready milled; mean particle size, 25 μm; containing 92% talc, 3% chlorite, 1% carbonate minerals and 0.5–1% quartz) per rat per day for 5 months (talc-containing diet was actually given for 101 days) and were then maintained on basal diet for life (average survival, 614 days). No differences in tumor incidence were noted between treated animals and control animals (eight/sex for an average survival of 641 days) (Wagner *et al.*, 1977).

In humans and experimental animals, the effects of talc are dependent on the route of exposure, and the dose and properties of the talc. Talc pneumoconiosis was somewhat more prevalent and severe among miners exposed to talc containing asbestiform minerals and/or asbestos than among those exposed to talc without such contaminants. However, the role of quartz and asbestos in the observed pneumoconiosis could not be ruled out. Among drug users, intravenous injection of talc present as a filler in the drugs resulted in microembolization in a variety of organs and alterations in pulmonary function. In animal studies, talc has been shown to cause granulomas and mild inflammation when inhaled. Observations of the effects that occurred in the lungs of rats exposed by inhalation to talc suggested that the operative mechanisms may be similar to those identified for carbon black, and talc is known to cause the release of cytokines, chemokines and growth factors from pleural mesothelial cells.

IARC: There is *inadequate evidence* in humans for the carcinogenicity of inhaled talc not containing asbestos or asbestiform fibres. There is *limited evidence* in experimental animals for the carcinogenicity of talc not containing asbestos or asbestiform fibres. Inhaled talc not containing asbestos or asbestiform fibres is *not classifiable as to its carcinogenicity (Group 3)*.

Genotoxicity

The IARC (1987) review of talc included unpublished results from a 1974 study conducted by Litton Bionetics that showed no mutagenic activity for talc *in vitro* or *in vivo*. Talc did not induce mutations in *Salmonella typhimurium* strains TA1530 or HisG46, or in the yeast, *Saccharomyces cerevisiae***.** No chromosomal aberrations were observed in human fibroblasts treated with talc *in vitro*. *In vivo* tests conducted in rats gave negative results for induction of chromosomal aberrations in bone marrow cells and dominant lethal mutations in germinal cells.

Three samples of respirable talc failed to elicit significant unscheduled DNA synthesis (10, 20 and 50 μg/cm^2, 24 hours), sister chromatid exchange or aneuploidy (2, 5, 10 and 15 μg/cm^2, 48 hours) in rat pleural mesothelial cells, in contrast to various positive controls. The three samples, *i.e.* Spanish talc (No. 5725), Italian talc (No. 5726) and French talc (No. 7841), contained 90–95% talc; the remaining contents were chlorite and dolomite. Electron microscopy analysis revealed that talc

particles were taken up by the rat pleural mesothelial cells, but no aneuploidy was observed in metaphases (Endo-Capron *et al.*, 1993).

Reproductive Toxicity

No data are available.

Developmental Toxicity

No teratologic effects were observed in hamsters, rats, mice, or rabbits after oral administration of talc. The doses used were 1,600 mg/kg for rats and mice on days *6* through 15 of gestation; 1,200 mg/kg for hamsters on day 6 through 10 of gestation; and 900 mg/kg for rabbits on days 6 through 18 of gestation.

Key Study/Critical Effect for Screening Criteria

There are no adequate studies for which to derive a oral reference dose. Talc is poorly absorbed from the gastrointestinal tract, if at all, and the limited data available by the oral route indicate that talc is essentially non-toxic by the oral route of exposure.

References

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Toxicity Profile

Triethanolamine
[2,2′,2′′-nitrilotriethanol]
(CAS No. 102-71-6)

Acute Toxicity

The oral LD_{50} in rats is 6,400 mg/kg (ECHA), and the dermal LD_{50} in rabbits is >2,000 mg/kg (ECHA). No deaths seen in rats following an 8-hour exposure to a saturated vapor atmosphere [approximately 1.8 mg/m^3] (ECHA).

Irritation

Triethanolamine is not a skin irritant to rabbits when applied for 4 hours under occluded conditions (ECHA). It is not irritating to the eyes of rabbits (Griffith *et al.*, 1980; ECHA).

Sensitization

Triethanolamine was not considered a skin sensitizer when tested in a guinea pig maximization test (ECHA).

Repeated Dose Toxicity (Oral only)

Male and female Cox CD rats were fed in their diet 0, 250, 500 or 1,000 mg/kg triethanolamine for 91 days (ECHA). There were no effects that were considered treatment-related. The NOAEL for this study is 1,000 mg/kg-day.

Genotoxicity

Triethanolamine was not mutagenic to *S. typhimurium* strains TA1535, TA1537, TA97, TA 98 or TA100 in the absence or presence of metabolic activation (Mortelsman *et al.*, 1986). Nor was triethanolamine mutagenic in mouse lymphoma L5178Y cells in the absence or presence of metabolic activation (ECHA). Triethanolamine did not increase sister chromatid exchanges (SCEs) or chromosomal aberrations in Chinese Hamster Ovary (CHO) cells in the absence or presence of metabolic activation (Galloway *et al.*, 1987).

Male and female $B6C3F_1$ mice were given dermal applications of triethanolamine, 5 days/week for 13 weeks (NTP, 2004). There were no increase in the frequency of micronucleated erythrocytes in the peripheral blood.

Triethanolamine did not induce sex-linked recessive lethal mutations in germ cells of adult male *Drosophila melanogaster* exposed by feeding or injection (Yoon *et al.*, 1985).

Carcinogenicity

Male and female B6C3F_1 mice were given in their drinking water 0, 1 or 2% triethanolamine (0 and approximately 1,600 and 3,200 mg/kg-day) for 82 weeks. (Konishi *et al.*, 1992). Mortality, organ weights and tumor incidences were similar between treated and control animals.

Male and female F344 rats were given dermal applications of triethanolamine, 5 days/week for two years (NTP, 1999). The doses were: 0, 32, 63 or 125 mg/kg-day for males, and 0, 63, 125 or 250 mg/kg-day for females. There were no treatment-related carcinogenic effects in either sexes.

Male and female B6C3F_1 mice were given dermal applications of triethanolamine, 5 days/week for two years (NTP, 2004). The doses were: 0, 200, 630 and 2,000 mg/kg-day for males, and 0, 100, 300 and 1,000 mg/kg-day for females. In females, there was some evidence of carcinogenicity activity based on increased incidences of hepatocellular adenomas. In males, there was equivocal evidence of carcinogenicity activity based on the incidence of liver hemangiosarcomas.

Reproductive/developmental Toxicity

In a reproductive and developmental toxicity screening (OECD 421) study, male and female Wistar rats were dosed by oral gavage with 0, 100, 300 or 1,000 mg/kg-day triethanolamine (ECHA). Most of the 1,000 mg/kg-day animals and one 100 mg/kg-day animals showed transient salivation for a few minutes immediately after each treatment. This effect was considered to be induced by the unpalatability of the test substance or from local irritation of the upper digestive tract. Body weight gain was slightly lower in the 1,000 mg/kg-day females during gestation and was considered to be caused by the increased postimplantation loss rather than by a systemic effect of the test substance. In the 1,000 mg/kg-day group, there were lower mean number of implantation sites, increased postimplantation loss, and lower average litter size. There were no treatment-related effects in the F_1 pups. The NOAEL for systemic toxicity is 1,000 mg/kg-day. The NOAEL for reproductive toxicity is 1,000 mg/kg-day. The NOAEL for developmental toxicity is 300 mg/kg-day.

Key Study/Critical Effect for Screening Criteria

There were no adverse effects in male or female rats given 1,000 mg/kg-day in the diet, the highest dose tested, for 91 days (ECHA). The NOAEL for this study is 1,000 mg/kg-day.

Oral RfD = 1,000/1,000 = 1.0 mg/kg/day

Drinking water guideline value = 3.5 ppm

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Santos

APPENDIX F.8 HALLIBURTON – WELL RM 08-14-3

Toxicity Profile

Acetic acid
(CAS No. 64-19-7)

Acetic acid dissociates in aqueous media to H^+ and the acetate anion ($CH_3CO_2^-$). It is naturally occurring as the acid in apple cider vinegar and other fruit-derived products. It and several of its salts are commonly used as food additives (*e.g.*, as flavor enhancers) and are listed as Generally Recognized as Safe (GRAS) by the U.S. Food and Drug Administration (FDA).

pH: 2.5 at 50 g/L and 20°C
pK_a: 4.76 @ 20°C

Acute Toxicity

The oral LD_{50} in rats is 4,950 mg/kg, and the dermal LD_{50} in rabbits is 1,060 mg/kg. The 4-hour LC_{50} in rats is 11.4 mg/L.

Irritation

In the EU, acetic acid is classified as a skin and eye irritant at concentrations <25%. At ≥25%, it is classified as corrosive to the skin.

Sensitization

No data are available.

Repeated Dose Toxicity

In an 8-month study, rats dosed with 60 mg/kg acetic acid (three times per week) developed hyperplasia in the esophagus and forestomach.

Genotoxicity

Acetic acid was not mutagenic to *Salmonella typhimurium* strains TA 98, TA 100, TA 1535, TA 1537, and TA 1538 in an *in vitro* bacterial mutation assay with or without metabolic activation. Acetic acid (in media adjusted to a pH of 8.5) was also not genotoxic in an *in vitro* chromosomal aberration test using Chinese Hamster Ovary cells with or without metabolic activation.

Carcinogenicity

No adequate carcinogenicity studies have been conducted on acetic acid.

Reproductive Toxicity

No studies could be located.

Developmental Toxicity

There were no effects on implantations or on maternal or fetal survival in mice, rats, or rabbits at doses up to 1,600 mg/kg.

Key Study/Critical Effect for Screening Criteria

There are no repeat dose toxicity studies that were considered adequate for human health risk assessment. The only study reported on the toxicity of acetic acid by oral gavage showed effects of irritation (probably due to the pH of acetic acid) at the site of contact in the gastrointestinal tract. No systemic effects were reported.

The Joint FAO/WHO Expert Committee on Food Additives (JECFA) has maintained a group ADI of "not limited" for acetic acid and its potassium and sodium salts.

The Australian drinking water guidance value for pH may apply to acetic acid.

References

ECHA REACH: http://apps.echa.europa.eu/registered/registered-sub.aspx

JECFA: http://apps.who.int/ipsc/database/evaluations/chemical.aspx?chemID=4785

U.S. EPA HPVIS database: http://www.epa.gov/chemrtk/hpvis/index.html

Toxicity Profile

Amorphous/Non-crystalline Silica
(CAS No. 7631-86-9[1])

Silica Gel
(CAS No. 112926-00-8)

Amorphous silica and silica gel have been reviewed in the OECD-SIDS program (OECD, 2004a,b).

The CAS No. 7631-86-9 is the general CAS No. for silicon dioxide which includes all forms of silicas (*e.g.* also crystalline and natural forms). Only the silica sub-classes, the synthetic amorphous silicas, are the subject of this assessment.

Synthetic amorphous silicas (SAS) are in powder form which have a low water solubility: ≤70 mg/L

Toxicokinetics

After oral ingestion, there is no accumulation of SAS in body tissues. Rapid elimination occurs after the end of exposure. Intestinal resorption appears to be insignificant in animals and humans.

After daily oral administration of 1,500 mg/kg SAS (FK 700) as aqueous suspension to rats for one month, there was no accumulation of SiO_2 in the body: the average SiO_2 content was: 1.5 µg in the liver, 6.4 µg in the kidney, and 5.3 µg in the spleen. The corresponding control values were 1.8, 7.2 and 7.8 µg SiO_2, respectively.

In a similar experiment in rats receiving 20 daily oral doses of 100 mg SAS (HDK V15) per animal (about 500 mg/kg) each, tissue values were slightly increased in liver and kidney: in liver 4.2 µg (control value 1.8 µg), in the spleen 5.5 µg (7.2 µg) and in the kidneys 14.2 µg (7.8 µg).

In 12 human volunteers, no significant increased renal excretion of SiO_2 was found following single oral ingestion of 2,500 mg (AEROSIL 175 and FK 700).

Acute Toxicity

The acute oral administration of various forms of SAS (aqueous suspension or gel) failed to produce signs of toxicity or deaths in treated animals with LD_{50} values greater than the top doses applied, either by gavage: >3100 to >20000 mg/kg in mice and rats; or in the diet for 24 hours.

Irritation

Synthetic amorphous silicas are not irritating to the skin of rabbits exposed to 0.19 g (one case) or 0.5 g of dry or moistened test item under occlusive conditions for 4 or 24 hours. All products tested as a powder (0.1 g) have shown no or only weak and transient irritating effects on the conjunctivae of the eyes of rabbits with the iris and cornea not affected at all.

Sensitization

No experimental data are available on the synthetic amorphous silicas. Medical surveillance records on workers gave no evidence of skin sensitization over decades of practical experience.

Repeated Dose Toxicity/Carcinogenicity

Fischer rats and $B6C3F_1$ mice were administered SAS in the diet at levels of 0, 1.25, 2.5, and 5% for 102 weeks. The animals were in good condition throughout and showed high survival. The tumor responses in all organs of SAS-fed rats and mice were not statistically significantly different from the controls. The NOAEL for rats and mice were 2,500 and 6,500 mg/kg-day, respectively.

Genotoxicity

There is no evidence for synthetic amorphous silica to induce mutations either *in vitro* or *in vivo* using standard genotoxicity tests.

Reproductive Toxicity

An early limited one-generation study on rats gave no evidence of adverse effects on reproduction performanc*e* at 500 mg/kg-day, the highest dose tested (NOAEL). But the reliability is poor due to the small group size of animals.

Developmental Toxicity

SAS was examined for embryotoxic and developmental effects during the gestation phase in various animals species, rat, mouse, rabbit and hamster, at oral doses up to 1,600 mg/kg-day. There were no significant signs of maternal or embryotoxic/developmental

toxic effects in any species tested. The number of abnormalities seen in either soft or skeletal tissues of the test groups did not differ from the frequencies occurring spontaneously in the control animals.

Key Study/Critical Effect for Screening Criteria

The lowest NOAEL from the two-year dietary study was 2,500 mg/kg-day for rats.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD = 2,500/100 = 2.5 mg/kg-day

Drinking water guidance value = 0.09 ppm

References

OECD (2004a). IUCLID Data Set for Synthetic Amorphous Silica and Silicates: Silicon Dioxide (CAS No. 7631-86-9, 112945-52-5, 112926-00-8; Silicic Acid, Aluminum Sodium Salt (CAS No. 1344-00-9); Silicic Acid, Calcium Salt (CAS No. 1344-95-2), UNEP Publications.

OECD (2004b). Screening Information Dataset (SIDS) Initial Assessment Report for Synthetic Amorphous Silica and Silicates: Silicon Dioxide (CAS No. 7631-86-9, 112945-52-5, 112926-00-8; Silicic Acid, Aluminum Sodium Salt (CAS No. 1344-00-9); Silicic Acid, Calcium Salt (CAS No. 1344-95-2), UNEP Publications.

Toxicity Profile

Diethanolamine
(CAS No. 111-42-2)

Pharmacokinetics/Metabolism

The disposition of diethanolamine varies across species, is dose-dependent, and is characterized by a relatively long elimination (Mathews *et al.* 1995; Mendrala *et al.* 2001). Absorption of diethanolamine applied dermally in rats varies with dose, ranging from 3 to 16% at 2 and 28 mg/kg, respectively (Mathews *et al.* 1997). In mice, doses ranging from 8-80 mg/kg were more readily absorbed through the skin (25-60%) in 48 hours. Once absorbed, diethanolamine shows a biphasic clearance from the blood, with a rapid initial phase (half-life of about 0.1 hours) followed by a prolonged phase (half-life of about 7 days) (Mendrala *et al.* 2001). The long elimination half-life is consistent with its accumulation in the live and kidney attributed to incorporation of diethanolamine into phospholipids (Mathews *et al.* 1995).

Acute Toxicity

The acute oral LD_{50} values range from 780 to 3,540 mg/kg in rats; 3,300 to 4,570 mg/kg in mice; and 2,200 mg/kg for rabbits and guinea pigs (OECD 2007).

A dermal LD_{50} value of 13,000 mg/kg in rabbits was reported (OECD 2007). No detailed information is given in the study report and it is unclear if diethanolamine was neutralized before testing. Repeated dermal exposure in rats with diethanolamine that was un-neutralized and formulated in ethanol induced higher toxicity with mortalities at $\geq$100 mg/kg after a few days of daily exposure.

No deaths were seen in rats after an 8-hour exposure to an atmosphere enriched with diethanolamine vapor (OECD 2007). In diethanolamine aerosol exposure studies from 1.5 to 4 hours and concentrations ranging from 30 to 1,476 ppm, deaths were seen in 5/8 rats after 105 minutes at 6.5 mg/L, but there were no deaths after exposure to 768 ppm for 4 hours (OECD 2007).

Irritation

Diethanolamine is a skin and severe eye irritant in rabbits and caused upper respiratory tract irritation in subchronic studies in rats (OECD 2007).

Sensitization

Diethanolamine was not a skin sensitizer when tested in a guinea pig maximization test (OECD 2007). Information from human use tests with cosmetic products containing diethanolamine in concentrations up to 2.7% or from an insufficiently documented human maximization test suggests that diethanolamine has no sensitizing potential humans (OECD 2007).

Repeated Dose Toxicity (Oral Studies Only)

Male and female F344 rats were given diethanolamine in their drinking water at concentrations of 0, 320, 630, 1,250, 2,500, or 5,000 ppm for males (0, 25, 48, 97, 2,202, or 436 mg/kg-day) or 0, 160, 320, 630, 1,250, or 2,500 ppm for females (0, 14, 32, 57, 124, or 242 mg/kg-day) for 13 weeks. In the top dose group, 2/10 males died during the study. Weight gain was reduced in the ≥630 ppm males and the ≥320 ppm females. A dose-dependent microcytic anemia was seen in all dose groups for both sexes. Relative kidney weights were increased in the ≥320 ppm males and ≥160 ppm females, accompanied by increases in the incidence and/or severity of nephropathy, renal tubular cell necrosis, or tubular mineralization (≥1,250 ppm males, ≥160 ppm females). Relative liver weights were increased in the ≥630 ppm males and ≥320 ppm females, with no corresponding histopathological changes in the liver. Decreases in testis and epididymis weights (≥1,250 ppm) were associated microscopically with degeneration of seminiferous epithelium and with hypospermia (≥2,500 ppm). Testicular degeneration was diagnosed in all high-dose males and in 3/10 of the 2,500 ppm males. Intraluminal cellular debris and reduced numbers of sperm cells were present in the epididymis. These findings correlated with decreases in sperm motility and sperm count per gram caudal tissue. There was also atrophy of the seminal vesicle and prostate glands in the higher dose group males. Cytoplasmic vacuolization of the adrenal cortex was seen in the 5,000 ppm males and in the ≥1,250 ppm females. Minimal to mild demyelination of the brain and spinal cord was noted in all rats at the two highest dose levels; there were no neurological clinical signs that could be attributed to these lesions. The most sensitive endpoint was the microcytic anemia, with the LOAELs of 320 ppm (25 mg/kg-day) in males and 160 ppm (14 mg/kg-day) in females (NTP 1992; Melnick et al. 1994a).

Male and female B6C3F1 mice were given diethanolamine in their drinking water at concentrations of 0, 630, 1,250, 2,500, 5,000 or 10,000 ppm (0, 104, 178, 442, 807, or 1,674 mg/kg-day for males; 0, 142, 347, 884, 1,154, or 1,128 mg/kg-day for females) for 13 weeks. All of the ≥5,000 ppm animals and 3/10 of the 2,500 ppm females died during the study. Absolute and relative liver weights were increased in a dose-dependent manner in male and female mice and was associated with increases in enzyme activities as well as with multiple morphological alterations in the liver (hypertrophy, increased eosinophilia, disruption of hepatic cords, increased nuclear pleomorphism, multinucleated hepatocytes and necrosis). Absolute and relative kidney weights were increased in males and were associated with a dose-dependent increase in the incidence of nephropathy among those mice that survived to the end of the study. Relative heart

weights were increased in the 2,500 ppm males and in the ≥1,250 ppm females, and was associated with minimal-to-marked degeneration and necrosis of cardiac myocytes at ≥2,500 ppm. Myocardial degeneration was generally more severe in mice that died early than in those that survived to study termination. The most sensitive endpoint was the increase in liver weights that were associated with the corresponding histopathological changes in the liver, with the LOAELs of 630 ppm (104 and 142 mg/kg-day in males and females, respectively) (NTP 1992; Melnick *et al.* 1992b).

Immunotoxicity

Female F344 rats were given oral gavage doses of 0, 50, 100, or 200 mg/kg diethanolamine for 14 days. Body weights and/or body weight changes were significantly decreased in the ≥100 mg/kg dose groups; liver and kidney weights were increased in a dose-dependent manner. A dose-dependent increase in urea nitrogen was seen in all dose groups. Erythrocytes, hematocrit, hemoglobin and reticulocytes were dose-dependently decreased. The reticulocytes were the most sensitive erythroid parameter, which was decreased at all dose levels. Besides an increase in the proliferative response to allogenic cells (MLR), several immune functional assays were decreased including the natural killer cell response and the cytotoxicity of resident macrophages. Conversely, the cytotoxicity of peptone-elicited macrophages was increased. The LOAEL was 50 mg/kg-day based on a significant decrease in reticulocyte number and increase in urea nitrogen (Munson *et al.* 1992a).

Female B6C3F1 mice were given oral gavage doses of 0, 100, 300, or 600 mg/kg diethanolamine for 14 days. There was no effect of body weights. The liver weights were increased and red blood cell count parameter were dose-dependently decreased at all dose levels. Diethanolamine treatment increased the number of B-cells, decreased the number of CD4+CD8- (18%) T-cell subsets. A dose-dependent decrease in the antibody-forming cell response to sheep erythrocytes at the high-dose was seen, as well as a decreae in the cytotoxic T-cell response at the highest effector/target ratio. The cytotoxicity of resident macrophages was decreased, but the cytotoxicity of resident macrophages stimulated with gamma interferon was not affected nor the cytotoxicity of peptone-elicited macrophages with or without stimulation. Among the three host resistance studies, a decrease in host resistance was observed to *Streptococcus pneumonia* and in the B16F10 melanoma tumor model. The LOAEL for this study was considered to be 100 mg/kg-day based on significantly reduced cytotoxic T lymphocytes (CTL) activity, an increase in tumor burden following challenge with the B16F10 melanoma tumor and a clear decrease in red blood cell parameter at the lowest dose (Munson *et al.* 1992b).

Genotoxicity

Diethanolamine did not induce reverse mutations in *Salmonella typhimurium* or *Escherichia coli* (NTP 1992, 1999; Dean *et al.* 1985; Haworth *et al.* 1983) and had no effect on gene conversion in *Saccharomyces cerevisiae* (Dean *et al.* 1985) In mammalian *in vitro* systems, diethanolamine did not induce chromosomal aberrations in rat

hepatocytes (Dean *et al.* 1985), gene mutation in mouse lymphoma cells (NTP 1992, 1999), sister chromatid exchange or chromosomal aberrations in Chinese hamster ovary cells (Loveday *et al.* 1989; NTP 1999). Diethanolamine formulated in ethanol did not induce micronuclei *in vivo* in peripheral blood erythrocytes of mice after repeated unoccluded dermal application for 13 weeks at doses clearly showing systemic availability (NTP 1992; Witt *et al.* 2000).

Carcinogenicity

Male and female F344/N rats were dosed with diethanolamine by dermal application for 104 weeks. For males, the doses were 0, 16, 32 or 64 mg/kg-day; and for females, the doses were 0, 8, 16 or 32 mg/kg-day. There was no difference in survival rates between treated and control animals. Mean body weights were lower in the 64 mg/kg-day males from week 8 to 89 and in the 32 mg/kg-day females from week 97 compared to the control animals. There was skin irritation (acanthosis, hyperkeratosis, exudation) predominantly at the site of application in the $\geq$32 mg/kg-day animals. The dosed females showed significantly increased incidences and severities of kidney nephropathy compared to the controls. The incidences of tumors was not increased in the diethanolamine -treated groups compared to those in the controls. In males, the NOAELs for local irritation and systemic toxicity was 16 and 32 mg/kg-day, respectively. In females, the LOAELs for local and systemic toxicity were 8 mg/kg-day, respectively (NTP 1999).

Male and female B6C3F$_1$ mice were dosed with 0, 40, 80 or 160 mg/kg-day diethanolamine by dermal application for 104 weeks. There was reduced survival in the treated female mice (88, 66, 66, and 46% for the 0, 40, 80 and 160 mg/kg-day groups, respectively). This was attributed to liver tumors. No differences were seen in survival rates in the treated male mice compared to the controls. Mean body weights in the 80 and 160 mg/kg-day males were lower than those in the control animals after week 88. Mean body weights in the treated female mice were lower than those of the controls from week 73 (40 and 80 mg/kg-day) and week 53 (160 mg/kg-day).

The incidence of hepatocellular adenomas and of hepatocellular adenomas and carcinomas (combined) were significantly increased in all male and female dose groups, while the incidences of hepatoblastoma was increased in the mid- and high-dose groups. In the female mice, the incidences of hepatocellular neoplasms were significantly higher in all dosed groups compared to the control. Non-neoplastic lesions were seen only in the liver of all male and female dose groups and consisted of cytoplasmic alteration, characterized by mild to moderate enlargement of centrilobular hepatocytes, and syncytial alteration, characterized by scattered hepatocytes with three or more small nuclei.

The incidence of renal tubule adenomas was also increased in males with a positive trend, but the incidences of carcinoma and hyperplasia did not follow this pattern. A step section evaluation found additional adenomas and hyperplasias in all treated male groups.

The combined analysis of single and step sections indicated a dose-related increase in the incidence of renal hyperplasia and renal tubule adenoma or carcinoma (combined), and increase in the incidences of renal tubule adenoma in male mice (NTP 1999).

Mode-of-Action for Mouse Liver Tumors

Effects of DEA on choline homeostatis

Dietary choline deficiency or deprivation induces liver tumors in rodents (Newberne *et al.*, 1982). In contrast, dietary supplementation of choline with or without methionine reduces the incidence of liver tumors in carcinogen-treated mice (Fullerton *et al.* 1990; Newberne *et al.* 1990). Diethanolamine is structurally similar to ethanolamine and choline, important endogenous precursors for normal membrane structure and function. Choline is also oxidized to betaine, an essential methyl group donor in 1-carbon metabolism. The mechanisms by which choline deficiency is thought to be carcinogenic include enhanced cell proliferation, altered methylation status, and altered signal transduction (Rogers 1995; Zeisel 1996; Zeisel and Blustjazn 1994). The development of intracellular choline deficiency as the mode of action by which diethanolamine cause the mouse liver tumors observed in the NTP bioassay is supported by the following experimental evidence:

1. B6C3F_1 mice dosed dermally with 160 mg/kg diethanolamine, 5 days/week for 2 weeks showed a marked decrease in choline metabolites and S-adenosylmethionine (SAM) levels in their livers similar to animals kept on a choline-devoid diet, indicating the development of choline deficiency. These effects were reversed following a 2-week recovery period (Lehman-MeKeeman *et al.* 2002). A significant reduction in the hepatic levels of choline metabolites, including choline, phosphocholine, and glycerophospho-choline, and SAM levels was also reported by Stott *et al.* (2000) with B6C3F_1 mice dosed in a similar regimen with diethanolamine via dermal and/or oral routes.

2. B6C3F_1 mice have a much lower ability than C57Bl/6 mice to maintain nascent methylation capacity, a characteristic that is believed to contribute to a higher spontaneous liver tumor incidence in B6C3F_1 mice (Counts *et al.* 1996). In a study by Lehman-McKeeman *et al.* (2002), choline deficiency, as evidenced by changes in phosphocholine concentrations, was produced in both strains of mice. However, unlike the B6C3F_1 mouse, diethanolamine did not alter SAM concentrations in the C57Bl/6 strain.

3. Diethanolamine is incorporated into rat liver phospholipids (Barbee and Hartung 1979; Mathews *et al.* 1995) and can alter the biosynthesis of hepatic phosphatidylethanolamine and phosphatidylcholine (PC). In cultured cells, diethanolamine inhibited cellular uptake of choline, decreased PC synthesis, and became incorporated into phospholipid fractions. These *in vitro* effects were prevented by culturing cells in the presence of excess choline (Lehman-McKeeman and Gamsky 1999).

4. Diethanolamine caused morphological transformation in Syrian hamster embryo (SHE) cell transformation assay. However, this response was prevented when SHE cells were cultured in a medium containing excess choline (Lehman-McKeeman and Gamsky 2000).

5. DNA synthesis was increased in mouse and rat, but not human, hepatocytes incubated with diethanolamine. Incubation of mouse and rat, but not human, hepatocytes in medium containing reduced choline increased DNA synthesis. Mouse and rat hepatocytes incubated in medium with excess choline reduced diethanolamine -induced DNA synthesis to control levels or below (Kamendulis and Klaunig 2005).

6. DNA hypomethylation in GC-rich promotor regions observed in primary mouse hepatocytes which have been treated with diethanolamine are similar to those caused by choline- deficient medium (Bachman *et al.* 2005).

In situ formation of N-nitrosodiethanolamine

Diethanolamine is a secondary amine and may react with a nitrosating agent under certain conditions to form N-nitrosodiethanolamine. This nitrosoamine has been shown to be mutagenic *in vitro* and cause liver tumors in rats and doses of 2 mg/kg-day and higher (ECETOC 1990). Rats given high, often toxic, oral bolus doses of diethanolamine and nitrite have shown or inferred to produce N-nitrosodiethanolamine (Preussman *et al.* 1981; Yamamoto *et al.* 1995). Studies by Stott *et al.* (2000) showed, however, that mimicking the dosing conditions in the NTP study (160 mg/kg DEA dermally) and drinking water supplemented with 170 ppm sodium nitrite to favor nitrosation did not result in N-nitrosodiethanolamine formation in the gastric contents, blood or urine of mice. The findings of Stott *et al.* (2000) suggest that the mouse liver tumors observed in the NTP bioassay were unlikely due to *in situ* nitrosamine formation.

Reproductive/developmental Toxicity (Oral Studies)

No reproductive toxicity studies have been conducted on diethanolamine by any route of exposure. In the NTP 13-week drinking water study, F344 rats were given 0, 160 (females only), 320, 630, 1,250, 2,500 or 5,000 ppm (males only) diethanolamine. All high-dose males and 3/10 of the 2,500 ppm males showed testicular degeneration; male rats in the higher dose groups also had atrophy of the seminal vesicles and prostate glands. Testis and epididymal weights in the $\geq$1,250 ppm males were decreased and were associated microscopically with degeneration of seminiferous epithelium, as well as hypospermia and reduced sperm motility in the $\geq$2,500 ppm males. The NOAEL for reproductive effects in males was 630 ppm (corresponding to 48 mg/kg-day). There were no effects noted in the female reproductive organs (NTP 1992; Melnick *et al.* 1994b).

A Chernoff-Kavlok screen was conducted on diethanolamine. Initially, four female CD-1 mice were given by oral gavage 0, 200, 380, 720, 1,370, 2,605, and 2,605 mg/kg diethanolamine during GD 6-15; a subsequent study was conducted which consisted of dosing 50 female CD-1 mice with 450 mg/kg during GD 6-15. Mortality was seen at

≥720 mg/kg, with 100% mortality in the ≥1,370 mg/kg groups. Dams dosed with ≥200 mg/kg showed clinical signs of intoxication. There was no mortality in the 450 mg/kg dams; nor was there any effect on litter size and pup birth weight, but the number of viable litters, the percent of pup survival, and pup weight gain were reduced (York *et al.* 1988).

Female SD rats were dosed by oral gavage with 0, 50, 125, 200, 250, or 300 mg/kg diethanolamine from GD 6-19. All dams in the 300 mg/kg group had to be killed early due to excessive toxicity. At 200 and 250 mg/kg, the dams exhibited either morbidity or died. Water intake was affected early in the gestation period in the 125 and 250 mg/kg dams; it was comparable to controls after GD 12. Reduced maternal body weight and weight change, as well as food intake, were seen in the ≥200 mg/kg dose groups. The ≥125 mg/kg dams had increased absolute kidney weights on postnatal day (PND) 21. There were no maternal effects in the 50 mg/kg dams. There was postimplantation deaths at ≥200 mg/kg on PND 0 and increased early postnatal mortality (PND 0-4) in the ≥125 mg/kg dose groups. Pup body weight was reduced at ≥200 mg/kg, with females affected more than males. Pup body weight gain was predominantly reduced during the early postnatal period. There were statistically significant differences at the end of the lactational period, which were flawed by the low number of animals. The NOAEL for maternal and postnatal developmental (screening) toxicity was 50 mg/kg-day (Price *et al.* 2005).

Key Study/Critical Effect for Screening Criteria

There are marked species differences in susceptibility to choline deficiency, with rats and mice being far more susceptible than other species including humans (Zeisel and Blusztajn 1994). Rats and mice have a higher dietary choline requirement than humans in large part because rodents oxidize choline more rapidly than humans (Sidransky and Farber 1960). Diethanolamine was carcinogenic in mice, but not in rats, in the NTP dermal carcinogenicity studies. The fact that diethanolamine was not carcinogenic to rats, a species highly susceptible to choline deficiency, should be an important consideration in the overall evaluation of human cancer risk. Diethanolamine is less readily absorbed across rat skin than mouse skin, and the resulting blood and tissue concentrations of diethanolamine are at least three-times lower in rats than in mice at similar dosages (Mathews *et al.* 1997). Lehman-McKeeman *et al.* (2002) determined the NOAEL for diethanolamine-induced choline deficiency in mice (based on phosphocholine concentrations) to be 10 mg/kg-day. Thus, there is a critical concentration of diethanolamine that must be reached in order to affect choline homeostatis. In the rats, the lack of a carcinogenic response suggests that it is unlikely that exposure to diethanolamine reached this concentration or that rats are not as susceptible as mice to the effects of diethanolamne on hepatic choline metabolism. Overall, the results suggest that the hepatocarcinogenic effects of diethanolamine in mice are not predictive of similar susceptibility in other laboratory animals or humans.

However, kidney tumors were increased in male mice. No information is available about the mode of action for these kidney tumors. Thus, a cancer risk assessment will be performed based on the increased incidence of kidney tumors (combined incidences of renal tubule adenoma and carcinoma) in male mice.

Wang *et al.* (2014) derived a cancer slope factor of 0.0024053 $(mg/kg\text{-}day)^{-1}$ based on applied dermal dose of diethanolamine in the NTP mouse study and the tumors fitted to the multistage cancer model in the BMDS software; a 10% incidence in tumor incidence as the benchmark response (BMR) was used.

The cancer slope factor was scaled to a human equivalent dose by the (human body weight (BW_h)/animal body weight (BW_{mice}))$^{1/4}$ ratio:

$$\text{Cancer Slope Factor}_{human} = \text{Cancer Slope Factor}_{male\ mice} \times (BW_h/BW_{male\ mice})^{1/4}$$
$$= 0.0024052 \times (70\ kg/0.0449\ kg)^{1/4}$$
$$= 0.015114\ (mg/kg\text{-}day)^{-1}$$

$$\text{Chronic Toxicity Value } (10^{-5}\ \text{cancer risk}) = 10^{-5} \div 0.015114\ (mg/kg\text{-}day)^{-1} \times 1000\ \mu g/mg$$
$$= 0.66\ \mu g/kg\text{-}day$$

Drinking water standard = 2.3 ppb

Note that this is a conservative estimate based on the assumption that the absorbed dose in mice is equal to the applied dose (absorption = 100%). However, dermal absorption data in mice show that absorption is dose-dependent: from 25% at 8 mg/kg to 60% at 80 mg/kg in 48 hours (Mathew *et al.* 1997).

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Toxicity Profile

Disodium Octaborate Tetrahydrate
(CAS No. 12280-03-4)

Toxicity data on borax and boric acid will be used to read across to disodium octaborate tetrahydrate ($Na_2B_8O_{13}\bullet 4H_2O$). The rationale is as follows:

Borax is also known as sodium borate, sodium tetraborate, or disodium tetraborate. With water content, borax can refer to a group of compounds that differ in their crystal water content, but typically it is disodium tetraborate decahydrate with the chemical structure ($Na_2B_4O_7\bullet 10H_2O$). Borax is moderately soluble in water, with the main species in freshwater being the borate ion $[B(OH)_4]^-$ and boric acid $B(OH)_3$, depending on the pH. The relative proportion of boric acid and borate ions is controlled by pH: $B(OH)_3 + 2H_2O \Leftrightarrow [B(OH)_4]^- + H_3O^-$. In dilute aqueous solutions, boric acid does not dissociate at pH <7; at pH values between 7 and 11, both boric acid and borate ions are present. In dilute aqueous solutions and physiological conditions, the predominant species present is un-dissociated boric acid. So, the consideration of boric acid addresses the relevant toxicological properties of borax.

Exposure to borates are often expressed in terms of boron (B) equivalents based on the fraction of boron in the source substance on a molecular weight basis. The B-equivalents used are a generic designation rather than a designation of the element boron. The factor for converting disodium tetraborate decahydrate (or disodium octaborate tetrahydrate) and boric acid to B-equivalents are 0.113 and 0.175, respectively.

Acute Toxicity

The acute oral LD_{50} value in rats for disodium tetraborate decahydrate is 5,560 mg/kg [628 mg B/kg] (Meyding and Foglhian 1961; Austria 2008). The acute dermal LD_{50} for disodium tetraborate decahydrate is >2,000 mg/kg [226 mg B/kg] (Reagan and Becci, 1985a; Austria 2008). The acute inhalation 4-hour LC_{50} is >2.03 mg/L [0.23 mg B/L] (Wnorowski 1994a; Austria 2008).

Irritation

Disodium tetraborate hydrate is mildly irritating to the abraded skin of rabbits (Roudabush *et al.* 1964; Austria 2008). In another study, it was non-irritating to the skin of rabbits with erythema and edema scores of 0 (Reagan and Becci 1985b; Austria 2008). Disodium tetraborate hydrate is irritating to the eyes of rabbits (Reagan and Becci 1985c; Doyle 1989; Austria 2008). In the study by Doyle (1989), the test substance was ground to a fine powder to reduce the glassy, sharp crystals.

Sensitization

Disodium tetraborate hydrate was not considered a skin sensitizer to the skin of guinea pigs (Wnorowski 1994b; Austria 2008).

Repeated Dose Toxicity

Rats were administered in their feed 0, 52.5, 175, 525, 1,750 or 5,250 ppm B equivalent (as boric acid or borax) for 90 days (Weir 1962; Weir and Fisher, 1972). The average intake has been estimated to be approximately 0, 2.6, 8.8, 26, 87.5 or 262.5 mg B/kg-day, respectively (U.S. EPA 2004). By week 6, all of the animals in the highest dose died. Clinical signs in the top two dose levels were rapid respiration, hunched position, bloody nasal discharge, urine stains on the abdomen, inflamed eyes, desquamation and swollen paws and tail. There was also reduced food consumption and body weight gain. The 1,750 ppm females showed reduced (liver, spleen and ovary weights; the 1,750 ppm males showed reduced kidney and adrenal weights. The adrenals of 4 of the 1,750 ppm males showed minor increases in lipid content and size of the cells in the zona reticularis. Atropied testis (complete atrophy of the spermatogenic epithelium and decreased in the size of the seminiferous tubules) was seen in all of the 1,750 ppm males. One 525 ppm male given boric acid had partial testicular atrophy; no effects were seen in male rats given disodium tetraborate decahydrate at this dose level.

Male and female $B6CF_1$ mice were administered 0, 1,200, 2,500, 5,000, 10,000 or 20,000 ppm boric acid for 13 or 16 weeks (NTP 1987). These dietary levels correspond to approximately 0, 34, 70, 141, 281 and 563 mg B/kg-day for males, respectively; and 0, 47, 97, 194, 388 and 776 mg B/kg-day for females, respectively. There >60% mortality in the 20,000 ppm group as well as hyperkeratosis and acanthosis. At 10,000 ppm, there was 10% mortality in the males. Degeneration or atrophy of the seminiferous tubules occurred in the $\geq$5,000 ppm males. Minimal to mild extramedullary hematopoiesis of the spleen was observed in all dose groups.

Male and female SD rats were administered in their feed 0, 117, 350 or 1,170 ppm borax or boric acid for two years (Weir 1966a,b; Weir and Fisher 1972). The average intake has been estimated to be approximately 0, 5.9, 17.5 or 58.5 mg B/kg-day, respectively (U.S. EPA 2004). The 1,170 ppm rats had decreased food consumption during the first 13 weeks of the study and suppressed growth throughout the study. Signs of toxicity in the 1,170 ppm animals included swelling and desquamation of the paws, scaly tails, inflammation of the eyelids, and bloody discharge from the eyes. All of the 1,170 ppm males had testicular atrophy at the 6, 12 and 24 month time points. The seminiferous epithelium was atrophied, and the tubular size in the testes was decreased. There were significant decreases in the absolute and relative testes weights. Brain and relative thyroid weights were increased. The NOAEL for this study is 350 ppm borax or boric acid (17.5 mg B/kg-day).

Male and female $B6C3F_1$ mice were given 0, 2,500 or 5,000 ppm boric acid in their feed for 103 weeks (NTP, 1987). These dose levels were equivalent to 0, 275 or 550 mg/kg-day boric acid or 0, 48 or 96 mg B/kg-day. At termination, the survival rates were 82, 60

and 44% in the control, low- and high-dose males, respectively; and 66, 66 and 74% in the control, low- and high-dose females, respectively. There was testicular atrophy and interstitial cell hyperplasia in the 5,000 ppm males. A dose-related increase in the incidences of splenic lymphoid depletion in male mice was also observed. NTP considered this lesion to be associated with stress and debilitation, and it is reflected in the increased mortality in these groups of male mice.

Genotoxicity

Disodium tetraborate decahydrate was not mutagenic when tested *in vitro* using V79 Chinese hamster cells, C3H/10T1/2 mouse embryo fibroblasts, and diploid human foreskin fibroblasts (Landolph 1985).

Boric acid has been tested in a variety of *in vitro* genotoxicity tests (NTP 1987; Haworth et al. 1983; Landolph 1985; Bakke 1991; Stewart 1991; Rudd 1991; U.S. EPA 2004). No evidence of mutagenicity of genotoxicity was observed.

Boric acid was not genotoxic in a mouse bone marrow micronucleus assay at oral doses of 0, 900, 1,800 and 3,500 mg/kg given on two consecutive days (O'Loughlin 1991).

Carcinogenicity

No carcinogenic effects were seen in the two-year rat dietary studies on disodium tetraborate decahydrate and boric acid (Weir 1966a,b; Weir and Fisher 1972). The dose levels in feed were 0, 117, 350 or 1,170 ppm borax or boric acid, which were estimated to be approximately 0, 5.9, 17.5 or 58.5 mg B/kg-day, respectively.

Male and female B6C3F_1 mice were given 0, 2,500 or 5,000 ppm boric acid in their feed for 103 weeks (NTP, 1987). These dose levels were equivalent to 0, 275 or 550 mg/kg-day boric acid or 0, 48 or 96 mg B/kg-day. No carcinogenic effects were observed.

Reproductive Toxicity

Three-generation reproductive toxicity studies were conducted in albino rats (strain not specified) with boric acid or disodium tetraborate decahydrate (Weir and Fisher 1972; reviewed in Moore 1997). Groups of rats (8 males and 16 females) were fed a diet that contained 0, 117, 350 or 1,170 ppm boron as borax or boric acid (approximately 0, 5.9, 17.5 or 58.5 mg B/kg-day, respectively). Male and female body weight gains in both studies were reduced in the 58.5 mg B/kg-day groups. Mating between treated males and females in the high-dose groups showed complete infertility, which was attributed to both sexes. Males had grossly atrophied testes and histologic examination showed an absence of viable sperm. When treated females were subsequently mated with control males, there was reduced fertility. Only 2/16 females produced live litters in the borax study, and one other female became pregnant and aborted her litter. None of the pups survived until weaning. One of 16 females fed boric acid produced a litter with six live pups; three females became pregnant and aborted their litters. Only three pups survived to weaning

of the six living pups. Histologic examinations from both studies showed that much of the decrease in female fertility was a product of reduced ovulation. The cause of the mortality in pups during the postnatal period is unknown. At the lower dose levels, the effects were minor with no obvious effects on fertility. The NOAEL was determined to be 17.5 mg B/kg-day.

In a continuous breeding protocol, male and female CD-1 mice were given 0, 1,000, 4,500 or 9,000 ppm boric acid in their feed (Fail *et al.* 1991). No litters were occurred in the high-dose breeding pairs. In the mid-dose, there was a successful first litter, after which there was a progressive decrease in fertility; only one pair produced a fourth and fifth litter. All fertility indices were affected in the mid-dose group. A complete crossover mating trial was conducted using control mice and the mid-dose mice, which indicated that the probable cause of the reduced fertility was a decrement in male fertility. A dose-related decrease in body, testicular and epididymal weights was observed in the mid- and high-dose F_0 males. Sperm count was significantly decreased in these dose groups, and percent motile sperm was decreased in all dose groups. Testicular histopathology showed seminiferous tubular atrophy in the high-dose males and partial atrophy of the seminiferous tubules in the mid-dose males. There were no histopathologic changes in the mid-dose females. No statistically significant decreases in mating index, fertility index, or live pups/litter in the mid-dose females, but the number of days to litter in this dose group was increased. Estrous cyclicity was unaffected. Reproductive organ weights were unaffected, but relative maternal liver and kidney/adrenal weights were reduced. An F_1 fertility trial was performed using offspring from the low-dose groups. There was no decreases in mating, fertility or reproductive performance. The F_2 adjusted live pup weight was slightly, but significantly, reduced from controls. A clear NOAEL for reproductive toxicity in males was not seen in this study. Decreased sperm motility was observed in the F_0 generation and sperm concentration was decreased in the F_1 generation in the low-dose males. Decreased F_2 pup relative body weight was statistically significant from controls. The NOAEL in females is 1,000 ppm boric acid (27 mg B/kg-day.

Male deer mice were fed a diet containing 0, 4,500 or 9000 ppm boric acid (0, 108 or 216 mg B/kg-day, respectively) for eight weeks (Fail *et al.* 1989; reviewed in Moore 1997). At the end of the 8-week exposure period, half of the male deer mice were mated with untreated adult female deer mice for one week. Following the mating trial, these males were killed and necropsied. The other groups of treated male deer mice were fed a diet containing no boric acid for an additional 9-week period to assess any recovery from the boron treatment. After the 9-week recovery period, the male deer mice were mated for one week with untreated adult female deer mice, then killed and necropsied. After each mating trial, the females were allowed to litter and the resulting pups were counted, sexed, and weighed at birth. Exposure of the male deer mice to 9,000 ppm boric acid for 8 weeks resulted in complete infertility. There was no decrease in fertility in the 4,500 ppm male deer mice. Decreased testicular and epididymal weights occurred in the 9,000 ppm male deer mice; and there was a reduction in the seminiferous index (a semi-quantitative rating of cell types present), which was thought to have resulted in the observed decrease in formation of mature sperm. There were no treatment-related

changes in body and organ weights, seminiferous index and litter measurements in the 4,500 ppm mice. Following a 9-week "recovery" period, the fertility performance in the high-dose male mice, as well as the necropsy results and histopathologic examination of the testes, were similar to the controls.

Male Fischer rats were administered 0, 3,000, 4,500, 6,000 or 9,000 ppm boric acid [0, 17.3, 25.9, 37.8, 51.8 or 68 mg B/kg-day] in their feed for 9 weeks (Ku *et al.* 1993; reviewed in Moore 1997). After 9 weeks on the test diet, a group of rats were returned to a control diet and recovery was assessed at 8, 16, 24 and 32 weeks post-treatment. There as a strong relationship between boric acid exposure and testicular lesions. Inhibition of spermiation, which was characterized as the aberrant retention of step 19 spermatids in stage IX-XI tubules, was seen in the 25.9 and 37.8 mg B/kg groups. The 51.8 and 63 mg B/kg rats developed severe inhibition of spermiation by week 2, which progressed to testicular atrophy (defined as complete absence of post-spermatogonial germ cells). There was no signs of recovery from the testicular atrophy in these two high-dose groups after 32 weeks of no exposure even though these tubules contained a normal complement of spermatogonia and Sertoli cells and the spermatogonia were seen to divide. These rats appeared to have an intact gonadotropin response since serum FSH and LH levels were increased. The authors referred to a preliminary study of the same size and duration, in which 2,000 ppm boric acid [17.3 mg B/kg-day B] was not observed to cause any testicular effects. Although the authors did not consider 25.9 mg B/kg-day to be an adverse effect because of the absence of changes in other testicular and reproductive indices, an Expert Committee (Moore 1997) considered this dose level to a LOAEL and 17.3 mg B/kg-day to be a NOAEL.

Developmental Toxicity

Pregnant SD rats were given 0, 0.1, 0.2 or 0.4% boric acid in their feed on gestational days (GD) 0 to 20 or 0.8% boric acid on GD 6 to 15 (Heindel *et al.* 1992). The average amounts of boric acid ingested were estimated to be 0, 78, 163, 330 or 539 mg/kg-day (0, 13.6, 28.5 or 57.7 mg B/kg-day), respectively. Effects on the dams were altered food and/or water intake at $\geq$0.2% boric acid, increased liver and kidney weights relative to body weights at $\geq$0.2%, reduced weight gain at $\geq$0.4%, and increased corrected weight gain at 0.4% boric acid. There was a reduction in fetal body weights in all treated groups (94, 87, 63, and 47% of control weight, respectively). Increased malformations occurred at $\geq$0.2% and prenatal mortality was increased at 0.8%. There was a dose-response for altered skeletal morphology in rats ($\geq$0.1%), and specific findings were significantly elevated above controls at $\geq$0.2%. Specifically, there was an increased incidence of short rib XIII (a malformation) and a decreased incidence or rudimentary or full rib(s) at lumbar I (an anatomical variation).

Pregnant SD rats were given 0, 0.025, 0.005, 0.075, 0.1 or 0.2% boric acid in their feed on GD 0 to 20 (Price *et al.* 1996a). Approximately half of the dams were terminated on GD 20, and the remaining dams delivered their litters. Pup growth and viability were monitored until postnatal day (PND) 21. The average amounts of boric acid ingested on GD 20 (PND 21) were: 0(0), 19(19), 36(37), 55(56), 76(74) or 143(145) mg/kg-day, [0,

3.3(3.2), 6.3(6.5), 9.6(9.7), 13.3(12.9), and 25(25.3) mg B/kg-day], respectively. Maternal toxicity consisted of increased relative kidney weights in the 0.2% group. There were no differences in the viability of the offspring between treated and controls. On GD 20, fetal body weight was 94% and 88% of controls in the 0.1% and 0.2% groups, respectively; recovery was complete at birth (~GD 22). The incidence of short rib XIII was increased in GD 20 in the ≥0.1% groups., but only in the 0.2% group at PND 21. The incidence of wavy rib was increased on GD 20 in the ≥0.1% group; the reversibility of this effect was confirmed on PND 21. There was a slight decrease in extra lumbar ribs in the 0.2% group on GD 20, and extra lumbar ribs were seen in the 0.2% group on PND 21. The developmental NOAEL was considered to be 0.075% boric acid (9.6 mg B/kg-day) on GD 20 and 0.1% boric acid (12.9 mg B/kg-day) on PND 21.

Pregnant Swiss mice were given 0, 0.1, 0.2 or 0.4% boric acid in their feed on gestational days (GD) 0 to 17 (Heindel *et al.* 1992). The average amounts of boric acid ingested were estimated to be 248, 452 or 1,003 mg/kg-day (0, 43.4, 79.0 or 175.3 mg/B/kg-day), respectively. Maternal toxicity consisted of mild kidney lesions (≥0.1%), increased water intake and relative kidney weights (0.4%), and decreased water intake during treatment. Fetal body weights were reduced in the ≥0.2% groups, and there were increased incidences of resorptions and malformed fetuses per litter in the 0.4% group.

Pregnant New Zealand rabbits were dosed by oral gavage with 0, 62.5, 125 or 250 mg/kg boric acid (0, 10.9, 21.9 or 43.7 mg B/kg) during GD 6-19 (Price *et al.* 1996b). There was reduced food intake during treatment in the 250 mg/kg maternal animals, but it was increased in the ≥125 mg/kg dose groups. In the 250 mg/kg group, there were decreased maternal body weight (GD 9-30), weight gain during treatment, gravid uterine weight, and number of ovarian corpora lutea. In the ≥125 mg/kg groups, maternal corrected gestational weight gain was increased. Maternal liver weights were unaffected by treatment. In the 250 mg/kg group, relative, but not absolute, kidney weights were increased, although no effects in the kidney were noted in the histopathological examination. Prenatal mortality was increased in the 250 mg/kg group (90% resorptions/litter versus 6% for controls); the proportion of pregnant females with no live fetuses was increased (73% versus 0%), and live litter size was reduced (2.3 fetuses versus 8.8). Thus, there were only 14 live fetuses (6 live litters) available for evaluation in the 250 mg/kg group. The percentage malformed fetuses/litter was increased in the 250 mg/kg group, primarily due to cardiovascular defects (72% versus 3% of controls). There was no definitive maternal or developmental toxicity in the 62.5 or 125 mg/kg dose groups.

Key Study/Critical Effect for Screening Criteria

The U.S. Environmental Protection Agency (U.S. EPA) derived an Oral Reference Dose (RfD) for boron of 0.2 mg B/kg-day (U.S. EPA 2004) based on developmental effects in rats from two studies (Price *et al.* 1996a; Heindel *et al.* 1992). The RfD was derived using the benchmark dose (BMD) method ($BMDL_{05}$ from Allen *et al.* 1996) using a data derived uncertainty factor of 66. Decreased fetal body weight was considered by Allen *et*

al. (1996) as the most suitable endpoint for developing a point of departure, because the benchmark doses calculated for the other endpoints (incidence of total malformations, enlarged lateral ventricles in the brain, shortening of rib XIII, and variations of the first lumbar rib) were higher.

Oral RfD = 0.2 mg B/kg-day

Drinking water guidance value = 0.7 ppm (boron)

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Toxicity Profile

Ethylene glycol
(CAS No. 107-21-1)

Ethylene glycol has been reviewed in the OECD-SIDS program (OECD, 2004a,b).

Toxicokinetics/Metabolism

Ethylene glycol is almost completely absorbed by laboratory animals via oral routes as would be expected from their total miscibility with water. In *in vivo* rodent dermal absorption studies, 1-51% of ethylene glycol was absorbed. Since ethylene glycol is completely soluble in water, it is expected to be well distributed throughout the aqueous tissues of the body with lower concentrations in adipose tissue. Uniform distribution has been demonstrated to a limited extent for ethylene glycol. The main metabolic pathway for metabolism of ethylene glycol is oxidation via alcohol dehydrogenases and aldehyde dehydrogenases. The main metabolites of ethylene glycol are carbon dioxide, oxalic acid and glycolic acid. Ethylene glycol may be directly eliminated by urinary excretion. Acid metabolites of ethylene glycol are also eliminated in urine and may also be metabolized to carbon dioxide and eliminated in exhaled breath.

Acute Toxicity

The oral LD_{50} values range from 589 to 13,400 mg/kg for rats (OECD, 2004b), 800 to 15,280 mg/kg for mice (OECD, 2004b), 661 to 11,000 mg/kg for guinea pigs (OECD, 2004b), and 5,000 mg/kg for rabbits (OECD, 2004b).

Irritation

Ethylene glycol was not irritating to rabbit skin (Guillot *et al.*, 1982), but there was some indication of irritation in a human primary irritation patch test (OECD, 2004b). It was not an eye irritant to rabbits (Guillot *et al.*, 1982).

Sensitization

Ethylene glycol was not a skin sensitizer to guinea pigs (Kurihara *et al.*, 1996).

Repeated Dose Toxicity (Oral Studies only)

Male and female Fischer 344 rats were given in their feed 0, 40, 200 or 1,000 mg/kg ethylene glycol for 24 months. At 1,000 mg/kg, the following effects were seen in males:

increased neutrophils, blood urea nitrogen, serum creatinine, urine volume, urine calcium oxalate crystals, water consumption rates, kidney weight (absolute and relative), mortality, mineralization of the heart, lungs, stomach, vas deferens and urinary system pathologic changes; decreased red blood cells, hematocrit, hemoglobin, serum glutamic pyruvic transaminase, mean corpuscular volume, urine specific gravity, urine pH, liver weight (absolute and relative), body weight gain, and life span. At the highest dose, the following effects were seen in females: increased mean corpuscular volume, urine specific gravity, urine calcium oxalate crystals, urine uric acid crystals, and kidney weight (absolute and relative); and decreased mean corpuscular hemoglobin concentration, urine pH, and urine volume. The NOAEL for this study is 200 mg/kg/day (DePass *et al.*, 1986a).

Male Wistar rats were given in their feed 0, 50, 150, 300 or 400 mg/kg ethylene glycol for one year. At the higher dose levels (300 and 400 mg/kg), the histopathological observations included basophilic foci of crystaluria-related nephropathy, renal tube dilation, bifringent crystals morphologically representative of calcium oxalate, dilation of the renal pelvis, and transitional cell hyperplasia in the renal pelvis or bladder. To determine renal effects, the severity of nephropathy in the kidney sections was graded on a scale of 0 to 5, with 0 representing no crystal nephropathy and 5 representing end-stage nephropathy indicative of impending renal failure. Ethylene glycol related nephropathy was not present in the kidney sections from the control group or the lower doses (50 and 150 mg/kg). In the 300 mg/kg group, severity grades ranged from 1 to 4 with the mode of occurring at 1 (minimal). In the 400 mg/kg group, severity grades ranged from 3 (moderate) to 5 (end-stage) with the mode at 4 (marked). The NOAEL for this study is 150 mg/kg/day (Wilson *et al.*, 2005).

Male Fischer 344 and Wistar rats were given in their feed 0, 150, 500 or 1,000 mg/kg ethylene glycol for 16 weeks. At 1000 mg/kg, the following effects were seen: mortality in Wistar strain (2/10) with prior clinical observations of emaciation and dermal atonia and macroscopic findings of changes in kidneys (pale, calculi) and small seminal vesicles in these animals; mean body weight losses, lower mean body weights and mean cumulative body weight changes in Wistar strain (weeks 2 – 16); lower mean food consumption in Wistar strain; higher mean water consumption in both F344 and Wistar strains; lower mean specific gravity and higher mean total urine volume in both F344 and Wistar strains; macroscopic findings of pale kidneys, presence of calculi, rough surface and dilated pelvis; higher mean absolute and relative kidney weights in both F344 and Wistar strains; renal macroscopic findings of crystal nephropathy in Wistar and F-344 rats, with more severe nephropathy in Wistar strain than in the F344 strain. At 500 mg/kg, the following effects were seen: lower mean body weights (study weeks 3, 6-8, and 10-12) and mean cumulative body weight changes in the Wistar strain throughout the study with slightly lower mean food consumption throughout the study; higher mean water consumption in the Wistar strain; lower mean urine specific gravity and higher mean total urine volume in the Wistar strain; macroscopic findings in the Wistar strain consisting of predominantly pale kidneys, presence of calculi, rough surface, and dilated pelvis; higher mean absolute and relative kidney weight in the Wistar strain; renal macroscopic findings of crystal nephropathy in Wistar and F-344 strains, with more

severe nephropathy in the Wistar strain than in the F344 strain. The NOAEL in both the F344 and Wistar rats is 150 mg/kg/day (Cruzan *et al.*, 2004).

Male and female Fischer 344 rats were given in their feed 0, 0.32, 0.63, 1.25, 2.5, or 5% ethylene glycol for 13 weeks. Mortality was seen in the 5% animals in males, but not in females. Mean weight gain was significantly decreased in the 2.5 and 5% males, while there was no significant differences in female rats. There was no apparent difference in feed consumption between both male and female rats and the control group. There was no significant change in right kidney weight (both sexes), but a significant increase was seen in the left kidney weight in the 2.5 and 5% dose groups (both sexes). Mean thymus ratio to terminal body weight was significantly decreased in the 5% males. Serum urea nitrogen levels were significantly increased in the 2.5 and 5% males, and significantly increased in the $\geq$0.32% females. For both sexes, creatinine levels were decreased in the 0.32% group and significantly increased in the 2.5 and 5% groups. Kidneys from the 2.5 and 5% male rats had rough, granular and/or pitted appearances. Nephrosis was seen only in the 5% females. Brains from the 5% male rats contained clusters of crystals. The NOAEL for this study is 1.25%, which was estimated to be 600 to 1,000 mg/kg/day (Melnick, 1984).

Male and female Sprague Dawley rats were given in their drinking water ethylene glycol for 90 days. The concentrations for females were 0, 0.5, 1.0, 2.0 or 4.0% (0, 597, 1,145, 3,087 or 5,744 mg/kg-day). The concentrations for males were 0, 0.25, 0.5, 1.0 or 2.0% (0, 205, 407, 947 or 3,134 mg/kg-day). Mortality was seen only at the highest dose level for both males and females. Decreased body weights were seen in the highest dosed males. Only males showed any significant changes in organ weights. Kidney weights were significantly increased in the 1% and 2% males, which heart, liver, and lung were significantly decreased in the 2% males. There was also a significant increase in the ratio to body weight for the brain and gonads of the males in the highest dose group. Leukocyte levels were significantly decreased in the 0.5, 2 and 4% females, but not in males. LDH, creatinine, ALT, calcium and glucose were significantly different in the 1% males, and phosphorus, BUN, and creatinine in the 2% males. There were significant increases in phosphorus in the 1% females and glucose in the 0.5 and 4% females. Kidney lesions were seen in the $\geq$2% females and in the $\geq$1% males. Lesions were more prominent in males than in females. Renal changes consisted of tubular dilation, tubular degeneration, acute inflammation, birefringent crystals in tubules and pelvic epithelium. The NOAEL for this study is 407 mg/kg-day for males. The LOAEL for females is 597 mg/kg/day; a NOAEL was not established (Robinson *et al.*, 1990).

Male and female Sprague-Dawley rats were given in their feed 0, 0.1, 0.2, 0.5, 1.0 or 4.0% ethylene glycol for two years. There was significant reduction in growth in the 4% males after week 16, and in the 1% males after week 70. The 4% females did not gain any weight past the first year of the study. Water consumption was double that of the controls in the 4% males that initiated soon after the start of the study. The 1% males had significant increases in water consumption after 6 months and some increase was observed in the 0.5% males. Females only showed increased water consumption in the 4% group. There was 100% mortality in the 1 and 4% males, while mortality of

additional dose levels were below that of the controls. There was 100% mortality in the 4% females, while the 1% females were similar to the controls; the 0.1, 0.2 and 0.5% females were increased compared to the controls. Since the 1 and 4% males and the 4% females all died before the study termination date, there are no data for these groups on terminal organ weight. For males, the terminal organ weights were decreased in all dose levels compared to the controls. For females, the organ weights were similar to the controls. The 1 and 4% males and females had kidneys with stones and crystals. The NOAEL for this study is 0.2% (data was insufficient to calculate the dose) (Blood, 1965).

Male and female B6C3F_1 mice were given in their feed 0, 0.32, 0.63, 1.25, 2.5, or 5.0% ethylene glycol for 13 weeks. There was no mortality for either male or female mice at any dose level. No clear dose-related effect was seen in mean weight gain, and there was no clear evidence of decreased feed consumption. There was no significant change in organ/body weight ratio for either sex for any dose level. Serum urea nitrogen and creatinine levels were unaffected. Kidney lesions were observed in half of the male mice in the 5% dose level and one mouse in the 2.5% dose level. Lesions were tubular dilation, cytoplasmic vacuolization, and regenerative hyperplasia. There was no evidence of crystal formation in the tubules. No kidney effects were seen in the female mice. Degenerative change was present in the livers of all male mice in the 2.5 and 5% dose levels. The NOAEL for this study is 1.25%, which was estimated to be 600 to 1,000 mg/kg/day (Melnick, 1984).

Male and female B6C3F_1 mice were given in their feed 0, 6,250 ppm (males only), 12,500 and 25,000 ppm (males and females) or 50,000 ppm (females only) for 103 weeks. These concentrations are approximately equivalent to 0, 1,500, 3,000, 6,000 or 12,000 mg/kg-day. There was no statistically significant difference in survival between dosed and control groups. Mean body weight and food consumption of mice administered ethylene glycol were generally similar to those of controls throughout the study. No chemical-related clinical findings were observed. Liver lesions (in male mice) and arterial hyperplasia (in females) were observed at 12,500 ppm, but no adverse effects were observed at 6250 ppm. The NOAEL for this study is 1,500 mg/kg/day (NTP, 1993).

Genotoxicity

Mutagenicity studies in bacteria and *in vitro* mutagenicity studies in mammalian cells have been uniformly negative (OECD, 2004a,b). The results of *in vitro assays* of ethylene glycol for chromosomal aberrations (CHO chromosomal aberration and sister chromatid exchange assays) have also been uniformly negative (OECD, 2004a,b).

Ethylene glycol was equivocal when tested in an *in vivo* mouse bone marrow micronucleus study (Conan *et al*., 1979). There were some findings of statistically significant increases in micronuclei, but no dose-related trends and potential confounding due to toxicity (lethality) at high doses. Ethylene glycol did not increase the incidence of chromosomal aberrations in mice *in vivo* (Conan *et al*., 1979). An *in vivo* rodent

dominant lethal mutagenesis assay conducted at doses up to 1,000 mg/kg in Fischer 344 rats was negative (DePass *et al*., 1986b).

Carcinogenicity

Male and female B6C3F_1 mice were given in their feed 0, 6,250 ppm (males only), 12,500 and 25,000 ppm (males and females) or 50,000 ppm (females only). These concentrations were approximately equivalent to 0, 1,500, 3,000, 6,000 or 12,000 mg/kg-day. Body weights, survival, and incidence of tumors were similar between treated and control mice (NTP, 1993).

Reproductive Toxicity

Ethylene glycol has been assessed by the Reproductive Assessment by Continuous Breeding (RACB) protocol in which parental mice received chemical via drinking water during pre-mating exposure, cohabitation, pregnancy, and lactation. The F_1 generation received prenatal exposure via maternal exposure during gestation, with the exposure continuing during lactation, weaning, and mating of F_1 animals and production of an F_2 litter. The doses were 0, 0.25, 0.5 or 1% ethylene glycol, which corresponded to approximately 0, 410, 840 or 1,640 mg/kg/day. No adverse effects were noted in the parental animals at doses up to 1%. There was a small, but statistically significant, effects on the numbers of litters per fertile pair, the number of live pups per litter, and live pup weight in the 1% dose group. Neither the 0.25 nor 0.5% dose groups were significantly affected. The number of live pups per litter was lower in the treated group, but differences were not statistically significant. Unusual facial features (*i.e.*, shorter snout and wide-set eye) and skeletal defects (shortened frontal, nasal, and parietal bones; fused ribs abnormally shaped or missing sternebrae, abnormally shaped vertebrae; and twisting of the spine at 1%) were noted on some of the offspring of the treated mice, but not in the controls. The parental NOAEL is 1% (approximately 1,640 mg/kg/day), and the NOAEL for reproductive toxicity is 0.5% (approximately 840 mg/kg/day (Lamb *et al*., 1985).

In a three-generation reproductive toxicity study, Fischer 344 rats were given in their diet 0, 40, 200 or 1,000 mg/kg/day ethylene glycol. There were no treatment-related effects on clinical signs of toxicity or survival in the parental animals. There were no significant effects on fertility index, gestation index, gestation survival for all three generations. Mean pup weights in the all three generations were similar between treated and control animals. The NOAELs for parental and reproductive toxicity are 1,000 mg/kg/day (DePass *et al.*, 1986b).

Developmental Toxicity (Oral and Dermal Studies only)

Pregnant Sprague-Dawley rats were dosed by oral gavage with 0, 50, 150, 500, 1,000 or 2,500 mg/kg ethylene glycol during gestational days (GD) 6-15. Maternal toxicity was

observed in the 2,500 mg/kg group and consisted of significantly decreased body weights, increased water consumption, decreased uterine weights, increased kidney weights, and increased relative liver weights. At 500 mg/kg, there were developmental effects, which included reduced fetal body weights, extra or missing ribs, missing arches, and poor ossification in thoracic and lumbar centra. In the 2500 mg/kg group, in addition to skeletal malformations, there was gastroschisis, hydrocephaly, lateral ventricle dilated (tissue depressed), umbilical hernia, and atelectasis. The NOAELs for maternal and developmental toxicity are 1,000 and 500 mg/kg/day, respectively (Neeper-Bradley *et al.*, 1995).

Pregnant CD rats were dosed by oral gavage with 0, 1,250 2,500 or 5,000 mg/kg ethylene glycol during GD 6-15. In the $\geq$2,500 mg/kg groups, the dams had increased relative kidney weights, decreased gravid uterine weight, and increased water consumption. Maternal body weight gain was significantly decreased in the 1,250 mg/kg group. Live litter size was significantly decreased in the 5,000 mg/kg group, and fetal body weights were decreased in the 1,250 and 5,000 mg/kg groups. Litters with malformed fetuses were observed in the $\geq$1,250 mg/kg groups. The LOAELs for maternal and developmental toxicity are 1,250 mg/kg/day; NOAELs were not established (Price *et al.*, 1985).

Pregnant Fischer 344 rats were given by oral gavage 0, 40, 200 or 1,000 mg/kg ethylene glycol during GD 6-15. No maternal toxicity was observed at any dose level. There were no significant effects on preimplantation loss, fetal length, fetal weight, total implantations or litter size. There was an increased incidence of skeletal alterations in the 1,000 mg/kg group, which consisted of poorly ossified and unossified vertebral centra. No significant increases in the incidence of major malformations were observed. The NOAELs for maternal and developmental toxicity are 1,000 and 400 mg/kg/day (Maronpot *et al.*, 1983).

Pregnant CD-1 mice were dosed by oral gavage with 0, 50, 150, 500 or 1,500 mg/kg ethylene glycol during gestational days (GD) 6 to 15. There was no maternal toxicity. At 1,500 mg/kg, there were reduced fetal body weights, fused ribs and arches, poor ossification in thoracic and lumbar centra, and increased occurrence of an extra 14^{th} rib. At 500 mg/kg, there was slight reductions in fetal body weight and increased incidences of extra ribs. The NOAELs for maternal and developmental toxicity were 1,500 and 150 mg/kg/day, respectively (Neeper-Bradley et al., 1995).

Pregnant CD-1 mice were dosed by oral gavage with 0, 750, 1,500 or 3,000 mg/kg ethylene glycol during GD 6 to 15. There was a significant decrease in maternal gain, gravid uterine weights, and liver weights in the 1,500 mg/kg group. A decreased number of implantation sites per litter was observed in the 1,500 mg/kg group. Significant decrease in liver litter size was observed in the 3,000 mg/kg group and decreased fetal body weights were seen at $\geq$750 mg/kg. Litters with a significant increase in malformed fetuses were observed in the $\geq$750 mg/kg groups. There was a significant dose-related increase in postimplantation loss per litter, though there were no significant pairwise comparisons. The NOAEL for maternal toxicity is 750 mg/kg/day;. The LOAEL for

developmental toxicity is 750 mg/kg/day; the NOAEL was not established (Price *et al.*, 1985).

In a short-term reproductive and developmental toxicity screen test, male and female Swiss Crl:CD-1 mice were allowed to mate over a three-day period. The males were dosed by oral gavage from study day 3 to study day 20. The Group A females were exposed throughout the 21-day test period; the Group B females were exposed during GD 8-14. The doses were 0, 250, 700 or 2,500 mg/kg ethylene glycol. The Group A females were sacrificed after 19 days of treatment, and the Group B females were allowed to litter and rear to postnatal day (PND) 4. There was no maternal or paternal toxicity. The 2,500 mg/kg females in Group A had significantly fewer liver implants and more dead implants. The 2,500 mg/kg in Group B had significantly lower total litter weights on PND 1 and 4. The NOAELs for parental and developmental toxicity are 2,500 and 700 mg/kg/day (Harris *et al.*, 1992).

In a Chernoff/Kavlock assay, pregnant CD-1 mice were dosed by oral gavage with 0 or 11,090 mg/kg ethylene glycol during GD 7-14. The females were allowed to litter and rear to PND 3. Ten percent of the maternal animals died. The number of surviving pups per litter (40% survived), birth weight and pup weight gain were reduced. The LOAELs for maternal and developmental toxicity are 11,090 mg/kg; NOAELs were not established (Schuler *et al.*, 1984; Hardin *et al.*, 1987).

Pregnant CD-1 mice were administered by dermal application 0, 400, 1,677 or 3,549 mg/kg ethylene glycol during GD 6-15. There was minimal, if any, treatment-related maternal toxicity. Copora lutea, total implants, percentage of live fetuses per litter, fetal body weights, and incidence of external or visceral malformations were unaffected by treatment. There was, however, a significant increase in two skeletal variations in the 3,549 mg/kg group. The NOAELs for maternal and developmental toxicity were considered to be 3,549 mg/kg/day (Tyl *et al.*, 1995).

Key Study/Critical Effect for Screening Criteria

The available data show that repeated oral exposures to ethylene glycol causes primarily kidney toxicity; is also a reproductive and developmental toxicant in rodents when administered at high doses by oral gavage. Rats develop kidney toxicity at substantially lower doses than mice. Among rats, there are differences in the susceptibility of strains towards developing kidney toxicity from ethylene glycol exposure. The renal toxicity of dietary ethylene glycol to rats was clearly related to oxalic acid levels in the kidney, which explained strain differences (Corley *et al.*, 2002). In animals chronically exposed to ethylene glycol histopathologically-detectable kidney damage is believed to be related to oxalate crystals (crystal nephropathy). No adverse chronic renal effects from ethylene glycol dosing were seen in animals exposed below 150 mg/kg/day. The oral RfD for ethylene glycol is thus based on the NOAEL of 150 mg/kg/day from the one-year rat feeding study by Wilson *et al.* (2005).

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD = 150/100 = 1.5 mg/kg/day

Drinking water guideline value = 5.3 ppm

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Toxicity Profile

Hemicellulase
(CAS No. 9025-56-3)

Hemicellulases are a group of enzymes that break down hemicellulose, which are polysaccharides that are present in cell walls of all terrestrial plants. These polysaccharides have a β-(1→4)-linked backbone and are composed of pentoses (xylose, arabinoses), hexoses (mannose, glucose, galactose), and sugar acids. Unlike cellulose which are polysaccharides consisting of linear chains of several hundred to over ten thousand β-(1→4) linked D-glucoses, hemicelluloses are not chemically homogeneous. The best characterized hemicellulases are the 1,4- β -D-xylanases and, in particular, those derived from fungal sources presumably because their substrates, xylans, constitute the largest proportion of hemicelluloses in pasture plants.

No toxicity information could be located on hemicellulases; however, mammalian toxicity information were found on the cellulase enzymes (HERA, 2005). Cellulases cleave the ß-1,4-glycosidic bonds in cellulose, and are used in the pulp and paper industry, the textile industry, and in detergents to remove deposits and stains.

Enzymes are catalytic proteins or polypeptides and consist of amino acid residues coupled via peptide bonds. They are primarily characterized by their biocatalytic or enzymatic activity. There is a broad range of detergent cellulases used both from fungal as well as from bacterial origin; all are characterized by ß-1,4-endoglucanase activity. For the purposes of risk assessment, the structure of hemicellulases would be expected to be similar to that of cellulases, given that hemicellulases and cellulases are both enzyme families that hydrolyze polysaccharides, although differing in their substrates. Thus, the toxicity data on cellulases will be used as read-across to hemicellulases.

Acute Toxicity

The oral LD_{50} of a cellulase enzyme was calculated to be 8,000 mg/kg for mice and >10,000 mg/kg for rats (HERA, 2005). The inhalation LC_{50} of the same cellulase enzyme in rats was >3.48 mg/L. The mass mean diameter was 7.8 μm with a geometric standard deviation of 2.1 μm (HERA, 2005).

Irritation

Cellulase enzymes are mild to non-irritating to the skin and eyes of rabbits (HERA, 2005). However, the irritation potential is dependent on the amount of protease contamination in the enzyme test preparation, particularly with regards to eye irritation.

Sensitization

A cellulase enzyme was not a skin sensitizer to guinea pigs (HERA, 2005).

Repeated Dose Toxicity

Male and female rats were dosed by oral gavage with 0, 300, 1,000 or 3,000 mg/kg of a cellulase enzyme for 4 weeks. There were no treatment-related clinical signs, but a slight dose-related increase in body weight gain (approx. 7%) was seen in the males. No treatment-related changes were noted in the hematology or clinical chemistry. There were no gross or histopathologic changes that were considered treatment-related (HERA, 2005).

Male and female rats were given in their feed concentrations of 0, 120, 600 or 3,000 mg/kg of a cellulase enzyme for 13 weeks. There were no treatment-related clinical signs. A reduction in body weight gain was seen in both sexes at the 3,000 mg/kg level (10% in males and 20% in females). A slight reduction in food consumption was also noted for the 3,000 mg/kg rats. Alkaline phosphatase was increased in the 600 and 3,000 mg/kg females in a dose-dependent manner. There were no gross or histopathologic changes that were considered treatment-related. The NOAEL for this study is 600 mg/kg/day (HERA, 2005).

Genotoxicity

In an *in vitro* bacterial mutation assay, a cellulase enzyme was not mutagenic to *Salmonella typhimurium* strains TA 1535, TA 100, TA 1537 and TA98 in the presence or absence of metabolic activation. In an *in vivo* bone marrow micronucleus assay, a cellulase enzyme was not genotoxic when given to rats by oral gavage (HERA, 2005).

Carcinogenicity

No data were found.

Reproductive Toxicity

No data were found.

Developmental Toxicity

No data were found.

Key Study/Critical Effect for Screening Criteria

In a 13-week dietary study, there was reduced body weight gain in rats given 3,000 mg/kg of a cellulase enzyme. No other adverse effects were observed. The NOAEL for this study is 600 mg/kg-day.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (subchronic to chronic)

Oral RfD = 600/1000 = 0.6 mg/kg-day

Drinking water guideline = 2 ppm

Reference

Human and Environmental Risk Assessment (HERA) on Ingredients of Household Cleaning Products: α-amylase, CAS No. 9000-90-2; Cellulase (β-(1,4)-glucanase), CAS No. 9012-54-8; Lipase, 9001-62-1, 2005. http://www.heraproject.com

Toxicity Profile

Hydroxypropyl Guar Gum
(CAS No. 39421-75-5)

No data could be located on hydroxypropyl guar gum; information in this profile will be read-across from guar gum.

Guar gum (CAS No. 9000-30-0) is the milled endosperm of the leguminous plant *Cyamopis tetragonoloba*. Structurally, it is a galactomannan (high-molecular weight carbohydrate polymer) consisting of a main chain of D-mannose with a side chain of D-galactose at approximately every second mannose unit. The mannose units are β-(l-4) linked, and the single D-galactose units are joined to the main chain by α-(1-6) linkages. The estimated molecular weight of guar gum ranges from 200,000 to 300,000 daltons (Glickman, 1969).

Guar gum is approved for use as a food additive by the U.S. Food and Drug Administration and is on the list of substances "generally recognized as safe" (CFR 1974).

Acute Toxicity

The oral LD_{50} is 8,100 mg/kg for mice and 9,400 mg/kg for rats (Bailey and Morgareidge, 1948).

Irritation

No data were found.

Sensitization

There are reports of respiratory sensitization in workers exposed occupationally to guar gum dusts (Maio, 1986).

Repeat Dose Toxicity Studies

F344 rats and B6C3F_1 mice were given diets containing 0, 6,300, 12,500, 25,000, 50,000 or 100,000 ppm guar gum for 13 weeks (NTP, 1982). Mean body weights were decreased in male rats (100,000 ppm group) and in female mice (50,000 and 100,000 ppm). A dose-related decrease in feed consumption was observed for male and female rats; male and female mice were comparable or higher than that of controls. There were no compound-related clinical signs or histopathological effects.

F344 rats and B6C3F$_1$ mice were given diets containing 0, 25,000 ppm or 50,000 ppm guar gum for 103 weeks (NTP, 1982). Mean body weights of the high-dose females were lower than those of the controls after week 20 for mice and week 40 for rats. No compound-related clinical signs or adverse effects on survival were observed. Feed consumption by dosed rats and mice of either sex was lower than that of controls. There were no non-neoplastic histopathological effects in either rats or mice that were treatment-related.

Genotoxicity

Guar gum was not mutagenic to *Salmonella typhimurium* TA 1530 or G-46 when tested without metabolic activation; however, it was mutagenic to *Saccharomyces cerevisiae* D-3 (Green, 1977). Guar gum also was reported to cause chromosomal aberrations in human embryonic lung cells WI-38 (Green, 1977). No *in vivo* genotoxicity studies have been conducted on guar gum.

Carcinogenicity

F344 rats and B6C3F$_1$ mice were given diets containing 0, 25,000 ppm or 50,000 ppm guar gum for 103 weeks (NTP, 1982). There were increased incidences of adenomas of the pituitary in male rats and pheochromocytomas of the adrenal in female rats that were statistically significant, but these differences were considered to be unrelated to guar gum administration. When pituitary adenomas or carcinomas and when pheochromocytomas or malignant pheochromocytomas are combined, the statistical differences disappear. Hepatocellular carcinomas occurred in treated male mice at incidences that were significantly lower than that in controls. The combined incidence of male mice with either hepatocellular adenomas or carcinomas was also significantly lower in the high-dose group. It was concluded that under conditions of this bioassay, guar gum was not carcinogenic for F344 rats or B6C3F$_1$ mice.

Reproductive Toxicity

No data were found.

Developmental Toxicity

Female rabbits were given daily (6 hours/day) dermal administration of 0, 2, 10 and 50 mg/kg guar gum during gestational days 6 through 18 (IRDC, 1988). Mortalities included 2 deaths at 50 mg/kg and 1 death at 10 mg/kg. A single animal was killed in extremis. A dose-related increase in dermal irritation (including erythema, edema, and desquamation) was observed in animals receiving 10 and 50 mg/kg. The number of early

resorptions was significantly increased and the number of viable fetuses was correspondingly decreased at 50 mg/kg/day ($p<0.05$). The frequency of fetal malformations and variations in the treated groups was comparable to that of the control group at all dose levels. The NOEL for this study is 2 mg/kg/day.

Key Study/Critical Effect for Screening Criteria

The key studies for the determination of a drinking water guidance value is the NTP two-year chronic bioassays. The LOAELs are based on decreased mean body weights in female mice and rats fed 50,000 ppm guar gum in diet for 103 weeks. The NOAELs for these studies are 25,000 ppm guar gum.

Rat: NOAEL (mg/kg/day) = 25,000 ppm * 0.05 = 1,250 mg/kg/day

Mouse: NOAEL (mg/kg/day) = 25,000 ppm * 0.13 = 3,250 mg/kg/day

Where 0.05 and 0.13 are the fraction of body weight that rats and mice, respectively, consume per day as food (U.S. EPA).

The lowest NOAEL of 1,250 mg/kg/day for the rat will be used to derive a drinking water guidance value.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD = 1,250/100 = 12.5 mg/kg/day

Drinking water guideline = 44 ppm

References

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Toxicity Profile

Lactose
(CAS No. 63-42-3)

Lactose is a disaccharide sugar composed of galactose and glucose. It is naturally synthesized in the mammary gland of virtually all mammals, occurring in milk at levels between 1 and 7%. Commercially, lactose is extracted from the whey of cow's milk (whey is the residual liquid of milk following cheese and casein production) and is purified extensively to remove fats, proteins, vitamins and minerals (Baldrick and Bamford, 1997; Goodhart, 1994).

Pharmacokinetics/Metabolism

Lactose *per se* is not readily absorbed by the oral route. After dietary intake, lactose is readily hydrolyzed to galactose and glucose by the enzyme lactase (Hansen, 1974; Williams, 1986). Lactase is a β-galactosidase found in the brush border of the intestinal epithelium. Once hydrolyzed, the monosaccharides are then readily absorbed. Lactose can also be hydrolyzed by other enzymes, such as acid β-galactosidase.

Acute Toxicity

The acute oral LD_{50} in rats is >10,000 mg/kg (Baldrick and Bamford, 1997).

Irritation

No data were located.

Sensitization

No data were located.

Repeated Dose Toxicity/Carcinogenicity

Wistar rats were fed 20% lactose for 12 weeks before mating, and during pregnancy and lactation. At weaning, the animals were fed the same diet and the study was terminated at week 130. There were low body weights; increased blood alkaline phosphatase and urinary calcium; decreased pH of cecum contents; enlargement/increased weight of the cecum; pelvic nephrocalcinosis of the kidneys; increased proliferation of the bile ducts; adrenal medullary hyperplasia and pheochromocytomas; and Leydig cell tumors (Sinkeldam *et al.*, 1992a).

Similar findings were also observed in another study in which rats were fed 20% lactose in their diet for 130 weeks. Findings included loose feces (week one and two only); decreased pH of the feces; low body weights; increased food and water consumption; increased blood alkaline phosphatase and decreased bicarbonate; increased calcium concentration and excretion; reduced urinary pH; increased cecum weight; mineralization of the renal pelvis; increased incidence of basophilic cell foci in the adrenal medulla; and Leydig cell hyperplasia (De Groot *et al.*, 1995).

Genotoxicity

Lactose was negative in an *in vitro* chromosomal aberration study with cultured human lymphocytes in the presence and absence of metabolic activation (Sinkeldam *et al.*, 1992a).

Reproductive/Developmental Toxicity

In a multi-generation study, rats were fed 20% lactose over three successive generations. There were no adverse effects on fertility or reproductive performance. There was a slight decrease in the number of pups born alive, litter size at birth, viability index and pup weight for F_0 and F_1 offspring. There were signs of low body weights in the parental animals, and enlargement and increased weight of the cecum (Sinkeldam *et al.*, 1992b).

Pregnant mice were given 10,000 mg/kg lactose during gestation days 8-12. No maternal toxicity was observed and there were no effects on litter size, body weight on days 1 and 3, or neonate survival (Seidenberg *et al.*, 1986).

Key Study/Critical Effect for Screening Criteria

Many of the findings from the oral studies on lactose can be related to the fact that it is poorly absorbed from the small intestine. This results in a large proportion reaching the cecum and colon where it is readily fermented by the intestinal microflora. Consequently, there is increased production of volatile fatty acids and lactic acid, and a lowering of the pH and increased osmotic pressure. These changes facilitate calcium absorption. The adrenal tumors are thought to be secondary to increased calcium absorption from the intestine. Increased Leydig cell tumors in rats are of questionable relevance to humans.

Adverse effects were noted in rats given 20% in their diet for 130 weeks. Since there was only one dose level, a NOAEL was not identified.

LOAEL (mg/kg/day) = 20,000 ppm * 0.05 = 1,000 mg/kg/day

Where 0.05 is the fraction of body weight that is consumed per day as food for the mouse (U.S. EPA).

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (LOAEL to NOAEL)

Oral Reference Dose = 1,000/1,000 = 1.0 mg/kg/day

Drinking water guideline value = 3.5 ppm

References

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Toxicity Profile

Monoethanolamine borate
(CAS No. 26038-87-9)

The toxicity profile includes toxicity data on boric acid, reaction products with ethanolamine and triethanolamine (CAS No. 68512-53-8), which is structurally similar to monoethanolamine borate.

Acute Toxicity

The acute oral LD_{50} in rats is >2,000 mg/kg, and the acute dermal LD_{50} of CAS 68512-53-8 in rats is >2,000 mg/kg.

Irritation

Monoethanolamine borate was slightly irritating and was not considered to be a skin irritant when tested on the skin of rabbits. Monoethanolamine (MEA) Polyborate 1:1 and MEA Polyborate 1:3 were tested for eye irritancy using the Bovine Corneal Opacity and Permeability test (BCOP test). Minimal to no ocular irritation was observed in both studies.

Sensitization

CAS No. 68512-53-8 was not a skin sensitizer to guinea pigs using the Buehler method.

Repeated Dose Toxicity

Groups of male and female rats received CAS No. 68512-53-8 by oral gavage at dose levels of 0, 62.5, 250 or 1,000 mg/kg body weight per day for a period of 28 days. No deaths occurred throughout the study. Behavior, state of health, body weight development and food consumption, were not affected by administration of the test substance. No treatment-related clinical signs were observed in all animals. No changes of the oral mucosa or impairment of dental growth was observed in all study groups. There were no substance related adverse findings either in hematological examinations, clinical chemistry or urine analyses throughout the study period. As a non-adverse finding, the test substance induced slightly lower total bilirubin, cholesterol and triglycerides in high dose group rats (1,000 mg/kg body weight) and possibly marginally lower hemoglobin and hematocrit content when compared to the controls at the end of the study period. These changes were at the lower range of the historical control data for this rat strain and age and hence, not considered to be of toxicological significance. The test

substance did not influence any of the neurotoxicological parameters. No test article related changes in organ weights were observed. Necropsy at terminal sacrifice revealed no gross pathology findings in the animals of all experimental groups. All microscopic findings sporadically observed in different organs of single animals were interpreted as not compound related. The NOAEL for this study is 1,000 mg/kg/day.

Genotoxicity

In an *in vitro* chromosomal aberration test using cultured peripheral human lymphocytes, MEA Polyborate 1:1 showed a clastogenic response in experiments where the pH of the treated cultures was above the pH of the solvent control. The clastogenicity was only observed in the first cytogenetic assay. Due to fact that the adjustment of the pH of the cultures treated with MEA Polyborate 1:1 did not show a clastogenic response in the third cytogenetic assay, it has to be assumed that the high pH is responsible for the detected clastogenic activity.

In an *in vitro* chromosomal aberration test using cultured peripheral human lymphocytes, MEA Polyborate 1:3 did not induce a statistically significant or biologically relevant increase in the number of cells with chromosome aberrations in the absence and presence of S9-mix, in either of the two independently repeated experiments. CAS No. 68512-53-8 did not induce gene mutations in an *in vitro* HPRT-test with V79 Chinese hamster lung fibroblast cells, either in the presence or in the absence of metabolic activation.

Carcinogenicity

No data are available.

Reproductive Toxicity

No data are available.

Developmental Toxicity

No data are available.

Key Study/Critical Effect for Screening Criteria

A 28-day oral toxicity study conducted was conducted in rats with CAS No. 68512-53-8 (Boric acid, reaction products with ethanolamine and triethanolamine). The NOAEL for this study is 1,000 mg/kg/day. Data from CAS No. 68512-53-8 is being used as read-across to monoethanolamine borate.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (subacute to chronic)

Oral RfD = 1000/1000 = 1 mg/kg/day

Drinking water guideline: 3.5 ppm

Reference

ECHA REACH database: http://apps.echa.europa.eu/registered/registered-sub.aspx

Toxicity Profile

Sodium carbonate
(CAS No. 497-19-8)

Sodium carbonate has been reviewed in the OECD-SIDS program (OECD, 2002a,b).

Sodium carbonate is a strong alkaline compound with a pH of 11.6 for a 0.1M aqueous solution. The pKa of carbonate (CO_3^{2-}) is 10.33, which means that at a pH of 10.33 both carbonate and bicarbonate are present in equal amounts.

In water, sodium carbonate dissociates into sodium ion (Na^+) and carbonate (CO_3^{2-}). The carbonate ions will react with water, resulting in the formation of bicarbonate and hydroxide, until an equilibrium is established.

Sodium carbonate is used in many countries (*e.g.* U.S. and EU) as a food additive. It is regarded as a 'Generally Recognised as Safe' (GRAS) substance in food with no limitation other than current good manufacturing practice.

Acute Toxicity

An acute oral LD_{50} of sodium carbonate monohydrate in rats is 2,800 mg/kg, and the acute dermal LD_{50} is >2,000 mg/kg. These studies were done with sodium carbonate monohydrate but due to the relatively low water content of sodium carbonate monohydrate, the toxicity of sodium carbonate is not expected to be significantly different. The LC_{50}s for guinea pigs, mice and rats were 800, 1,200 and 2,300 mg/m , respectively, when male animals were exposed for 2 hours to sodium combustion products containing mainly sodium carbonate.

Irritation

Skin irritation studies have been performed with solid sodium carbonate and a 50 % solution of sodium carbonate with both animals and human volunteers. Erythema and edema were not observed for the intact skin. Thus, sodium carbonate has little to no skin irritation potential.

The available eye irritation tests show differing results. Studies using a dose of 0.1 ml sodium carbonate monohydrate and sodium carbonate (anhydrous) resulted in a classification of irritating and highly irritating, respectively. However, based on a study with a dose of 0.1 g sodium carbonate it was not classified as an ocular irritant. Overall, the results indicat that sodium carbonate is irritating to the eyes.

Sensitization

No data are available.

Repeated Dose Toxicity

No animal data are available on repeated dose toxicity studies by the oral route. Carbonate would be neutralized in the stomach by the low pH of the gastric juice and would not be available for uptake into the body.

Genotoxicity

The available *in vitro* mutagenicity test with sodium carbonate was negative.

Carcinogenicity

No data are available.

Reproductive/Developmental Toxicity

Aqueous solutions of sodium carbonate were administered daily via oral intubation to pregnant mice at doses ranging from 3.4 to 340 mg/kg during days 6-15 of gestation. There was no effect on implantation or on the survival of dams and fetuses. There were no significant differences in soft and skeletal tissue anomalies between treated and control animals. Negative results were reported for rats and rabbits for daily doses from 2.45 to 245 mg/kg and 1.79 to 179 mg/kg, respectively.

Key Study/Critical Effect for Screening Criteria

The Australian drinking water screening value for sodium (180 ppm, aesthetic) and pH may apply to sodium carbonate.

References

OECD (2002a). IUCLID Data Set for Sodium carbonate (CAS No. 497-19-8), UNEP Publications.

OECD (2002b). Screening Information Dataset (SIDS) Initial Assessment Report for Sodium carbonate (CAS No. 497-19-8), UNEP Publications.

Toxicity Profile

Sodium hydroxide
(CAS No. 1310-73-2)

Sodium hydroxide (NaOH) has been reviewed in the OECD-SIDS program (OECD, 2002a,b).

Sodium hydroxide (NaOH) is present in the environment as sodium (Na^+) and hydroxyl ions (OH^-). Sodium is a normal constituent of the blood and an excess is excreted in the urine. A significant amount of sodium is taken up via the food because the normal uptake of sodium via food is 3.1-6.0 g per day according to Fodor *et al.* (1999). Exposure to NaOH could potentially increase the pH of the blood. However, the pH of the blood is regulated between narrow ranges to maintain homeostasis (pH of 7.4 to 7.5) by urinary excretion of bicarbonate and via exhalation of carbon dioxide.

Acute Toxicity

An oral LD_{50} of a 1-10% solution of NaOH in rabbits was reported to be 325 mg/kg (expressed as 100% NaOH). Mortality was also observed when 1% NaOH was dosed, but in this case, the applied volume was relatively high (24 mL per kg body weight).

Irritation

A NaOH solution of 8% can be considered corrosive based on animal data. Human data indicate that concentrations of 0.5 to 4% were irritating. In two different studies a concentration of 0.5% was irritating for only 55 and 61% of the volunteers, respectively. Thus, it is assumed that a concentration, which is slightly lower than 0.5%, is the non-irritating concentration.

The available animal data on eye irritation showed that the non-irritant level was 0.2-1.0 %, while the corrosive concentration was 1.2 % or >2%.

Sensitization

Male volunteers were exposed on the back to sodium hydroxide concentrations of 0.063 – 1.0% (induction). After 7 days the volunteers were challenged to a concentration of 0.125%. The irritant response correlated well with the concentration of NaOH, but an increased response was not observed when the previously patch tested sites were re-challenged. Based on this study sodium hydroxide has no skin sensitization potential.

Repeated Dose Toxicity

No animal data are available on repeated dose toxicity studies by oral, dermal, inhalation or by other routes for NaOH. It is not useful to study the repeated dose toxicity of hydroxide via an oral study because at high concentrations the substance is corrosive or irritating, while at low concentrations the hydroxide will be neutralized in the stomach by gastric juice, which has a very low pH.

Genotoxicity

Both the *in vitro* and the *in vivo* genotoxicity tests are negative.

Carcinogenicity

No carcinogenicity studies on sodium hydroxide were identified.

Reproductive Toxicity

No valid studies were identified regarding toxicity to reproduction in animals after oral, dermal or inhalation exposure to NaOH. It is not useful to study the reproduction/developmental toxicity of hydroxide via an oral study because at high concentrations the substance is corrosive or irritating, while at low concentrations the hydroxide will be neutralized in the stomach by gastric juice, which has a very low pH.

Developmental Toxicity

No valid studies were identified regarding developmental toxicity in animals after oral, dermal or inhalation exposure to NaOH. It is not useful to study the reproduction/developmental toxicity of hydroxide via an oral study because at high concentrations the substance is corrosive or irritating, while at low concentrations the hydroxide will be neutralized in the stomach by gastric juice, which has a very low pH.

Key Study/Critical Effect for Screening Criteria

The Australian drinking water guideline value for pH may apply to sodium hydroxide.

Reference

OECD (2002). IUCLID Data Set for Sodium hydroxide (CAS No. 1310-73-2), UNEP Publications.

OECD (2002). Screening Information Dataset (SIDS) Initial Assessment Report for Sodium hydroxide (CAS No. 1310-73-2), UNEP Publications.

Toxicity Profile

Triethanolamine
[2,2′,2″-nitrilotriethanol]
(CAS No. 102-71-6)

Acute Toxicity

The oral LD_{50} in rats is 6,400 mg/kg (ECHA), and the dermal LD_{50} in rabbits is >2,000 mg/kg (ECHA). No deaths seen in rats following an 8-hour exposure to a saturated vapor atmosphere [approximately 1.8 mg/m^3] (ECHA).

Irritation

Triethanolamine is not a skin irritant to rabbits when applied for 4 hours under occluded conditions (ECHA). It is not irritating to the eyes of rabbits (Griffith *et al.*, 1980; ECHA).

Sensitization

Triethanolamine was not considered a skin sensitizer when tested in a guinea pig maximization test (ECHA).

Repeated Dose Toxicity (Oral only)

Male and female Cox CD rats were fed in their diet 0, 250, 500 or 1,000 mg/kg triethanolamine for 91 days (ECHA). There were no effects that were considered treatment-related. The NOAEL for this study is 1,000 mg/kg-day.

Genotoxicity

Triethanolamine was not mutagenic to *S. typhimurium* strains TA1535, TA1537, TA97, TA 98 or TA100 in the absence or presence of metabolic activation (Mortelsman *et al.*, 1986). Nor was triethanolamine mutagenic in mouse lymphoma L5178Y cells in the absence or presence of metabolic activation (ECHA). Triethanolamine did not increase sister chromatid exchanges (SCEs) or chromosomal aberrations in Chinese Hamster Ovary (CHO) cells in the absence or presence of metabolic activation (Galloway *et al.*, 1987).

Male and female B6C3F$_1$ mice were given dermal applications of triethanolamine, 5 days/week for 13 weeks (NTP, 2004). There were no increase in the frequency of micronucleated erythrocytes in the peripheral blood.

Triethanolamine did not induce sex-linked recessive lethal mutations in germ cells of adult male *Drosophila melanogaster* exposed by feeding or injection (Yoon *et al.*, 1985).

Carcinogenicity

Male and female B6C3F$_1$ mice were given in their drinking water 0, 1 or 2% triethanolamine (0 and approximately 1,600 and 3,200 mg/kg-day) for 82 weeks. (Konishi *et al.*, 1992). Mortality, organ weights and tumor incidences were similar between treated and control animals.

Male and female F344 rats were given dermal applications of triethanolamine, 5 days/week for two years (NTP, 1999). The doses were: 0, 32, 63 or 125 mg/kg-day for males, and 0, 63, 125 or 250 mg/kg-day for females. There were no treatment-related carcinogenic effects in either sexes.

Male and female B6C3F$_1$ mice were given dermal applications of triethanolamine, 5 days/week for two years (NTP, 2004). The doses were: 0, 200, 630 and 2,000 mg/kg-day for males, and 0, 100, 300 and 1,000 mg/kg-day for females. In females, there was some evidence of carcinogenicity activity based on increased incidences of hepatocellular adenomas. In males, there was equivocal evidence of carcinogenicity activity based on the incidence of liver hemangiosarcomas.

Reproductive/developmental Toxicity

In a reproductive and developmental toxicity screening (OECD 421) study, male and female Wistar rats were dosed by oral gavage with 0, 100, 300 or 1,000 mg/kg-day triethanolamine (ECHA). Most of the 1,000 mg/kg-day animals and one 100 mg/kg-day animals showed transient salivation for a few minutes immediately after each treatment. This effect was considered to be induced by the unpalatability of the test substance or from local irritation of the upper digestive tract. Body weight gain was slightly lower in the 1,000 mg/kg-day females during gestation and was considered to be caused by the increased postimplantation loss rather than by a systemic effect of the test substance. In the 1,000 mg/kg-day group, there were lower mean number of implantation sites, increased postimplantation loss, and lower average litter size. There were no treatment-related effects in the F$_1$ pups. The NOAEL for systemic toxicity is 1,000 mg/kg-day. The NOAEL for reproductive toxicity is 1,000 mg/kg-day. The NOAEL for developmental toxicity is 300 mg/kg-day.

Key Study/Critical Effect for Screening Criteria

There were no adverse effects in male or female rats given 1,000 mg/kg-day in the diet, the highest dose tested, for 91 days (ECHA). The NOAEL for this study is 1,000 mg/kg-day.

Oral RfD = 1,000/1,000 = 1.0 mg/kg/day

Drinking water guideline value = 3.5 ppm

References

ECHA REACH database: http://apps.echa.europa.eu/registered/registered-sub.aspx

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Toxicity Profile

Tributyl Tetradecyl Phosphonium Chloride [TTPC]
(CAS No. 81741-28-8)

Acute Toxicity

An oral LD_{50} in rats was reported to be 1,002 mg/kg. The 4-hour LC_{50} to rats is <0.9 mg/L (aerosol) (MSDS for Bellecide 350).

Irritation

TTPC is corrosive to the skin and eyes (MSDS for Bellecide 350).

Sensitization

TTPC is not a skin sensitizer (MSDS for Bellecide 350).

Repeated Dose Toxicity

A 90-day rat drinking water study has been conducted on a product containing TTPC. The LOAEL for the active ingredient (TTPC) is 27.2 and 32.3 mg/kg-day in males and females, respectively, based on various clinical signs and significantly reduced body weights, feed and water consumption. The NOAEL for TTPC is 8.66 mg/kg-day (EPA 2006).

Genotoxicity

TTPC tested negative in an Ames test (MSDS for Bellecide 350).

Carcinogenicity

No data were found.

Reproductive Toxicity

No data were found.

Developmental Toxicity

Female Tif:RAIf(SPF) rats were dosed by oral gavage with 0, 20, 60, or 120 mg/kg Belclene® [50% active ingredient: TTPC] during gestational days (GD) 6 through 15. In the high-dose dams, there were two possible treatment-related spontaneous deaths (GD 9 and 14) and another death on GD 15 due to an intubation error. Clinical signs included dyspnea in one mid-dose and 4 high-dose animals, and vaginal bleeding in one mid-dose female on GD 15. In the high-dose dams, maternal body weight gain was significantly lower during the treatment period (GD 6-15) and throughout the gestational period (GD 0-20). Mean food consumption was significantly reduced during GD 6-11 for both the mid- and high-dose animals. The number of females with implantations and the number of implantations/females were similar across all groups. Embryonic and fetal deaths were similar between treated and control groups. There were no soft tissue changes. There was an increased incidence of incomplete ossification of the 5th sternebra in the mid- and high-dose groups. The NOAELs for maternal and developmental toxicity for the active ingredient TTPC in this study is 30 and 10 mg/kg-day (EPA 2006).

Female chinchilla rabbits were dosed by oral gavage with 0, 7.5, 22.5, or 45 mg/kg Belclene® [50% active ingredient: TTPC] during gestational days (GD) 6 through 18. In the mid- and high-dose groups, body weight gain was significantly reduced during GD 6-18 and feed consumption was reduced during GD 6-11. Fetal body weights were significantly reduced in the mid-(males only) and high-dose dose groups. There was also an increased incidence of delayed ossification of the hindlimb phalangeal nuclei in the mid- and high-dose groups. The NOAELs for maternal and developmental toxicity for the active ingredient TTPC in this study are 3.75 mg/kg-day (EPA 2006).

Key Study/Critical Effect for Screening Criteria

The NOAEL from the rat 90-day drinking water study with TTPC as the active ingredient is 8.66 mg/kg-day.

Oral

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (subchronic to chronic)

Oral RfD = 8.66/1000 = 0.009 mg/kg-day

Drinking water guidance value = 0.03 ppm

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Material Safety Data Sheet for Bellacide 350, BWA Water Additives, SDS No. 10794, Report Date: 10/03/2009.

Toxicity Profile

Ulexite
(CAS No. 1319-33-1)

Ulexite is a structurally complex mineral with the chemical structure ($NaCaB_5O_6(OH)_6 \bullet 5H_2O$). It is slightly soluble in water. One of the uses of ground alexite is in agricultural applications as a source of slow-release boron. No toxicity data exists on boron. It is unclear whether any boron would be released from ulexite if ingested. However, for the purposes of this toxicity profile, toxicity data on borax and boric acid will be used to read across to ulexite. The rationale is as follows:

Borax is also known as sodium borate, sodium tetraborate, or disodium tetraborate. With water content, borax can refer to a group of compounds that differ in their crystal water content, but typically it is disodium tetraborate decahydrate with the chemical structure ($Na_2B_4O_7 \bullet 10H_2O$). Borax is moderately soluble in water, with the main species in freshwater being the borate ion $[B(OH)_4]^-$ and boric acid $B(OH)_3$, depending on the pH. The relative proportion of boric acid and borate ions is controlled by pH: $B(OH)_3 + 2H_2O \Leftrightarrow [B(OH)_4]^- + H_3O^-$. In dilute aqueous solutions, boric acid does not dissociate at pH <7; at pH values between 7 and 11, both boric acid and borate ions are present. In dilute aqueous solutions and physiological conditions, the predominant species present is un-dissociated boric acid. So, the consideration of boric acid addresses the relevant toxicological properties of borax.

Exposure to borates are often expressed in terms of boron (B) equivalents based on the fraction of boron in the source substance on a molecular weight basis. The B-equivalents used are a generic designation rather than a designation of the element boron. The factor for converting disodium tetraborate decahydrate, boric acid, and ulexite to B-equivalents are 0.113, 0.175, and 0.133, respectively.

Acute Toxicity

The acute oral LD_{50} value in rats for disodium tetraborate decahydrate is 5,560 mg/kg [628 mg B/kg] (Meyding and Foglhian 1961; Austria 2008). The acute dermal LD_{50} for disodium tetraborate decahydrate is >2,000 mg/kg [226 mg B/kg] (Reagan and Becci, 1985a; Austria 2008). The acute inhalation 4-hour LC_{50} is >2.03 mg/L [0.23 mg B/L] (Wnorowski 1994a; Austria 2008).

Irritation

Disodium tetraborate hydrate is mildly irritating to the abraded skin of rabbits (Roudabush *et al.* 1964; Austria 2008). In another study, it was non-irritating to the skin of rabbits with erythema and edema scores of 0 (Reagan and Becci 1985b; Austria 2008). Disodium tetraborate hydrate is irritating to the eyes of rabbits (Reagan and Becci 1985c; Doyle 1989; Austria 2008). In the study by Doyle (1989), the test substance was ground to a fine powder to reduce the glassy, sharp crystals.

Sensitization

Disodium tetraborate hydrate was not considered a skin sensitizer to the skin of guinea pigs (Wnorowski 1994b; Austria 2008).

Repeated Dose Toxicity

Rats were administered in their feed 0, 52.5, 175, 525, 1,750 or 5,250 ppm B equivalent (as boric acid or borax) for 90 days (Weir 1962; Weir and Fisher, 1972). The average intake has been estimated to be approximately 0, 2.6, 8.8, 26, 87.5 or 262.5 mg B/kg-day, respectively (U.S. EPA 2004). By week 6, all of the animals in the highest dose died. Clinical signs in the top two dose levels were rapid respiration, hunched position, bloody nasal discharge, urine stains on the abdomen, inflamed eyes, desquamation and swollen paws and tail. There was also reduced food consumption and body weight gain. The 1,750 ppm females showed reduced (liver, spleen and ovary weights; the 1,750 ppm males showed reduced kidney and adrenal weights. The adrenals of 4 of the 1,750 ppm males showed minor increases in lipid content and size of the cells in the zona reticularis. Atropied testis (complete atrophy of the spermatogenic epithelium and decreased in the size of the seminiferous tubules) was seen in all of the 1,750 ppm males. One 525 ppm male given boric acid had partial testicular atrophy; no effects were seen in male rats given disodium tetraborate decahydrate at this dose level.

Male and female $B6CF_1$ mice were administered 0, 1,200, 2,500, 5,000, 10,000 or 20,000 ppm boric acid for 13 or 16 weeks (NTP 1987). These dietary levels correspond to approximately 0, 34, 70, 141, 281 and 563 mg B/kg-day for males, respectively; and 0, 47, 97, 194, 388 and 776 mg B/kg-day for females, respectively. There >60% mortality in the 20,000 ppm group as well as hyperkeratosis and acanthosis. At 10,000 ppm, there was 10% mortality in the males. Degeneration or atrophy of the seminiferous tubules occurred in the $\geq$5,000 ppm males. Minimal to mild extramedullary hematopoiesis of the spleen was observed in all dose groups.

Male and female SD rats were administered in their feed 0, 117, 350 or 1,170 ppm borax or boric acid for two years (Weir 1966a,b; Weir and Fisher 1972). The average intake has been estimated to be approximately 0, 5.9, 17.5 or 58.5 mg B/kg-day, respectively (U.S. EPA 2004). The 1,170 ppm rats had decreased food consumption during the first 13 weeks of the study and suppressed growth throughout the study. Signs of toxicity in the 1,170 ppm animals included swelling and desquamation of the paws, scaly tails, inflammation of the eyelids, and bloody discharge from the eyes. All of the 1,170 ppm males had testicular atrophy at the 6, 12 and 24 month time points. The seminiferous epithelium was atrophied, and the tubular size in the testes was decreased. There were significant decreases in the absolute and relative testes weights. Brain and relative thyroid weights were increased. The NOAEL for this study is 350 ppm borax or boric acid (17.5 mg B/kg-day).

Male and female B6C3F$_1$ mice were given 0, 2,500 or 5,000 ppm boric acid in their feed for 103 weeks (NTP, 1987). These dose levels were equivalent to 0, 275 or 550 mg/kg-day boric acid or 0, 48 or 96 mg B/kg-day. At termination, the survival rates were 82, 60 and 44% in the control, low- and high-dose males, respectively; and 66, 66 and 74% in the control, low- and high-dose females, respectively. There was testicular atrophy and interstitial cell hyperplasia in the 5,000 ppm males. A dose-related increase in the incidences of splenic lymphoid depletion in male mice was also observed. NTP considered this lesion to be associated with stress and debilitation, and it is reflected in the increased mortality in these groups of male mice.

Genotoxicity

Disodium tetraborate decahydrate was not mutagenic when tested *in vitro* using V79 Chinese hamster cells, C3H/10T1/2 mouse embryo fibroblasts, and diploid human foreskin fibroblasts (Landolph 1985).

Boric acid has been tested in a variety of *in vitro* genotoxicity tests (NTP 1987; Haworth et al. 1983; Landolph 1985; Bakke 1991; Stewart 1991; Rudd 1991; U.S. EPA 2004). No evidence of mutagenicity of genotoxicity was observed.

Boric acid was not genotoxic in a mouse bone marrow micronucleus assay at oral doses of 0, 900, 1,800 and 3,500 mg/kg given on two consecutive days (O'Loughlin 1991).

Carcinogenicity

No carcinogenic effects were seen in the two-year rat dietary studies on disodium tetraborate decahydrate and boric acid (Weir 1966a,b; Weir and Fisher 1972). The dose levels in feed were 0, 117, 350 or 1,170 ppm borax or boric acid, which were estimated to be approximately 0, 5.9, 17.5 or 58.5 mg B/kg-day, respectively.

Male and female B6C3F$_1$ mice were given 0, 2,500 or 5,000 ppm boric acid in their feed for 103 weeks (NTP, 1987). These dose levels were equivalent to 0, 275 or 550 mg/kg-day boric acid or 0, 48 or 96 mg B/kg-day. No carcinogenic effects were observed.

Reproductive Toxicity

Three-generation reproductive toxicity studies were conducted in albino rats (strain not specified) with boric acid or disodium tetraborate decahydrate (Weir and Fisher 1972; reviewed in Moore 1997). Groups of rats (8 males and 16 females) were fed a diet that contained 0, 117, 350 or 1,170 ppm boron as borax or boric acid (approximately 0, 5.9, 17.5 or 58.5 mg B/kg-day, respectively). Male and female body weight gains in both studies were reduced in the 58.5 mg B/kg-day groups. Mating between treated males and females in the high-dose groups showed complete infertility, which was attributed to both sexes. Males had grossly atrophied testes and histologic examination showed an absence of viable sperm. When treated females were subsequently mated with control males,

there was reduced fertility. Only 2/16 females produced live litters in the borax study, and one other female became pregnant and aborted her litter. None of the pups survived until weaning. One of 16 females fed boric acid produced a litter with six live pups; three females became pregnant and aborted their litters. Only three pups survived to weaning of the six living pups. Histologic examinations from both studies showed that much of the decrease in female fertility was a product of reduced ovulation. The cause of the mortality in pups during the postnatal period is unknown. At the lower dose levels, the effects were minor with no obvious effects on fertility. The NOAEL was determined to be 17.5 mg B/kg-day.

In a continuous breeding protocol, male and female CD-1 mice were given 0, 1,000, 4,500 or 9,000 ppm boric acid in their feed (Fail *et al.* 1991). No litters were occurred in the high-dose breeding pairs. In the mid-dose, there was a successful first litter, after which there was a progressive decrease in fertility; only one pair produced a fourth and fifth litter. All fertility indices were affected in the mid-dose group. A complete crossover mating trial was conducted using control mice and the mid-dose mice, which indicated that the probable cause of the reduced fertility was a decrement in male fertility. A dose-related decrease in body, testicular and epididymal weights was observed in the mid- and high-dose F_0 males. Sperm count was significantly decreased in these dose groups, and percent motile sperm was decreased in all dose groups. Testicular histopathology showed seminiferous tubular atrophy in the high-dose males and partial atrophy of the seminiferous tubules in the mid-dose males. There were no histopathologic changes in the mid-dose females. No statistically significant decreases in mating index, fertility index, or live pups/litter in the mid-dose females, but the number of days to litter in this dose group was increased. Estrous cyclicity was unaffected. Reproductive organ weights were unaffected, but relative maternal liver and kidney/adrenal weights were reduced. An F_1 fertility trial was performed using offspring from the low-dose groups. There was no decreases in mating, fertility or reproductive performance. The F_2 adjusted live pup weight was slightly, but significantly, reduced from controls. A clear NOAEL for reproductive toxicity in males was not seen in this study. Decreased sperm motility was observed in the F_0 generation and sperm concentration was decreased in the F_1 generation in the low-dose males. Decreased F_2 pup relative body weight was statistically significant from controls. The NOAEL in females is 1,000 ppm boric acid (27 mg B/kg-day.

Male deer mice were fed a diet containing 0, 4,500 or 9000 ppm boric acid (0, 108 or 216 mg B/kg-day, respectively) for eight weeks (Fail *et al.* 1989; reviewed in Moore 1997). At the end of the 8-week exposure period, half of the male deer mice were mated with untreated adult female deer mice for one week. Following the mating trial, these males were killed and necropsied. The other groups of treated male deer mice were fed a diet containing no boric acid for an additional 9-week period to assess any recovery from the boron treatment. After the 9-week recovery period, the male deer mice were mated for one week with untreated adult female deer mice, then killed and necropsied. After each mating trial, the females were allowed to litter and the resulting pups were counted, sexed, and weighed at birth. Exposure of the male deer mice to 9,000 ppm boric acid for 8 weeks resulted in complete infertility. There was no decrease in fertility in the 4,500

ppm male deer mice. Decreased testicular and epididymal weights occurred in the 9,000 ppm male deer mice; and there was a reduction in the seminiferous index (a semi-quantitative rating of cell types present), which was thought to have resulted in the observed decrease in formation of mature sperm. There were no treatment-related changes in body and organ weights, seminiferous index and litter measurements in the 4,500 ppm mice. Following a 9-week "recovery" period, the fertility performance in the high-dose male mice, as well as the necropsy results and histopathologic examination of the testes, were similar to the controls.

Male Fischer rats were administered 0, 3,000, 4,500, 6,000 or 9,000 ppm boric acid [0, 17.3, 25.9, 37.8, 51.8 or 68 mg B/kg-day] in their feed for 9 weeks (Ku *et al.* 1993; reviewed in Moore 1997). After 9 weeks on the test diet, a group of rats were returned to a control diet and recovery was assessed at 8, 16, 24 and 32 weeks post-treatment. There as a strong relationship between boric acid exposure and testicular lesions. Inhibition of spermiation, which was characterized as the aberrant retention of step 19 spermatids in stage IX-XI tubules, was seen in the 25.9 and 37.8 mg B/kg groups. The 51.8 and 63 mg B/kg rats developed severe inhibition of spermiation by week 2, which progressed to testicular atrophy (defined as complete absence of post-spermatogonial germ cells). There was no signs of recovery from the testicular atrophy in these two high-dose groups after 32 weeks of no exposure even though these tubules contained a normal complement of spermatogonia and Sertoli cells and the spermatogonia were seen to divide. These rats appeared to have an intact gonadotropin response since serum FSH and LH levels were increased. The authors referred to a preliminary study of the same size and duration, in which 2,000 ppm boric acid [17.3 mg B/kg-day B] was not observed to cause any testicular effects. Although the authors did not consider 25.9 mg B/kg-day to be an adverse effect because of the absence of changes in other testicular and reproductive indices, an Expert Committee (Moore 1997) considered this dose level to a LOAEL and 17.3 mg B/kg-day to be a NOAEL.

Developmental Toxicity

Pregnant SD rats were given 0, 0.1, 0.2 or 0.4% boric acid in their feed on gestational days (GD) 0 to 20 or 0.8% boric acid on GD 6 to 15 (Heindel *et al.* 1992). The average amounts of boric acid ingested were estimated to be 0, 78, 163, 330 or 539 mg/kg-day (0, 13.6, 28.5 or 57.7 mg B/kg-day), respectively. Effects on the dams were altered food and/or water intake at $\geq$0.2% boric acid, increased liver and kidney weights relative to body weights at $\geq$0.2%, reduced weight gain at $\geq$0.4%, and increased corrected weight gain at 0.4% boric acid. There was a reduction in fetal body weights in all treated groups (94, 87, 63, and 47% of control weight, respectively). Increased malformations occurred at $\geq$0.2% and prenatal mortality was increased at 0.8%. There was a dose-response for altered skeletal morphology in rats ($\geq$0.1%), and specific findings were significantly elevated above controls at $\geq$0.2%. Specifically, there was an increased incidence of short rib XIII (a malformation) and a decreased incidence or rudimentary or full rib(s) at lumbar I (an anatomical variation).

Pregnant SD rats were given 0, 0.025, 0.005, 0.075, 0.1 or 0.2% boric acid in their feed on GD 0 to 20 (Price *et al.* 1996a). Approximately half of the dams were terminated on GD 20, and the remaining dams delivered their litters. Pup growth and viability were monitored until postnatal day (PND) 21. The average amounts of boric acid ingested on GD 20 (PND 21) were: 0(0), 19(19), 36(37), 55(56), 76(74) or 143(145) mg/kg-day, [0, 3.3(3.2), 6.3(6.5), 9.6(9.7), 13.3(12.9), and 25(25.3) mg B/kg-day], respectively. Maternal toxicity consisted of increased relative kidney weights in the 0.2% group. There were no differences in the viability of the offspring between treated and controls. On GD 20, fetal body weight was 94% and 88% of controls in the 0.1% and 0.2% groups, respectively; recovery was complete at birth (~GD 22). The incidence of short rib XIII was increased in GD 20 in the $\geq$0.1% groups., but only in the 0.2% group at PND 21. The incidence of wavy rib was increased on GD 20 in the $\geq$0.1% group; the reversibility of this effect was confirmed on PND 21. There was a slight decrease in extra lumbar ribs in the 0.2% group on GD 20, and extra lumbar ribs were seen in the 0.2% group on PND 21. The developmental NOAEL was considered to be 0.075% boric acid (9.6 mg B/kg-day) on GD 20 and 0.1% boric acid (12.9 mg B/kg-day) on PND 21.

Pregnant Swiss mice were given 0, 0.1, 0.2 or 0.4% boric acid in their feed on gestational days (GD) 0 to 17 (Heindel *et al.* 1992). The average amounts of boric acid ingested were estimated to be 248, 452 or 1,003 mg/kg-day (0, 43.4, 79.0 or 175.3 mg/B/kg-day), respectively. Maternal toxicity consisted of mild kidney lesions ($\geq$0.1%), increased water intake and relative kidney weights (0.4%), and decreased water intake during treatment. Fetal body weights were reduced in the $\geq$0.2% groups, and there were increased incidences of resorptions and malformed fetuses per litter in the 0.4% group.

Pregnant New Zealand rabbits were dosed by oral gavage with 0, 62.5, 125 or 250 mg/kg boric acid (0, 10.9, 21.9 or 43.7 mg B/kg) during GD 6-19 (Price *et al.* 1996b). There was reduced food intake during treatment in the 250 mg/kg maternal animals, but it was increased in the $\geq$125 mg/kg dose groups. In the 250 mg/kg group, there were decreased maternal body weight (GD 9-30), weight gain during treatment, gravid uterine weight, and number of ovarian corpora lutea. In the $\geq$125 mg/kg groups, maternal corrected gestational weight gain was increased. Maternal liver weights were unaffected by treatment. In the 250 mg/kg group, relative, but not absolute, kidney weights were increased, although no effects in the kidney were noted in the histopathological examination. Prenatal mortality was increased in the 250 mg/kg group (90% resorptions/litter versus 6% for controls); the proportion of pregnant females with no live fetuses was increased (73% versus 0%), and live litter size was reduced (2.3 fetuses versus 8.8). Thus, there were only 14 live fetuses (6 live litters) available for evaluation in the 250 mg/kg group. The percentage malformed fetuses/litter was increased in the 250 mg/kg group, primarily due to cardiovascular defects (72% versus 3% of controls). There was no definitive maternal or developmental toxicity in the 62.5 or 125 mg/kg dose groups.

Key Study/Critical Effect for Screening Criteria

The U.S. Environmental Protection Agency (U.S. EPA) derived an Oral Reference Dose (RfD) for boron of 0.2 mg B/kg-day (U.S. EPA 2004) based on developmental effects in rats from two studies (Price *et al.* 1996a; Heindel *et al.* 1992). The RfD was derived using the benchmark dose (BMD) method ($BMDL_{05}$ from Allen *et al.* 1996) using a data derived uncertainty factor of 66. Decreased fetal body weight was considered by Allen *et al.* (1996) as the most suitable endpoint for developing a point of departure, because the benchmark doses calculated for the other endpoints (incidence of total malformations, enlarged lateral ventricles in the brain, shortening of rib XIII, and variations of the first lumbar rib) were higher.

Oral RfD = 0.2 mg B/kg-day

Drinking water guidance value = 0.7 ppm (boron)

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Santos

APPENDIX F.9 FLUOROSCEIN DYE

Toxicity Profile

Potassium chloride
(CAS No. 7447-40-7)

Potassium chloride (KCl) has been reviewed in the OECD-SIDS program (OECD, 2001).

Potassium chloride (KCl) is an inorganic salt that readily dissociates in aqueous media to K^+ and Cl^-.

Acute Toxicity

The oral LD_{50} in rats has been reported to be 3,020 mg/kg (Boyd and Shanas, 1961).

Irritation

Potassium chloride did not produce an irritant response in an *in vitro* skin irritation OECD 439 test or an *in vitro* eye irritation test (ECHA).

Repeated Dose Toxicity

Fourteen female rats were given KCl in their drinking water (approximately 5,250 mg/kg/day) for 105 days. Ten rats were sacrificed after 105 days of exposure for examination of the heart, kidneys and the adrenals; four rats (recovery group) were kept for an additional month. KCl exposure resulted in decreased heart weight, increased kidney weight, and enlargement of part of the adrenals. All changes were reversible within one month of exposure (Bacchus, 1951).

F344/Slc male rats were given 0, 110, 450 or 1,820 mg/kg/day KCl in feed for two years. At the end of the study, survival rates were 48%, 64%, 58% and 84% in the controls, 110, 45 and 1,820 mg/kg/day groups. Nephritis was reported to be predominant in all groups, including the controls. The only treatment-related effect observed was gastritis (inflammation of the stomach lining). The incidence of gastritis and ulcers were 6%, 18%, 18% and 30% in the controls, 110, 450 and 1,820 mg/kg/day groups (Imai *et al.*, 1968).

Male and female Wistar rats were fed diets containing 0 or 3% KCl over a total period of 30 months: Examination after 13 weeks (10 rats/sex/group), after 18 months (15 rats/sex/group) and after 30 months (50 rats/sex /group). Due to the reduction of feed intake the mean test substance intake and mean body weight decreased in time. After 30 months of treatment, there was hypertrophy of the zona glomerulosa in the adrenals (24/50 treated rats versus 4/50 in controls); and cystitis in the urinary bladder (males: 3/59; females 3/50) and single epithelial hyperplasia of the bladder (males 3/50; females

2/50) (Lina *et al.*, 1994; Lina and Kuijpers, 2004)**.**

Genotoxicity

Potassium chloride was not mutagenic to *Salmonella typhimurium* strains TA100, TA 1535, TA 1537 and TA 98 strains in an *in vitro* bacterial mutation assay in the presence or absence of metabolic activation (Mortelmans *et al.*, 1986). KCl was also not mutagenic to *E. coli* in a SOS chromotest (Olivier and Marzin, 1987).

In two different studies, KCl was found to be weakly mutagenic to mouse lymphoma L5178Y cells at high concentrations (Myhr and Caspary, 1988; Mitchell *et al.*, 1988).

Potassium chloride induced a significant increase in chromosomal aberrations in Chinese Hamster lung fibroblasts (V79) cells only at the highest test dose (12,000 µg/ml) in the absence of a metabolic activation system. Measurements of the osmotic pressure of the medium revealed a two-fold increase at this test compound concentration when compared to the normal medium (530 mOsmol/ kg versus 253 mOsmol/kg (Hasegawa *et al.*, 1984). There are two other reports on the effect of KCl on formation of chromosome aberrations in Chinese hamster ovary cells (CHO). In these studies KCl concentrations of 75 and 80 mM (approximately 5500 and 6000 µg/ml) resulted in 19% and 28% aberrant cells respectively. Increased number of chromosome aberrations was observed with KCl concentrations that reduced cell survival 40% and more. It is reasonable to conclude that the increases in mutagenicity and chromosome aberrations observed in these studies are related to cytotoxicity resulting from the high KCl concentrations used. This argument is supported by the studies on the effect of increased osmolarity on genotoxicity in cultured mammalian cells.

The reported mutagenic effect of KCl most probably results from a disruption of osmotic balance of cells with a subsequent interference with chromosomal stability. This may result in the clastogenic effects (DNA breakage and chromosome structural instability) due to K^+ effects on sequestering of Mg^{++} ions required for normal maintenance of chromatin integrity. Other chemicals may also exert such effect (*e.g.*, NaCl, sucrose).

Carcinogenicity

F344/Slc male rats were given 0, 110, 450 or 1,820 mg/kg/day KCl in feed for two years. At the end of the study, survival rates were 48%, 64%, 58% and 84% in the controls, 110, 45 and 1,820 mg/kg/day groups. There was no increased incidence of tumors that were considered to be treatment-related (Imai *et al.*, 1968).

Reproductive/Developmental Toxicity

Pregnant female Wistar rats were given by oral gavage 3.1 to 310 mg/kg KCl during gestation days 5 through 15, and sacrificed on gestation day 20. There were no effects on

survival, total number of corpora lutea, implant sites, resorptions, soft tissue observations (urogenital tract), or live offspring. No treatment-related effects were seen in the offspring with regards to survival, sex ratio, average offspring weight, external congenital abnormalities, soft tissue or skeletal defects. The maternal and developmental NOAELs were 310 mg/kg/day (FDRL, 1975).

Female CD-1 mice were given by oral gavage 2.35 to 235 mg/kg KCL during gestation days 5 through 15, and sacrificed on gestation day 17. There were no effects on survival, total number of corpora lutea, implant sites, resorptions, soft tissue observations (urogenital tract), or live offspring. No treatment-related effects were seen in the offspring with regards to survival, sex ratio, average offspring weight, external congenital abnormalities, soft tissue or skeletal defects. The maternal and developmental NOAELs were 235 mg/kg/day (FDRL, 1975).

Key Study/Critical Effect for Screening Criteria

In a two-year rat feeding study, there was an increased incidence of gastritis and ulcers at dose levels of $\geq$110 mg/kg/day (Imai *et al.*, 1968). There was no NOAEL. Thus, the LOAEL for this study is 110 mg/kg-day. Since the gastritis and ulcers are the result of a localized irritation effect of the test substance (site of contact) in the gastrointestinal tract, an uncertainty factor for interspecies variability is deemed unnecessary.

For systemic effects, the NOAEL for the two-year rat feeding study is considered to be 1,820 mg/kg/day, the highest dose tested.

Uncertainty factors: 10 (intraspecies variability); 10 (interspecies variability); 1 (intraspecies variability)

Oral Reference Dose = 1,820/100 = 18.2 mg/kg/day

Drinking water guideline: 64 ppm

References

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Toxicity Profile

Sodium Fluorescein
[D&C Yellow No. 8; Acid Yellow 73]
(CAS No. 518-47-8)

Acute Toxicity

The oral LD_{50} values in rats and mice are 6,721 and 4,738 mg/kg (Yankell and Loux 1977).

Irritation

No studies were located.

Sensitization

No studies were located.

Repeat Dose Toxicity Studies

No studies were located.

Genotoxicity

The National Toxicology Program (NTP) conducted *in vitro* and *in vivo* genotoxicity studies on sodium fluorescein. Sodium fluorescein was not mutagenic to *Salmonella* in a bacterial reverse mutation assay, but is was mutagenic to mouse lymphoma L5178Y cells. When tested in Chinese hamster (CHO) cells, it was negative for chromosomal aberrations but positive for sister chromatid exchanges (SCEs). Mice administered sodium fluorescein showed an increased incidence of SCEs, but no increase for micronuclei or chromosomal aberrations. Sodium fluorescein was inactive to Drosophila in a reciprocal translocation/sex-linked recessive lethal test (NTP 2015).

Carcinogenicity

The National Toxicology Program (NTP) conducted a cancer bioassay on sodium fluorescein. Rat and mice were given doses of 0.25 to 1.0% in drinking for two years. NTP considered the studies inadequate and a technical report was not written.

Reproductive/Developmental Toxicity

Pregnant SD rats were dosed by oral gavage with 0, 100, 500, or 1,500 mg/kg-day sodium fluorescein on gestational days 6 to 19. There was no maternal or developmental toxicity noted at any dose level. The NOAELs for maternal and developmental toxicity is 1,500 mg/kg-day (Burnett and Goldenthal 1986).

Pregnant Dutch Belted rabbits were dosed by oral gavage with 0, 30, 100, or 250 mg/kg-day sodium fluorescein on gestational days 6 to 27. There was no maternal or developmental toxicity noted at any dose level. The NOAELs for maternal and developmental toxicity is 250 mg/kg-day (Burnett and Goldenthal 1986).

Key Study/Critical Effect for Screening Criteria

The NOAEL of 250 mg/kg-day from the rabbit developmental toxicity study will be used to derive a drinking water guidance value.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD = 250/100 = 2.5 mg/kg-day

Drinking water guideline = 8.8 ppm

References

Burnett, C.M., and Goldenthal, E.I. (1986). The teratogenic potential in rats and rabbits of D&C yellow No. 8. Fd. Chem. Toxic. 24: 819-823.

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Toxicity Profile

Tributyl Tetradecyl Phosphonium Chloride [TTPC]
(CAS No. 81741-28-8)

Acute Toxicity

An oral LD_{50} in rats was reported to be 1,002 mg/kg. The 4-hour LC_{50} to rats is <0.9 mg/L (aerosol) (MSDS for Bellecide 350).

Irritation

TTPC is corrosive to the skin and eyes (MSDS for Bellecide 350).

Sensitization

TTPC is not a skin sensitizer (MSDS for Bellecide 350).

Repeated Dose Toxicity

A 90-day rat drinking water study has been conducted on a product containing TTPC. The LOAEL for the active ingredient (TTPC) is 27.2 and 32.3 mg/kg-day in males and females, respectively, based on various clinical signs and significantly reduced body weights, feed and water consumption. The NOAEL for TTPC is 8.66 mg/kg-day (EPA 2006).

Genotoxicity

TTPC tested negative in an Ames test (MSDS for Bellecide 350).

Carcinogenicity

No data were found.

Reproductive Toxicity

No data were found.

Developmental Toxicity

Female Tif:RAIf(SPF) rats were dosed by oral gavage with 0, 20, 60, or 120 mg/kg Belclene® [50% active ingredient: TTPC] during gestational days (GD) 6 through 15. In the high-dose dams, there were two possible treatment-related spontaneous deaths (GD 9 and 14) and another death on GD 15 due to an intubation error. Clinical signs included dyspnea in one mid-dose and 4 high-dose animals, and vaginal bleeding in one mid-dose female on GD 15. In the high-dose dams, maternal body weight gain was significantly lower during the treatment period (GD 6-15) and throughout the gestational period (GD 0-20). Mean food consumption was significantly reduced during GD 6-11 for both the mid- and high-dose animals. The number of females with implantations and the number of implantations/females were similar across all groups. Embryonic and fetal deaths were similar between treated and control groups. There were no soft tissue changes. There was an increased incidence of incomplete ossification of the 5th sternebra in the mid- and high-dose groups. The NOAELs for maternal and developmental toxicity for the active ingredient TTPC in this study is 30 and 10 mg/kg-day (EPA 2006).

Female chinchilla rabbits were dosed by oral gavage with 0, 7.5, 22.5, or 45 mg/kg Belclene® [50% active ingredient: TTPC] during gestational days (GD) 6 through 18. In the mid- and high-dose groups, body weight gain was significantly reduced during GD 6-18 and feed consumption was reduced during GD 6-11. Fetal body weights were significantly reduced in the mid-(males only) and high-dose dose groups. There was also an increased incidence of delayed ossification of the hindlimb phalangeal nuclei in the mid- and high-dose groups. The NOAELs for maternal and developmental toxicity for the active ingredient TTPC in this study are 3.75 mg/kg-day (EPA 2006).

Key Study/Critical Effect for Screening Criteria

The NOAEL from the rat 90-day drinking water study with TTPC as the active ingredient is 8.66 mg/kg-day.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (subchronic to chronic)

Oral RfD = 8.66/1000 = 0.009 mg/kg-day

Drinking water guidance value = 0.03 ppm

References

Commonwealth of Australia (2012). Australian Exposure Factor Guidance. Guidelines for assessing human health risks from environmental hazards. Accessed

at: http://www.health.gov.au/internet/main/publishing.nsf/Content/A12B57E41EC9F326CA257BF0001F9E7D/$File/doha-aefg-120910.pdf

EPA (2006). Memorandum: Agency's Response to the Registrant Response for Acute Neurotoxicity and Repeated Exposure Inhalation Study and Determination of Inhalation MOE* and Developmental Toxicity Review for: Belclene 350 [Tri-n-butyl tetradecyl phosphonium chloride]. Office of Prevention, Pesticides and Toxic Substances, United States Environmental Protection Agency, June 27, 2006. Accessed at: http://www.epa.gov/opp00001/chem_search/cleared_reviews/csr_PC-128824_27-Jun-06_a.pdf

Material Safety Data Sheet for Bellacide 350, BWA Water Additives, SDS No. 10794, Report Date: 10/03/2009.

Santos

APPENDIX F.10 CONDOR ENERGY SYSTEMS

Toxicity Profile

2-Ethoxynaphthalene
(CAS No. 93-18-5)

Acute Toxicity

The oral LD_{50} in rats is 3,110 mg/kg (ECHA) [Kl. score = 2]. The dermal LD_{50} in rabbits is >5,000 mg/kg (ECHA) [Kl. score = 2]. There are no available acute inhalation toxicity studies.

Irritation

No skin irritation was observed when 2,000 mg/kg 2-ethoxynaphthalene was applied to the skin of rabbits for 24 hours under occlusive conditions. (ECHA) [Kl. score = 1]. Application of 2-ethoxynaphthalene to the skin of rabbits for 24 hours under occlusive conditions was moderately irritating (ECHA) [Kl. score = 2]. 2-Ethoxynaphthalene (2% in petrolatum) was not irritating to the skin after a 48-hour closed-patch test on human subjects (ECHA).

Instillation of 0.1 g 2-ethoxynaphthalene into the eyes of rabbits was irritating. The mean of the 24, 48, and 72-hour scores were: 1.00 for corneal opacity; 0.00 for iridial lesions; 2.00 for conjunctival redness; and 1.22 for chemosis (ECHA) [Kl. score = 1].

Sensitization

2-Ethoxynaphthalene was not a skin sensitizer in a guinea pig open epicutaneous test (ECHA) [Kl. score = 2]. 2-Ethoxynaphthalene was not a skin sensitizer in two human repeated insult patch tests involving 25 or 50 human volunteers (ECHA).

Repeated Dose Toxicity

Male and female rats fed in their diets 0 or 5 mg/kg 2-ethoxynaphthalene for 90 days. The actual dosages were 5.1 mg/kg-day for males and 5.7 mg/kg-day for females. There were no treatment-related effects. The NOAEL for this study is 5.1 and 5.7 mg/kg-day for males and females, respectively (Oser et al., 1965; ECHA) [Kl. score = 2].

Genotoxicity

The *in vitro* genotoxicity studies on 2-ethoxynapthalene are presented below in Table 1.

Table 1: *In vitro* Genotoxicity Studies on 2-Ethoxynapthalene

Test System	**Results***		**Klimisch Score**	**Reference**
	-S9	**+S9**		
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	ECHA
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	ECHA

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	ECHA

Carcinogenicity

No studies are available.

Reproductive Toxicity

No studies are available.

Developmental Toxicity

No studies are available.

Derivation of Toxicological Reference and Drinking Water Guidance Values

A 90-day dietary study in rats showed no effects at 5 mg/kg-day, the only dose tested (Oser et al., 1965; ECHA). The NOAEL of 5 mg/kg-day will be used to derive an oral reference value and a drinking water value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 3
UF_D (database uncertainty) = 1

Oral RfD = 5/(10 x 10 x 1 x 3 x 1) = 5/300 = 0.02 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (0.02 x 70 x 0.1)/2 = 0.07 mg/L

References

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

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Toxicity Profile

2-Mercaptoethyl alcohol
[2-ME]
(CAS No. 60-24-2)

Acute Toxicity

The oral LD_{50} values in rats are 162 and 336 mg/kg (ECHA) [Kl. scores = 1 and 2, respectively]. The 4-hour LC_{50} value in rats is 2 mg/L (ECHA) [Kl. score = 2]. The dermal LD_{50} in rabbits range from 112 to 224 mg/kg (ECHA) [Kl. score = 2].

Irritation

Application of 2-ME to the skin of rabbits for 4 hours under occlusive conditions was considered irritating (ECHA) [Kl. score = 2]. Instillation of 2-ME into the eyes of rabbits was corrosive when the eyes were not rinsed and irritating when the eyes were rinsed (ECHA) [Kl. scores = 2].

Sensitization

2-ME was considered a skin sensitizer when tested in a guinea pig maximization test (ECHA) [Kl. score = 2].

Repeated Dose Toxicity

2-ME was tested in a combined repeated dose toxicity study with a reproduction/developmental toxicity screening (OECD TG 407 and 422) test. Male and female SD rats were dosed by oral gavage with 0, 15, 50, or 75 mg/kg 2-ME over a study period of about 7 weeks. No toxic effects were recorded in the 15 mg/kg animals. A slightly higher body weight gain and food consumption was seen in the ≥50 mg/kg females (not significant, also at higher dose levels), whereas the ≥50 mg/kg males showed a significant lower body weight gain (-11 to -24%) compared to controls. Ptyalism was observed in both genders at ≥50 mg/kg. The ≥50 mg/kg males showed paleness and accentuated lobular pattern of the liver at necropsy, and minimal to marked vacuolated hepatocytes was seen in the histopathologic examination accompanied by lower blood cholesterol and triglyceride. The 75 mg/kg males had significantly increased absolute and relative liver weight (22 and 36%, respectively) and minimal to slight hypertrophy of hepatocytes. In the ≥50 mg/kg females, absolute and relative liver weight were significantly increased, and paleness of the liver was detected at termination; histopathological examinations showed minimal to slight liver cell hypertrophy, and increased incidence and severity of vacuolated hepatocytes. The incidence and severity of cardiomyopathy was increased in the 75 mg/kg males and in the ≥50 mg/kg females. There were no effects seen in the hematology, seminology, and urine analysis. The NOAEL is 15 mg/kg-day (ECHA) [Kl. score = 1].

Genotoxicity

The *in vitro* genotoxicity studies on 2-ME are presented below in Table 1.

Table 1: *In vitro* Genotoxicity Studies on 2-Mercaptoethyl Alcohol

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* strains	-	-	2	ECHA
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	-	-	2	ECHA
Chromosomal aberrations (human lymphocytes)	-	-	2	ECHA

Male and female mice were given a single intraperitoneal injection of 0, 50, 100, or 300 mg/kg 2-ME. The 300 mg/kg dose resulted in clinical signs of toxicity. The ≥100 mg/kg males had a decrease in the ratio of polychromatic to normochromatic erythrocytes, indicating bone marrow toxicity. The 300 mg/kg males showed a slight, but statistically significant, increase in the frequency of micronucleated polychromatic erythrocytes (MPE), but data generated in the additional analysis (further 2,000 polychromatic erythrocytes per animal evaluated) showed no significant difference between the 300 mg/kg males and the controls. There were no other increases in MPE in the other treated groups. Thus, it was concluded that 2-ME was not genotoxic in this study (ECHA) [Kl. score = 1]

Carcinogenicity

No studies are available.

Reproductive/Developmental Toxicity

2-ME was tested in a combined repeated dose toxicity study with a reproduction/developmental toxicity screening (OECD TG 422) test. Male and female SD rats were dosed by oral gavage with 0, 15, 50, or 75 mg/kg 2-ME. Males were treated 5 weeks before mating, during mating and post-mating period until sacrifice after ca. 7 weeks. Females were treated 5 weeks before mating, during mating and pregnancy and lactation until day 21 post-partum inclusive except at the mid and high dose when treatment was interrupted from days 19 and 20 post coitum until delivery due to toxic effects (see below); all females were sacrificed on day 21 post-partum. There were no treatment-related effects on mating and fertility parameters at any dose level. Seminology in males revealed no effects on sperm count, motility, and morphology. The estrous cycle, mating and fertility indices, and pre-coital time were not affected, and no treatment-related effects were detected in reproductive organs on macro- or microscopic examination. Maternal toxicity was evident with deaths of pregnant females at ≥50 mg/kg (six dead or sacrificed on post coitum (PC) days 19-23 at 75 mg/kg, three dead on PC day 21 or day 2 post-partum at 50 mg/kg). Surviving females in the mid- and high-dose groups showed higher body weight gain (≥52 %) and food consumption (14%; statistically significant in the high-dose group) during the premating period and lactation, while those in the top-dose group

had reduced body weight gain (-47% in last week of pregnancy). Effects on body weight gain and food consumption were considered by the investigators to be treatment related.

At 75 mg/kg, the duration of gestation was increased (22.3 days v 21.5 days in controls) and the number of live born pups/litter was significantly decreased due to one dam with only 1 live born pup. The number of females with live-born pups was reduced in the mid- and high-dose groups (7/10 and 4/10 versus 8/9 in controls; statistically significant at the high dose). Gestation indices were given as 78% and 40% in the mid- and high-dose groups compared to 100% in the low-dose group and the controls. There was no effect on sex ratio.

The primary treatment-related effect on reproduction in the TG 422 study was prolonged labor and dystocia at dose levels of ≥50 mg/kg. Certain aliphatic thiol compounds, including 2-mercaptoethanol, have been shown to act as antagonists to the neuropeptide oxytocin, blocking the contractile response of oxytocin on the rat uterus in vitro (Martin and Schild, 1965). Oxytocin is secreted primarily by the posterior pituitary gland and is critical to the normal progress of parturition and sustaining sufficient uterine contractions during labor to expel the fetus(es) and to ligate severed blood vessels within the contracted myometrium after the placenta separates, thus preventing hemorrhage. It is possible that oral administration of 2-mercaptoethanol to pregnant rats in the TG 422 study was sufficient to disrupt the normal oxytocin-mediated progression of parturition by diminishing uterine contractions and prolonging labor.

Slightly higher pup body weights were noted at birth in the 75 mg/kg group, probably as a result of the slight increase in the length of pregnancy. However, despite these higher pup weights at birth, mean pup body weight at 75 mg/kg was lower than control values throughout the remainder of the lactation period as a result of significantly lower pup body weight gain beginning on postnatal day 4. It is not clear whether the effects on pup body weight and survival at 75 mg/kg are the result of direct exposure to the test article in utero or via the milk or perhaps secondary to maternal care issues related to the condition of the dams or an effect on maternal milk production. Oxytocin is known to play an important role, not only in parturition, but also in milk production during lactation. Given the potential antagonistic effects of 2-mercaptoethanol on oxytocin, it is possible that maternal exposure to 2-mercaptoethanol during lactation may hinder milk production and consequently pup growth and viability.

In addition to the effects on parturition and pup body weight, mean live litter size was significantly ($p<0.5$) lower in the 75 mg/kg group compared to the control group (10.0 versus 14.9 pups). The smaller litter size at 75 mg/kg was primarily attributed to one dam (out of 4 surviving dams) that delivered a single pup. This reduction in mean live litter size correlated with higher post-implantation loss and decreased pup survival at the same dose level. However, the small number of surviving dams/litters available for evaluation at 75 mg/kg (n=3 or 4 dams) is a potential major confounding factor in establishing a relationship between these endpoints (live litter size and pup survival) and test article administration. No apparent effects on mating or fertility indices or on male reproductive parameters were observed at any dose level evaluated. The NOAELs for reproductive toxicity are 75 and 15 mg/kg-day for males and females, respectively. The NOAEL for parental systemic toxicity is 15 mg/kg-day. The NOAEL for developmental toxicity is 15 mg/kg-day (ECHA) [Kl. score = 1]

A reproductive/developmental toxicity screening (OECD TG 421) study was conducted on sodium mercaptoacetate. 2-ME is metabolized in the body to 2-mercaptoacetate. Male and female SD rats were dosed by oral gavage with 0, 20, 40, or 80 mg/kg sodium mercaptoacetate

(0, 16, 32, or 64 mg/kg mercaptoacetic acid). In the 80 mg/kg group, there were two males and one female that were found dead during the pre-mating or mating periods with no clinical signs observed before death and no relevant post-mortem findings. On GD 23 post-coitum, 3/11 surviving 80 mg/kg females were found dead, all having delivered pups, although one female had one fetus in the vagina and still had 11 dead fetuses in the uterine horns at necropsy. Another pregnant female with dead and live fetuses in the uterine horns was sacrificed on GD 23 because of poor clinical condition. One additional 80 mg/kg female was prematurely sacrificed on LD 1 because all the pups were dead and another female was found dead on LD 2. One 40 mg/kg female was found dead on GD 22, pregnant with dead fetuses in the uterine horns. Ptyalism [excess saliva] was observed in the $\geq$ 40 mg/kg animals and may have been related to the taste of the test material. Mean body weight gains and generally feed consumption were unaffected by treatment. Vaginal cyclicity was unaffected by treatment. There were no effects on male or female mating behavior or fertility; embryo-fetal development was considered unaffected by treatment. The 80 mg/kg females had a significantly longer gestation period (22.8 vs. 21.6 days, controls). Mean pup body weight gain was significantly lower between PND 1 and 5 in the $\geq$40 mg/kg groups, but there was no treatment-related clinical signs or post-mortem findings. Sperm morphology, motility, and counts were unaffected by treatment. The mean liver and kidney weights were slightly but significantly higher for the 80 mg/kg males. The higher liver weights correlated with a trend towards increased glycogen content at this dose level, an effect that was considered to be toxicologically important. There were no corresponding histopathological changes for the kidney weight changes. The mean absolute seminal vesicle weights were significantly lower for the $\geq$20 mg/kg males and was dose-related; this correlated with a slight decrease in secretory content in the seminal vesicles observed microscopically of the 80 mg/kg males. The OAEL for male reproductive toxicity is 64 mg/kg-day as mercaptoacetic acid. The NOAEL for female reproductive toxicity is 16 mg/kg-day as mercaptoacetic acid, based on deaths in late gestation and delayed delivery. NOAEL for parental toxicity is 16 mg/kg-day as mercaptoacetic acid, based on mortality. The NOAEL for offspring toxicity is 32 mg/kg-day as mercaptoacetic acid based on the dead litter at 64 mg/kg-day (ECHA) [Kl. score = 1].

Pregnant female Wistar rats were dosed by oral gavage with 0, 5, 15, or 25 mg/kg 2-ME on gestational days 6 to 19. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity is 25 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 1]

Derivation of Toxicological Reference and Drinking Water Guidance Values

An OECD 422 study was conducted on 2-ME. Males were treated 5 weeks before mating, during mating and post-mating period until sacrifice after ca. 7 weeks. Females were treated 5 weeks before mating, during mating and pregnancy and lactation until day 21 post-partum inclusive except at the mid and high dose when treatment was interrupted from days 19 and 20 post-coitum until delivery due to toxic effects; all females were sacrificed on day 21 post-partum. The NOAEL for female reproductive toxicity and parental systemic toxicity is 15 mg/kg-day. The NOAEL of 15 mg/kg-day will be used to derive the oral reference dose.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 3
UF_D (database uncertainty) = 1

Oral RfD = 15/(10 x 10 x 1 x 3 x 1) = 15/300 = 0.05 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (0.05 x 70 x 0.1)/2 = 0.18 mg/L

References

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

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Toxicity Profile

Acetic acid
(CAS No. 64-19-7)

Acetic acid readily dissociates in aqueous media to the acetate ($H_3C2O_2^-$) and hydrogen (H^+) ions.

Acute Toxicity

The oral LD_{50} of the sodium salt of acetic acid in rats is 3,310 mg/kg (Woodard et al., 1941; ECHA) [Kl. score =2]. The oral LD_{50} of the acetic acid in unfasted rats is 3,530 mg/kg (ECHA) [Kl. score =4]. The oral LD_{50} of the sodium salt of acetic acid in mice is 4,960 mg/kg (Smyth et al., 1951; ECHA) [Kl. score =2].

The 4-hour inhalation LC_{50} in rats for acetic acid vapor is 11.4 mg/L. There were clinical signs that were indicative of corrosion (ECHA) [Kl. score = 2].

Irritation

Application of a 3.3% or a 10% aqueous solution of acetic acid to the skin of rabbits for 4 hours was slightly irritating. The Primary Dermal Irritation Index scores were 0.5 and 1.1, respectively (Nixon et al., 1990; ECHA) [Kl. score = 2]. Application of a 10% solution of acetic acid to the skin of rabbits for 4 hours under semi-occlusive conditions was slightly irritating (ECHA) [Kl. score = 2].

Instillation of 0.1 mL of a 10% solution of acetic acid to the eyes of rabbits was considered irritating. The mean of the 24, 48, and 72 hours scores were: 2.67 for erythema; 1.67 for chemosis; 1.72 for corneal opacity; and a mean of 87% corneal swelling (Jacobs and Martens, 1989; ECHA) [Kl. score = 2].

Sensitization

No studies are available.

Repeated Dose Toxicity

No adequate studies for human health risk assessment are available.

Genotoxicity

The *in vitro* genotoxicity studies on acetic acid are presented below in Table 1.

Table 1: *In vitro* Genotoxicity Studies on Acetic Acid

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* strains)	NC	-	2	Ishidate et al. (1984); ECHA
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	Zeiger et al. (1992); ECHA
Chromosomal aberrations (CHO cells)	-**	-**	2	Morita et al. (1990); ECHA
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	-***	-***	2	Seifried et al. (2006); ECHA

*+, positive; -, negative; NC, not conducted.
**A dose-dependent increase in chromosomal aberrations was observed with 10 mM acetic acid (-S9) and 8 mM acetic acid (+S9). These concentrations were close to the cytotoxic limit at which the cells could no longer be evaluated. These effects were abolished by neutralizing the test medium or increasing the buffer capacity. These results suggest that the positive findings are due to the acidic pH of the incubation medium rather than a consequence of an intrinsic clastogenic potential of acetic acid.
***Acetic anhydride (hydrolyzes to acetic acid in aqueous media).

There are no *in vivo* genotoxicity studies on acetic acid. A bone marrow micronucleus study has been conducted on acetic anhydride (which hydrolyses to acetic acid). Male and female SD rats were exposed by inhalation to 0, 1, 5, or 20 ppm acetic anhydride, 6 hours/day, 5 days/week for 13 weeks. The incidences of micronucleated immature erythrocytes were not increased at any exposure concentration (ECHA) [Kl. score = 1].

Carcinogenicity

No oral or inhalation studies are available. No deaths and no skin tumors were seen when acetic acid was applied dermally once a week to CD-1 mice for 32 weeks (Slaga et al., 1975; ECHA) [Kl. score = 4].

Reproductive toxicity

No studies are available.

Developmental Toxicity

Pregnant female Wistar rats were dosed by oral gavage with 0 or various concentrations up to 1,600 mg/kg apple cider vinegar (5% acetic acid) on gestational days 6 to 15. There were no maternal or developmental toxicity at any dose level. The NOAEL for maternal and developmental toxicity is 1,600 mg/kg-day (ECHA) [Kl. score = 2].

Pregnant female CD-1 mice were dosed by oral gavage with 0, 16, 74.3, 345, or 1,600 mg/kg apple cider vinegar (5% acetic acid) on gestational days 6 to 15. There were no treatment-related effects on maternal or fetal survival, or on soft or skeletal tissues. There was no effect on the fetal development in the presence of slight maternal toxicity (reduced body weight gain) at 345 mg/kg. At 1,600 mg/kg, there was an increase in the number of litters containing a dead fetus and some reductions in ossification. The NOAELs for maternal and developmental toxicity are 74.3 and 345 mg/kg-day, respectively (ECHA) [Kl. score = 2].

Pregnant female Dutch-belted rabbits were dosed by oral gavage with 0, 16, 74.3, 345, or 1,600 mg/kg apple cider vinegar (5% acetic acid) on gestational days 6 to 18. There were no treatment-related effects on maternal or fetal survival, or on soft or skeletal tissues. There was a reduction in the pregnancy rate in the high-dose group; and a dose-dependent decrease in maternal body weights at ≥74.3 mg/kg. Some deaths or abortions occurred in all treated groups and some litter losses were reported at ≥345 mg/kg. Maternal effects were much more noticeable than the effects on fetal development. These findings have been considered a consequence of the bactericidal properties of orally administered acetic acid within the gastrointestinal tract of female rabbits, and not a direct effect on embryonic implantation and development of acetic acid (ECHA). It is likely that this accounts for the apparent increased sensitivity of this species to oral administration of acetic acid. The NOAEL for developmental toxicity is 1,600 mg/kg-day; a NOAEL for maternal toxicity was not identified (ECHA) [Kl. score = 2].

Derivation of toxicological reference and drinking water guidance values

There are no repeated dose toxicity studies that were considered adequate for human health risk assessment. The Joint FAO/WHO Expert Committee on Food Additives (JECFA) has maintained a group ADI of "not limited" for acetic acid and its potassium and sodium salts (JECFA). The Australian drinking water guidance value for pH may apply to acetic acid.

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Toxicity Profile

Acrylamide/sodium acrylate copolymer (Anionic polyacrylamide)
(CAS No. 25085-02-3)

Polyacrylamide polymers can exist in cationic, anionic, or non-ionic forms, depending on their ionic charge. The non-ionic form of polyacrylamide is generated from the basic polymerization of acrylamide. Anionic polyacrylamide polymer can then be formed from the hydrolysis of the acrylamide homopolymer either simultaneously during the polymerization process or as a subsequent step (Zheng et al., 2013). Anionic polyacrylamide polymer can also be formed from the copolymerization of acrylamide and acrylic acid (Lyons and Vasconcellos, 1997; Zheng et al., 2013). The molecular weight of polyacrylamide co-polymers used as flocculents are 1,000,000 to >50,000,000 (Lyons and Vasconcellos, 1977).

Toxicokinetics and Metabolism

Female rats were dosed by oral gavage with 140 mg/kg [^{14}C]-anionic polyacrylamide (molecular weight of 3,000,000). No radioactivity was observed in any of the animals. After 25 hours, the sum of the radioactivity recovered in the feces was 95.13% of the administered dose, and the gastrointestinal tract and contents accounted for 1.64% of the dose. The urine contained activity representing 0.82% of the dose and carbon dioxide in the expired air was 0.07%. Liver and kidney tissue contained about 0.05% (McCollister et al., 1965).

A male rat were dosed by oral gavage with 175 mg/kg [^{14}C]-anionic polyacrylamide (molecular weight of 3,000,000). After 5 days, 99% of the recovered activity was in the feces and the gastrointestinal tract and its contents (McCollister et al., 1965).

Acute Toxicity

No deaths were observed in rats given either non-ionic or anionic polyacrylamide at oral doses up to 4,000 mg/kg. The oral LD_{50} is >4,000 mg/kg (McCollister et al., 1965).

Irritation

Application of a 5% solution of polyacrylamide to the skin of rabbits was “well tolerated” (CIR, 2005). Polyacrylamide is non-irritating to slightly irritating to the eyes (CIR, 2005).

Sensitization

No studies are available.

Repeated Dose Toxicity

Male and female rats were given in their diet 0, 5, or 10% anionic polyacrylamide (molecular weight of 3,000,000) for two years. The animals in the 10% dose group showed significant retardation of growth. At the end of the study, there was a slight statistically significant increase in kidney weights in the 10% males and in the ≥5% females. Gross and microscopic examination of the tissues from the ≥5% groups at 12 months showed some slight diffuse cloudy swelling, areas of focal necrosis, and mild replacement fibrosis in the liver. At 18 and 24 months, all the animals showed tissue changes indicative of old age. These changes

involved the small arterioles of the heart, kidney, spleen, pancreas, and to a lesser degree, the liver. All groups of animals were affected including the controls, but the degree of severity was somewhat increased in the ≥5% animals. The authors of the study suggested that the effects seen in the ≥5% dietary groups are attributed indirectly to the large, hydrophilic, non-nutritive bulkiness of the polymer in the gastrointestinal tract. For instance, reduced caloric intake may be partially responsible for the growth retardation; there may also have been interference of the absorption of dietary nutrients. Moreover, the [C^{14}] polymer bioavailability studies show no gastrointestinal absorption. The NOAEL for this study is 10% in the diet (McCollister et al., 1965).

Genotoxicity

No studies are available.

Carcinogenicity

Male and female rats were fed 0, 5, or 10% anionic polyacrylamide (molecular weight of 3,000,000) in their diet for two years. The tumor incidences were similar between the treated and control animals (McCollister et al., 1965).

Reproductive/Developmental Toxicity

In an abstract, it was reported that rats fed up to 2,000 ppm polyacrylamide in a three-generation reproductive toxicity study showed no reproductive, developmental, or parental toxicity (CIR, 2005).

Derivation of Toxicological Reference and Drinking Water Guidance Values

No adverse effects were reported in rats fed anionic polyacrylamide in their diet at doses up to 10% for two years (McCollister et al., 1965). Using 0.05 as the fraction of body weight that is consumed per day as food for the rat, the NOAEL for this study is 5,000 mg/kg-day. The NOAEL of 5,000 mg/kg-day will be used for determining the oral reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:

UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 5,000/(10 x 10 x 1 x 1 x 1) = 5,000/100 = 50 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,

Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

Where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (50 x 70 x 0.1)/2 = <u>175 mg/L</u>

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Toxicity Profile

Ammonium persulfate
(CAS No. 7727-54-0)

Acute Toxicity

The oral LD_{50} values in rats are 300 and 700 mg/kg for males and females, respectively (ECHA) [Kl. score = 1].

The inhalation 4-hour LC_{50} in rats is >2.95 mg/L. Particles sizes of <10 μm and <7 μm were 96.6% – 97.4% and 84.6% – 86%, respectively (ECHA) [Kl. score = 1].

The dermal LD_{50} in rats is >2,000 mg/kg (ECHA) [Kl. score = 1].

Irritation

Application of 0.5 g. ammonium persulfate to the skin of rabbits for 4 hours under occlusive conditions was not irritating. The mean of the 24, 48, and 72 hours scores were 0.00 for both erythema and edema (ECHA) [Kl. score = 2].

Studies in humans indicate that persulfates have the potential for skin irritation (NICNAS, 2001). Calnan and Schuster (1963) reported skin irritation in a human patch test with 5% ammonium persulfate. Jordan (1998) reported that a mixture with 17.5% persulfates (ammonium, potassium, and sodium) induced skin irritation in human subjects from patches applied under occlusive conditions.

Instillation of 0.1 mL ammonium persulfate into the eyes of rabbits was considered slightly irritating. The mean of the 24, 48, and 72 hours scores were: 1.33 for corneal opacity; 0.00 for iridial lesions; 1.00 for conjunctival redness; and 0.33 for chemosis (ECHA) [Kl. score = 1].

Sensitization

Ammonium persulfate was considered a skin sensitizer in a guinea pig maximization test (ECHA) [Kl. score = 2].

Human exposure to persulfates have been linked to a variety of skin and respiratory complaints indicative of sensitization. The complaints consist of immediate and delayed contact hypersensitivity, contact urticarial, rhinitis, bronchitis, and asthma (NICNAS, 2001).

Repeated Dose Toxicity

Oral
Male and female CR-CD rats were fed in their diet 0, 100, 300, or 600 ppm ammonium persulfate for 28 days. The estimated daily intakes are 0, 13, 41, and 82 mg/kg-day. There were no treatment-related effects. The NOAEL is 82 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 2].

Male and female CR strain rats were fed in their diet 0, 300, 1,000, or 3,000 ppm sodium persulfate for 90-days. On day 48 of the study, the dietary concentration of the group receiving 1,000 ppm was increased to 5,000 ppm for the remainder of the study. Body weights was decreased in the two highest dose groups during the last six weeks of treatment. There were no treatment-related effects on urinalysis, clinical chemistry, or hematology parameters. Histopathological findings were limited to the 3,000 ppm group only and consisted of necrosis and atrophy of the gastrointestinal tract epithelial lining. The absence of the gastrointestinal lesions in the group receiving 1,000 ppm for 8 weeks, followed by 5000 ppm for 5 weeks, indicates that the lesions are related both to concentration in diet (dose) and length of exposure. A clear NOAEL for this study is 300 ppm, which is estimated to be 22 mg/kg-day. Another NOAEL may be the 1,000 ppm dietary group for an 8-week exposure period (ECHA; OECD, 2005a,b) [Kl. score = 2].

Inhalation

Male and female SD rats were exposed (whole-body) by inhalation to 0, 5, 10.3, or 25 mg/m^3 ammonium persulfate dust, 6 hours/day, 5 days/week for 13 weeks. Additional groups of animals were exposed for 13 weeks, followed by either a 4- or 13-week recovery period. The MMAD was 2.5, 2.7, and 2.5 μm for the 5, 10, and 25 mg/m^3 groups, respectively. No deaths occurred during the study that were considered to be exposure-related. The 25 mg/m^3 animals showed increased respiration rates, as well as a few of the 25 mg/m^3 animals. This clinical sign disappeared during the first few weeks of the recovery period. Body weights of the 25 mg/m^3 animals were significantly lower during most of the exposure period; by the end of the recovery period the body weights were comparable to the controls. Lung weights were increased in the 25 mg/m^3 animals at the end of the 13-week exposure period but were similar to controls after 6 weeks in the recovery period. Histopathologic changes indicative of irritation was seen in the trachea and bronchi/bronchioles in the 25 mg/m^3 animals; these lesions were not seen after 6 weeks in the recovery period. The NOAEL for this study is 10.3 mg/m^3 (ECHA) [Kl. score = 1].

Genotoxicity

There are no available genotoxicity studies on ammonium persulfate. The *in vitro* genotoxicity studies on sodium persulfate are presented below in Table 1.

Table 1: *In vitro* Genotoxicity Studies on Sodium Persulfate

Test System	**Results***		**Klimisch Score**	**Reference**
	-S9	**+S9**		
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	1	ECHA
Unscheduled DNA synthesis (rat hepatocytes)	NA	-	1	ECHA

*+, positive; -, negative; NA, not applicable

In vivo Studies

Sodium persulfate did not induce micronuclei in the bone marrow cells of male and female mice given a single intraperitoneal injection of 0, 85, 169, or 338 mg/kg sodium persulfate (ECHA) [Kl. score = 2].

Carcinogenicity

A 51-week dermal study in female SENCAR mice exposed to 0.2 ml of a 200 mg/mL solution of ammonium persulfate showed that ammonium persulfate is neither a tumor promoter nor a complete carcinogen when applied to the skin (OECD, 2005a,b; ECHA) [Kl. score = 2].

Reproductive/Developmental Toxicity

A reproductive and developmental toxicity screening study (OECD 421) has been conducted on ammonium persulfate. Male and female Crl:CD (SD)GS BR rats were fed in their diet 0, 40, 100, or 250 mg/kg ammonium persulfate. In the parental animals, there was no treatment-related mortality, clinical signs, body or organ weight changes, or effects seen in gross necropsy. There were no effects on reproductive performance, fertility, fetal anomalies, fetal viability, spermatogenesis, spermatogenic cycle. The NOAEL for reproductive and developmental toxicity and parental toxicity is 250 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 1].

Derivation of Toxicological Reference and Drinking Water Guidance Values

Toxicological reference values were not derived. Ammonium persulfate dissociates in water to ammonium and persulfate ions. The persulfate ions will further hydrolyze to sulfate ions.

The Australian drinking water guideline value for sulfate is 500 mg/L based on health. Concentrations of >500 mg/L can have purgative effects. There is also an Australian drinking water guideline value for sulfate of 250 mg/L based on aesthetics; it is the taste threshold (ADWG, 2011).

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Toxicity Profile

2-Propenoic acid, homopolymer, ammonium salt
[Ammonium polyacrylate]
(CAS No. 9003-03-6)

No information could be located on 2-propenoic acid, homopolymer, ammonium salt (ammonium polyacrylate). Therefore, data on sodium polyacrylates will be used to read-across to ammonium polyacrylate.

Sodium polyacrylates are polymers that range in molecular weight (MW) from 1,000 to 78,000 (HERA, 2014). The sodium polyacrylates mostly used in detergents have a typical molecular weight of approximately 4,500 (HERA, 2014).

Acute Toxicity

Acute oral toxicity studies have been conducted in rats on sodium polyacrylates with molecular weights (MW) of 1,000 to 78,000. The oral LD_{50} values are >5,000 or >10,000 mg/kg (the highest doses tested), with the exception of one study on a 3,500 MW sodium polyacrylate, which was reported to be >1,000 mg/kg (the attainable limit dose of a 10% aqueous solution) (HERA, 2014). [Kl. scores = 2]

The dermal LD_{50} values in rabbits for sodium polyacrylates with MW of 1,000 or 4,500 are >5,000 mg/kg (HERA, 2014). [Kl. scores = 2]

Irritation

The sodium polyacrylates with MW of 1,000 to 78,000 are not irritating to the skin or eyes (HERA, 2014). [Kl. scores = 2]

Sensitization

Sodium polyacrylates with MW of 4,500 or 78,000 were not dermal sensitizers in the guinea pig maximization test (HERA, 2014). [Kl. scores = 2 and 4, respectively]

Repeated Dose Toxicity

Oral

Male rats were fed diets containing 0 or 2.5% sodium polyacrylate (MW 2,500) for four weeks. Body weight, body weight gain, and appearance of the animals were similar between treated and control animals. In the fourth week of the study, a small, but significant, decrease in total weight of bone minerals was detected and confirmed by radiographic and histological examination. There was a significant reduction in the concentration of magnesium in the bones and plasma of the treated animals. Calcium loss was slight and not statistically significant. Urinary excretion of sodium and phosphorus was markedly increased; calcium only slightly increased. The authors of the study interpreted the finding as a metabolic imbalance rather than systemic toxicity. Sodium excretion could have been increased by the high intake of the sodium-neutralized test substance. The NOAEL for the study was considered to be 2.5%

sodium polyacrylate in the diet, which was estimated to be 1,136 mg/kg-day (HERA, 2014). [Kl. score = 2]

Inhalation

Male and female rats were exposed by inhalation to 0, 0.2, 1.0, or 5.0 mg/m^3 sodium polyacrylate (MW 4,500) as an aerosol for 6 hours/day, 5 days/week for 13 weeks. Additional groups of animals were exposed for 13 weeks followed by a 91-day recovery period. There were no treatment-related effects on body weights, organ weights, feed and water consumption, clinical observations, and blood chemistry. In the histopathologic examination, the lungs of the mid- and high-dose animals showed signs of mild pulmonary irritation: increases in polymorphonuclear granulocytes or alveolar macrophages, pneumocyte hyperplasia, alveolar wall thickening and focal alveolitis. The lung effects were reversible and were not seen in the recovery group animals. The NOEC for systemic effects in this study was considered to be 5 mg/m^3, and the NOEC for localized irritation is 0.2 mg/m^3 (HERA, 2014). [Kl. score = 2]

Genotoxicity

The results of the *in vitro* studies on sodium polyacrylates are presented below in Table 1. All of the studies show that sodium polyacrylates are not mutagenic or genotoxic.

Table 1: In Vitro Genotoxicity Studies on Sodium Polyacrylates (HERA, 2014)

Mean MW	Test System	Results*	Klimisch Score	Reference
2,000	Bacterial reverse mutation	-	2	HERA (2014)
2,000	Mouse lymphoma	-	2	HERA (2014)
2,000	Unscheduled DNA synthesis	-	2	HERA (2014)
4,500	Bacterial reverse mutation	-	2	HERA (2014)
4,500	Mouse lymphoma	-	2	HERA (2014)
4,500	Unscheduled DNA synthesis	-	2	HERA (2014)
4,500	Cytogenetic (CHO cells)	-	2	HERA (2014)
4,500	Bacterial reverse mutation	-	2	HERA (2014)
4,500	Mammalian cell gene mutation	-	2	HERA (2014)
4,500	Unscheduled DNA synthesis	-	2	HERA (2014)

*+, positive; -, negative

There was no increase in micronuclei in polychromatic erythrocytes from the bone marrow of mice given a single oral gavage dose of 13,850 mg/kg sodium polyacrylate with a MW of 2,000 (HERA, 2014).

Carcinogenicity

No studies are available.

Reproductive Toxicity

No studies are available.

Developmental Toxicity

Pregnant female rats were dosed by oral gavage with 0, 500, 1,000, or 3,000 mg/kg sodium polyacrylate (MW 4,500) on GD 6 to 15. At 3,000 mg/kg, the dams had soft or liquid stools during the treatment period. There was no maternal or developmental toxicity observed in this study. The NOAEL for maternal and developmental toxicity is 3,000 mg/kg-day (HERA, 2014). [Kl. score = 2]

Pregnant female rats were dosed by oral gavage with 0, 125, 375, or 1,125 mg/kg sodium polyacrylate (MW 90,000 as a 77.5% aq. solution) during GD 6 to 13. Some of the dams were sacrificed on GD 13 and the remaining on GD 19. One mid-dose dam and 6 high-dose dams died during the study; of these, three of the high-dose deaths were treatment-related and the remaining were considered the result of gavage errors. There was a transient decrease in feed consumption in the high-dose dams during GD 7-9, but not other indications of maternal toxicity. There was no developmental toxicity. The NOAELs for maternal and developmental toxicity are 375 and 1,125 mg/kg-day (HERA, 2014). [Kl. score = 2]

Derivation of Toxicological Reference and Drinking Water Guidance Values

NICNAS has assessed sodium polyacrylates in an IMAP Tier 1 assessment and considers it "a chemical identified as low concern to human health by application of expert validated rules".[1]

A 4-week dietary study showed no systemic toxicity in rats given 2.5% sodium polyacrylate (MW 2,500) in their feed. The estimated dose is 1,136 mg/kg-day. Two pre-natal developmental toxicity studies showed no effects at the highest dose tested: 3,000 and 1,125 mg/kg-day for sodium polyacrylates with MW of 4,500 and 90,000, respectively. The NOAEL of 1,136 mg/kg-day from the 4-week dietary study will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

[1] https://www.nicnas.gov.au/chemical-information/imap-assessments/imap-assessments/tier-i-human-health-assessments#cas-A_9003-04-7

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subacute to chronic) = 10
UF_D (database uncertainty) = 1

Oral RfD = 1,136 (10 x 10 x 1 x 10 x 1) = 1,136/1,000 = 1.0 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD:

Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (1 x 70 x 0.1)/2 = 3.5 mg/L

References

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

HERA (2014). Human & Environmental Risk Assessment (HERA) on ingredients of European household cleaning products. Polycarboxylates used in detergents (Part I): Polyacrylic acid homopolymers and their sodium salts (CAS 9003-04-7). (http://www.heraproject.com/files/HERA_P-AA_final_v3_23012014.pdf)

Toxicity Profile

Ammonium sulfate
(CAS No. 7783-20-2)

Acute Toxicity

The oral LD_{50} of a 30% aqueous solution of ammonium sulfate to rats was 4,250 mg/kg (ECHA) [Kl. score = 2]. The oral LD_{50} of ammonium sulfate to rats was >2,000 mg/kg (ECHA) [Kl. score = 2].

The dermal LD_{50} of ammonium sulfate to rats is >2,000 mg/kg (ECHA) [Kl. score = 2].

Irritation

Application of an 80% solution of ammonium sulfate to the skin of rabbits for 20 hours under occlusive conditions was not irritating (ECHA) [Kl. score = 2].

Instillation of 0.05 mg. ammonium sulfate into the eyes of rabbits was not irritating (ECHA) [Kl. score = 2].

Sensitization

There are no studies on ammonium sulfate.

Ammonium chloride was not a skin sensitizer in a guinea pig maximization test (ECHA) [Kl. score = 1]. Sodium sulfate was not considered a skin sensitizer in a mouse local lymph node assay (ECHA) [Kl. score = 1].

Repeated Dose Toxicity

Male and female F344 rats were fed in their diet 0, 0.1, 0.6, or 3% ammonium sulfate for 52 weeks. The estimated daily intake was 0, 42, 256, or 1,527 mg/kg-day for males; and 0, 48, 284, or 1,490 mg/kg-day for females. Survival, body weights, and feed consumption were similar across all groups. There were no treatment-related changes in hematology or clinical chemistry parameters. Absolute and relative kidney weights were increased or showed a tendency for increase in the 3% dietary group in both sexes. Absolute spleen weights were decreased, and relative liver weights were increased in the 3% males. Gross pathology and histopathology showed no treatment-related effects. The NOAEL is 3% in the diet, which corresponds to 1,527 and 1,490 mg/kg-day for males and females, respectively (ECHA) [Kl. score = 1].

Genotoxicity

The *in vitro* genotoxicity studies on ammonium sulfate are presented below in Table 1.

Table 1: *In vitro* Genotoxicity Studies on Ammonium Sulfate

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	ECHA
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	ECHA
Mammalian cell gene mutation (CHL fibroblast [V79] cells)	-	-	1	
Chromosomal aberrations (human lymphocytes)	-	-	2	ECHA

*+, positive; -, negative

Carcinogenicity

Male and female F344 rats were fed in their diet 0, 1.5, or 3% ammonium sulfate for 52 weeks. The estimated daily intake was 0, 564, or 1,288 mg/kg-day for males; and 0, 650, or 1,371 mg/kg-day for females. Survival, body weights, and feed consumption were similar across all groups. There were no treatment-related changes in hematology or clinical chemistry parameters. The incidence of tumors was similar between the treated and control rats (ECHA) [Kl. score = 1].

Reproductive/Developmental Toxicity

No studies are available on ammonium sulfate.

A reproductive and developmental toxicity screening (OECD 421) study has been conducted on sodium sulfate. Male and female Wistar rats were dosed by oral gavage with 0, 100, 300, or 1,000 mg/kg sodium sulfate. There were no deaths during the study and no clinical signs. Body weights, body weight gain, and feed consumption were similar across all groups. There was no reproductive or developmental toxicity at any dose level. The NOAEL for systemic, reproductive, and developmental toxicity is 1,000 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 1].

Derivation of Toxicological Reference and Drinking Water Guidance Values

Toxicological reference values were not derived. Ammonium sulfate dissociates in water to ammonium and sulfate ions.

The Australian drinking water guideline value for sulfate is 500 mg/L based on health. Concentrations of >500 mg/L can have purgative effects. There is also an Australian drinking water guideline value for sulfate of 250 mg/L based on aesthetics; it is the taste threshold (ADWG, 2011).

References

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

Toxicity Profile

Alpha-Amylase
[α-Amylase]
(CAS No. 9000-90-2)

Enzymes are catalytic proteins or polypeptides and consist of amino acid residues coupled via peptide bonds. α-Amylases are enzymes that catalyze the endo-hydrolysis of 1,4-α-D-glycosidic linkages in polysaccharide, such as starches, glycogen, and oligosaccharides containing three or more 1,4-α-linked glucose units. (HERA, 2005).

Acute Toxicity

The oral LD_{50} value in rats is >1,911 mg TOS[1]/kg (ECHA) [Kl. score = 1].

The inhalation 4-hour LC_{50} in rats is >4.96 mg/L as an aerosol. The respirable fraction (<4 μm) as percent of the aerosol mass was 73.1%. The mass median aerodynamic diameter was 2.7μm (ECHA) [Kl. score =1].

There are no available acute dermal toxicity studies.

Irritation

Application of 0.5 mL alpha-amylase to the skin of rabbits for 4 hours under semi-occlusive conditions was not irritating. The mean of the 24, 48, and 72 hours scores were 0.3 for erythema and 0.00 for edema (ECHA) [Kl. score = 1].

Instillation of 0.1 mL alpha-amylase into the eyes of rabbits was not irritating. The mean of the 24, 48, and 72-hour scores were: 0.00 for corneal opacity; 0.00 for iridial lesions; 0.30 for conjunctival redness; and 0.10 for chemosis (ECHA) [Kl. score = 1].

Sensitization

alpha-Amylases were not considered skin sensitizers in two separate guinea pig maximization tests (HERA, 2005). An alpha-amylase did not show a skin sensitizing response when evaluated in a human repeat insult patch test (HRIPT) involving 89 volunteers (HERA, 2005).

A number of enzymes from bacteria, plants, and fungi have the potential to cause occupational respiratory allergy, even asthma (Basketter et al., 2015).

Repeated Dose Toxicity

Oral

[1] Total Organic Solid.

Male and female SD rats were dosed by oral gavage with 0, 110, 362, or 1,110 mg TOS/kg amylase, alpha for 13 weeks. There were no treatment-related effects. The NOAEL for this study is 1,100 mg TOS/kg-day, the highest dose tested (ECHA) [Kl. score = 1].

Dermal

Male and female New Zealand White rabbits were given dermal applications of 0 or 12.4 mg/kg amylase, alpha for 4 hours/day for 28 days. The skin was either intact or abraded, and the test material was either buffered or unbuffered. The only effects noted were minor effects at the site of application without any detectable systemic response. The NOAEL for systemic toxicity is 12.4 mg/kg-day (ECHA) [Kl. score = 2].

Genotoxicity

The *in vitro* genotoxicity studies on amylase, alpha are presented below in Table 1.

Table 1: *In vitro* Genotoxicity Studies on Amylase, Alpha

Test System	**Results***		**Klimisch Score**	**Reference**
	-S9	**+S9**		
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	1	ECHA
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	-	-	1	ECHA
Chromosomal aberrations (human lymphocytes)	-	-	1	ECHA
Micronucleus (human lymphocytes)	-	-	1	ECHA

* - negative; + positive

Carcinogenicity

No studies are available.

Reproductive Toxicity

Two alpha-amylases, one from *B. stearothermophilus* (Bsa) and the other from a genetically modified strain of *B. subtilis* (cBsa), were evaluated in one-generation reproductive toxicity studies. Male and female F344 rats were fed in their diet 0, 36, or 72 units alpha-amylase/g food for 13 weeks (Bsa) or 4 weeks (cBsa)) before breeding and through weaning of the F_1 pups; selected F_1 rats received the same diets for at least 13 weeks from weaning until sacrifice. There was no reproductive toxicity. Ophthalmic, hematological, macroscopic, or microscopic findings, and body weights were similar between the treated and controls animals. Mean body weights of the F_1 pups from F_0 rats exposed to 72 units/g (cBsa) were significantly lower than those of the controls on lactation day 28. This effect may have been related to the slight reduction in body weights and significant reduction in feed consumption (gestational days 14-

20) of the F_0 dams. Body weights in this dose group were, however, similar to the controls during the growth phase of the F_1 generation. There were no treatment-related effects in clinical pathology values in the Bsa-treated rats, and the organ weight data did not correlate with either the macroscopic or microscopic findings. The NOAEL for this study is 36 units/g food (MacKenzie et al., 1989; HERA, 2005).

Developmental Toxicity

No studies are available.

Derivation of Toxicological Reference and Drinking Water Guidance Values

There were no adverse effects seen in a 13-week rat oral toxicity study conducted on amylase, alpha. The NOAEL of 1,110 mg TOS/kg-day, the highest dose tested, will be used to derive the oral reference dose and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 3
UF_D (database uncertainty) = 1

Oral RfD = 1,110/(10 x 10 x 1 x 3 x 1) = 1,110/300 = 4 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (3.7 x 70 x 0.1)/2 = 13 mg/L

References

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

Basketter, D.A., Kruszewski, F.H., Mathieu, S., Kirchner, D.B., Panepinto, A., Fieldsend, M., Siegert, V., Barnes, F., Bookstaff, R., Simonsen, M., and Concoby, B. (2015). Managing the risk of occupational allergy in the enzyme detergent industry. J. Occup. Environ. Hyg. 12: 421-437.

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

HERA (2005). Human and Environmental Risk Assessment (HERA) on Ingredients of Household Cleaning Products: α-amylase, CAS No. 9000-90-2; Cellulase (β-(1,4)-glucanase), CAS No. 9012-54-8; Lipase, 9001-62-1, 2005. http://www.heraproject.com.

MacKenzie, K.M., Petsel, S.R.W., Weltman, R.H., Zeman, N.W. (1989). Subchronic toxicity studies in dogs and in utero rats fed diets containing Bacillus stearothermophilus alpha-amylase from a natural or recombinant DNA host. Food and Chemical Toxicology, 27: 599-606.

Toxicity Profile

Alcohols C9-11, ethoxylated
(CAS No. 68439-46-3)

Alcohol ethoxylates (AE) are a class of non-ionic surfactants that have the basic structure $C_{x-y}AE_n$. The subscript (x-y) following the 'C' indicates the range of carbon chain units. The hydrocarbon chain can be either linear or branched. AEs also contain an ethylene oxide (E) chain attached to the alcohol. The degree of ethylene oxide polymerization is indicated by the subscript (n) which indicates the average number of ethylene oxide units. In household products the average ethylene oxide chain length commonly ranges between 3 and 12 units.

The toxicity profile of alcohols C9-11, ethoxylated has been developed from a risk assessment report on alcohol ethoxylates ranging from C8 to C18 prepared by the household cleaning product and chemical industry (HERA, 2009).

Acute Toxicity

The oral LD_{50} for $C_{11}AE_9$ is 1,100 mg/kg. The oral LD_{50} of C9-11AE_8 in fasted rats was found to be 1,200 mg/kg. The oral LD_{50} for C9-11$AE_{2.5}$ in rats was calculated to be >4,000 mg/kg and <10,000 mg/kg.

The dermal LD_{50} for $C_{9-11}AE_6$ is >2,000 mg/kg. In another study, 5/8 rabbits died after a dermal dose of 5,000 mg/kg $C_{9-11}AE_6$. The dermal LD_{50} values for AEs with an alkyl chain length of 9 – 11 carbon atoms in three different rat studies were determined to be >2,000 mg/kg and >4,000 mg/kg.

The acute rat 4 hr-LC_{50} of C9-11AE_5 generated as a mist was determined to be >0.22 mg/L. Talmage (1994) reported that alcohol ethoxylates were not acutely toxic to rats at concentrations less than or equal to their saturated vapor concentrations in air. Acute toxic thresholds were reached only when animals were exposed to the undiluted test chemical in the form of a respirable mist or aerosol. Under these conditions, 1- or 4-hour inhalation LC_{50} values ranged from 1.5 to 20.7 mg/L. Some studies reported no mortalities (1-hours LC_{50} -study) occurred at concentrations as high as 52 mg/L.

Irritation

Alcohol ethoxylates with varying alkyl chain lengths and ethoxylation degree were found to be slightly to severely irritating to skin in rabbits and rats. The degree of irritation was dependent on the type of patches used (open application versus full occlusion), the exposure time as well as the concentration of the test material. In humans, AEs are less irritating to skin than in animals. Neat applications of a range AEs in a 4-hr human patch test did not warrant these chemicals to be classified as skin irritants under EU legislation, while the same AEs would have been classified for skin irritation on the basis of animal data.

Alcohol ethoxylates range from mildly to severely irritating to rabbit eyes. Generally,

concentration of 0.1% were non-irritating, and concentrations of 1 to 10% ranged from slight to moderately irritating. No relationship could be established between the chemical structures of the tested AEs and their eye irritation responses.

Sensitization

Alcohol ethoxylates should not be considered as skin sensitizers. A substantial amount of skin sensitization studies in guinea pigs following either the Magnusson-Kligman maximization or the Buehler testing protocol are available to evaluate the skin sensitization potential of AEs. Although a mild skin sensitization reaction was observed in a study following the Magnusson-Kligman protocol, the weight of evidence clearly supports the assessment that AEs should not be considered as skin sensitizers. This is further supported by clinical and market data that demonstrate the absence of skin sensitization responses to AEs when tested under the conditions of the HRIPT or when used in AE containing consumer products.

Repeated Dose Toxicity

Rats were given in their diet 0, 125, 250, or 500 mg/kg $C_{10}AE_5$ for 90 days. There were no treatment-related clinical signs, body weight gain, food consumption, or feed efficiency. There was a slight increase in absolute liver weights as well as a trend toward a dose-dependent increase in the liver weight/body weight ratio, with a statistically significant increase in the high dose group. However, the histological evaluation did not reveal any indication of hepatotoxicity and therefore the increase in liver weights was not interpreted to be a toxicological effect. It can be considered to be an adaptive response as a result of extensive metabolism of the test compound by the liver. There were no other gross or histopathological changes that were considered treatment-related. The NOAEL for this study is 500 mg/kg-day.

Rats were given in their diet 0, 125, 250, 500, 1,000, or 3,000 ppm $C_{9\text{-}11}AE_6$ for 90 days. There were no signs of toxicity at any dose level. The NOAEL is 3,000 ppm (approximately 150 mg/kg-day).

Rats were given in their diet 0. 0.04, 0.2, or 1.0% $C_{9\text{-}11}AE_8$ for 90 days. Lower body weight gain and decreased food consumption were noted in the 1% males and females and in the 0.2% females from week 1 through the end of the study. Further statistical analyses revealed a significant decrease in the mean body weight gain noted in the 1% females and the decreases in mean food consumption noted in the 1% males and females. The differences noted in the 0.2% females were not statistically significant. The investigators considered these observations to be the result of poor palatability of the test substance. There were no other treatment-related effects. The NOAEL for this study is 1.0% in the diet (about 400 mg/kg-day).

Genotoxicity

The genotoxicity studies conducted on alcohol ethoxylates are reviewed in HERA (2009). In all available *in vitro* and *in vivo* genotoxicity studies, there were no indication of genetic toxicity of a broad range of structurally different alcohol ethoxylates. The results of few of the *in vitro* studies on similar alcohol ethoxylates

are presented below in Table 1.

Table 1: *In Vitro* Genotoxicity Studies on Selected Alcohol Ethoxylates

Test Substance	Test System	Results*		Klimisch Score	Reference
		-S9	+S9		
$C_{7-9}AE_6$	Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	HERA, 2009
$C_{14-15}AE_7$	Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	HERA, 2009
$C_{14}AE_{12}$	Chromosomal aberrations (CHO cells)	-	-	2	HERA, 2009

*+, positive; -, negative

In two separate studies, CD-1 mice were given an intraperitoneal dose of 0, 50, or 100 mg/kg $C_{12-15}AE_3$ or $C_{12-14}AE_9$. There were no increases in the micronuclei of bone marrow cells (Talmage, 1994).

Male and female Tunstall rats were given a single oral gavage dose of 0, 250, 500, or 1,000 mg/kg $C_{14-15}AE_7$. There were no increases in chromosomal aberrations in the bone marrow cells.

Carcinogenicity

Alcohol ethoxylates as a class are not carcinogenic by the oral route, based of available oral long-term toxicity/carcinogenicity studies on AEs.

Male and female Sprague-Dawley rats were given $C_{12-13}AE_{6.5}$ in their diet at doses up to 1% (500 mg/kg-day). Reduced food consumption was noted at the higher dose levels (*i.e.*, 0.5 and 1% for females and 1% for males), resulting in a lower body weight gain compared to the control group. No treatment-related histopathology was found and no increase in tumor incidence was observed.

Male and female Charles River rats were given in their diet 0, 0.1, 0.5, or 1% $C_{14-15}AE_7$ for two years. There were no treatment-related changes in general behavior and appearance. The survival rate of the test animals was comparable if not better than the controls. Body weights of the 0.5% females and the 1% males and females had significantly lower weight gains than the control. There were no treatment-related effects on organ weights and tumor incidence.

Male and female Sprague-Dawley rats were given in their diet $C_{14-15}AE_7$ at 0.1, 0.5, and 1% for two years. A treatment-related body weight depression was observed in females at the two highest treatment levels and in males at the 1% dose level, probably due to the poor palatability of the diet. There was no evidence for any carcinogenic activity.

Reproductive Toxicity

In a two-generation reproductive toxicity study, Charles River rats were given in their diet 0, 0.05, 0.1 and 0.5% (about 0, 25, 50 and 250 mgkg-day) $C_{12}AE_6$ in the diet. There were no treatment related effects in the parents or pups on general behaviour, appearance, or survival. Fertility of treated groups was comparable with the controls. The only observation was related to a reduced weight gain of parental rats and pups relative to the control at the 0.5% dose level. The NOAEL for reproduction is 0.5% in the diet, which corresponds to 250 mg/kg-day.

Developmental Toxicity

In a two-generation reproductive toxicity study, Charles River rats were given in their diet 0, 0.05, 0.1 and 0.5% (about 0, 25, 50 and 250 mg/kg-day) $C_{12}AE_6$. General behavior, appearance and survival were unaffected by treatment. At the 0.5% dose level, adults and pups gained less weight than the control rats. In the 0.5% dose group, there was a statistical increase in embryo lethality and soft tissue anomalies and at the 0.1% there was a statistical decrease in mean fetal liver weight. Neither of these effects was considered to be treatment-related by the authors as they showed no dose response characteristics. The NOAEL for maternal toxicity is 50 mg/kg-day. The NOAEL for developmental and teratogenicity is 0.1% in the diet (50 mg/kg-day).

Pregnant rabbits were given by oral gavage 0, 50, 100, or 200 mg/kg $C_{12}AE$ from gestational days 2 to 16. Nine control rabbits and 31 treated rabbits died during the study. Surviving rabbits at the 200 mg/kg dose level generally showed slight losses of body weight. At 100 and 200 mg/kg, ataxia and a slight decrease in body weight was observed in the pregnant animals. In seven treated and two control rabbits, early deliveries were recorded. There were no treatment-related effects on corpora lutea, implantations, number of live fetuses and spontaneous abortions. The NOAEL for maternal toxicity is 50 mg/kg-day; the NOAEL for developmental toxicity is 200 mg/kg-day.

Derivation of Toxicological Reference and Drinking Water Guidance Values

The lowest NOAEL from several rat 90-day oral toxicity studies on alcohol ethoxylates ranging in carbon number from 9 to 11 is 150 mg/kg-day. The NOAEL of 150 mg/kg-day will be used to derive an oral reference dose and drinking water guidance value for the alcohols C9-11, ethoxylated.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 3
UF_D (database uncertainty) = 1

Oral RfD = 150/(10 x 10 x 1 x 3 x 1) = 150/300 = 0.5 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (0.5 x 70 x 0.1)/2 = 1.8 mg/L

References

ADWG. (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

Human and Environmental Risk Assessment (HERA) on Ingredients of Household Cleaning Products: Alcohol Ethoxylates (2009), http://www.heraproject.com.

Talmage, S.S. (1994). Environmental and Human Safety of Major Surfactants – Alcohol Ethoxylates and Alkylphenol Ethoxylates, pp. 35, The Soap and Detergent Association, Lewis Publishers, Boca Raton, Florida.

Toxicity Profile

Castor Oil, Ethoxylated
(CAS No. 61791-12-6)

Ethoxylated castor oil is an UVCB substance.

Acute Toxicity

The oral LD_{50} for castor oil, ethoxylated is >6,400 mg/kg in rats (ECHA) [Kl. score = 2]. The dermal LD_{50} for castor oil, ethoxylated is >2,000 mg/kg in rats (ECHA) [Kl. score = 1]. No acute inhalation studies were identified.

Irritation

Application of 0.5 mL castor oil, ethoxylated to the skin of rabbits for 4 hours under occlusive conditions was not irritating. The mean of eh 24, 48, and 72-hour scores were 0.00 for both erythema and edema (ECHA) [Kl. score = 1].

Instillation of 0.1 mL castor oil, ethoxylated to the eyes of rabbits was non-irritating. The 24, 48, and 72 hours were 0.00 for all endpoints, except for the 24-hour conjunctival redness score of 1.00 for one animal (ECHA) [Kl. score = 1].

Sensitization

Castor oil, ethoxylated was not considered a skin sensitizer when tested in a two separate guinea pig maximization tests (ECHA) [Kl. score = 2].

Repeated Dose Toxicity

Male and female Sherman-Wistar rats were fed diets containing 0, 0.1%, 0.04%, 0.16%, 0.64%, 2.5%, or 5.0% castor oil, ethoxylated (PEG-40 Castor oil) for 13 weeks. There were no effects on body weight, feed consumption, hematological parameters, gross or microscopic pathology. The NOAEL is 5% in the diet, which corresponds to 2,500 mg/kg-day (ECHA) [Kl. score = 2].

Dermal

Male and female SD rats were administered dermal applications of 0 or 0.25% PEG-40 Hydrogenated castor oil 5 days/week for 13 weeks. There were no treatment-related effects. The NOAEL for this study is 0.25%, which corresponds to 4.1 mg/kg-day (ECHA) [Kl. score = 2].

Genotoxicity

Castor oil, ethoxylated was negative in a chromosomal aberration test using CHO cells (ECHA) [Kl. score = 2].

Carcinogenicity

No studies are available.

Reproductive Toxicity

No studies are available on castor oil, ethoxylated.

A multi-generation reproductive toxicity study on polyoxyethylene (65) sorbitan monolaurate [Tween 65] has been used to read-across to castor oil, ethoxylated. Male and female rats were fed in their diet 0, 5, 10, or 20% Tween 65 for three generations over a two-year period. At 10% in the diet, Tween 65 was found to have an effect on reproductive indices and offspring viability, reproductive performance, mortality, fertility, and reduction in lactation period compared to the controls. It was observed that better survival of the offspring occurred following an addition of fat in the basal diet. The NOAEL for this study is 5% in the diet, which is estimated to be 2,500 mg/kg-day (Oser and Oser, 1956; ECHA) [Kl. score = 2].

Developmental Toxicity

Pregnant female mice were fed in their diet 0, 5,000, or 10,000 mg/kg PEG-40 Hydrogenated castor oil on gestational days 6 to 15. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity is 10,000 mg/kg-day (ECHA) [Kl. score = 2].

Derivation of Toxicological Reference and Drinking Water Guidance Values

In a 13-week dietary study, there were no effects in male and female rats at doses up to 5% castor oil, ethoxylated, which corresponds to an estimated daily intake of 2,500 mg/kg-day (ECHA). The NOAEL of 2,500 mg/kg-day from this study will be used to derive an oral reference value and a drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 3
UF_D (database uncertainty) = 1

Oral RfD = 2,500/(10 x 10 x 1 x 3 x 1) = 2,500/300 = 8 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,

Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (8 x 70 x 0.1)/2 = 28 mg/L

References

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Toxicity Profile

Choline chloride
(CAS No. 67-48-1)

Metabolism

Choline is a vitamin-like essential nutrient. Although the body can synthesize choline in small amounts, it is insufficient to maintain health and must be consumed in the diet. Choline is required for the synthesis of phospholipids in cell membranes, methyl group metabolism and acetylcholine synthesis (neurotransmitter) (Zeisel and Blusztajn, 1994).

Dietary choline is taken up into the body by transporter proteins present in the cells lining the small intestine (IOM, 2000). In the small intestine, prior to uptake into the small intestinal cells, some choline is metabolized by bacteria to betaine and methylamines (Zeisel et al., 1980). Dietary choline can be present as free choline or in esterified forms (i.e., phosphocholine, glycerophosphocholine, sphingomyelin, and phosphatidylcholine) (Zeisel and Blusztain, 1994). Free choline is formed from these esterified choline compounds by pancreatic enzymes.

Choline is involved in a number of biochemical pathways in eukaryotic and prokaryotic cells. It is a precursor for acetylcholine (a neurotransmitter); phospholipids (structural integrity and signaling roles for cell membranes); and a major source for methyl groups (IOM, 2000).

Acute Toxicity

The oral LD_{50} values of choline in rats are approximately 3,500 and 5,500 mg/kg (ECHA). [Kl.
scores = 2]

Irritation

Application of a 70% aqueous solution to the skin of rabbits for 20 hours under occlusive conditions resulted in ambiguous skin irritation (BASF AG, 1963a; OECD, 2004). [Kl. score = 2]

Slight eye irritation was seen in the eyes of rabbits after instillation of a 70% aqueous solution of choline chloride; no effects were seen 24 hours after exposure (BASF AG, 1963b; OECD, 2004). [Kl. score = 2]

Sensitization

No data are available in animals. In a Human Repeated Insult Patch Test (HRIPT), there was no evidence of dermal sensitization in two hundred subjects given 0.5% (w/v) aqueous solution of choline chloride during the induction phase and 0.2% (w/v) aqueous solution during the challenge phase (Colgate-Palmolive, 2003; OECD, 2004).

Repeated Dose Toxicity

A 72-week feeding study was conducted to investigate the impact of choline chloride on the liver tumor promoting activity of phenobarbital and DDT in diethylnitroamine-initiated Fischer 344 rats. Animals received approximately 500 mg/kg-day choline chloride. Following the end of the exposure period, the animals were kept on the same untreated diet as the control group until study termination at week 103. Histopathology was limited to the liver and organs that developed gross abnormalities. There were no significant differences between treated and control animals on survival rates, body weights, and relative liver weights. There were no increased number of neoplastic liver nodules, hepatocellular carcinomas, lung tumors, leukemia or other tumors between treated and control animals. The NOAEL for choline chloride in this study is 500 mg/kg-day (Shivapurkar *et al.*, 1986). [Kl. score = 3]

In humans, oral administration of 10,000 mg/day choline chloride in a pilot study treating a small number of patients with Alzheimer's disease resulted in a slight hypotensive effect (Boyd *et al.*, 1977). This dose was regarded as a LOAEL by the U.S. Institute of Medicine (IOM) Standing Committee on the Scientific Evaluation of Dietary Reference Intake (2000).

Genotoxicity

Choline chloride was not mutagenic to bacteria in reverse mutation assays (Haworth *et al.*, 1980; Litton Bionetics, 1977; OECD, 2004).

A small, but statistically significant, and dose-related increase in chromosomal aberrations was reported in Chinese Hamster Ovary (CHO) cells at doses of 50 and 500 µg/ml choline chloride in the absence of S9 only (Bloom *et al.*, 1982). No higher concentrations were examined. These results could not be confirmed in two studies using CHO cells at concentrations of choline chloride up to 5,000 µg/ml (Galloway *et al.*,1985).

In sister chromatid exchange (SCE) assays, ambiguous results were obtained in two parallel studies (at two different laboratories) in CHO cells at concentrations up to 50 and 500 µg/ml choline chloride, respectively. Cytotoxicity was observed at 5,000 µg/ml. In laboratory 2, the increase in SCEs, which was sporadic and not dose-related, that was observed with metabolic activation was not reproduced in laboratory 1. Laboratory 1 showed a weak positive at the top dose without metabolic activation, but a comparison with laboratory 2 was not possible due to insufficient number of cells analyzed (Bloom *et al.*, 1982; Galloway *et al.*, 1985).

Choline chloride was negative in a gene conversion assay with *Saccharomyces cerevisiae* strain D4 in the presence or absence of metabolic activation (Litton Bionetics, 1977; OECD, 2004).

Carcinogenicity

No studies are available.

Reproductive Toxicity

No reliable studies have been conducted that address female fertility or reproductive toxicity by a relevant route of exposure.

Developmental Toxicity

Pregnant female mice were given in their feed 0, 1, 2.5, 5, or 10% choline chloride (0 or approximately 1,250, 4,160, 10,800, or 20,000 mg/kg choline chloride) on gestational days 1 to 18. Maternal body weight gain was reduced in all treated groups except for the 1,250 mg/kg group. Maternal weight gain of dams with embryonic/fetal absorptions showed no net weight gain at ≥4,160 mg/kg, but there was net weight loss in the 20,000 mg/kg group. All fetuses were resorbed in the 20,000 mg/kg group. Embryonic/fetal lethality of 35% and 69% were seen in the 4,160 and 10,800 mg/kg groups, respectively. No resorptions occurred in the 1,250 mg/kg group. Developmental toxicity was seen at ≥4,160 mg/kg group. There were no statistically significant increases in malformations in any dose group. The NOAEL for maternal and developmental toxicity is 1,250 mg/kg-day (BASF AG 1966; OECD 2004). [Kl. score = 2]

Derivation of Toxicological Reference and Drinking Water Guidance Values

The Standing Committee on the Scientific Evaluation of Dietary Reference Intakes selected hypotension as the critical effect from the study by Boyd *et al.* (1977) when deriving a Tolerable Upper Intake Level. Boyd *et al.* (1977) reported a LOAEL of 10,000 mg/day choline chloride (7,500 mg/day choline). An uncertainty factor of 2 was chosen because of the limited data regarding hypotension and the inter-individual variation in response to cholinergic effects. Thus, the value for the Tolerable Upper Intake Value for repeated exposure of adults to choline is 3,500 mg/day choline.

Note that the Australian National Health and Medical Research Council (2014) concluded that there are no data to suggest that there is increased susceptibility to choline during pregnancy or lactation; thus, the upper level of intake choline is the same for women during pregnancy or lactation as it is for adults (3,500 mg/day choline).

Oral Reference Dose (oral RfD)

An oral RfD for choline is derived as follows: the LOAEL of 7,500 mg/day from the Boyd *et al.* (1977) study is divided by an uncertainty factor of 2 to obtain a value of 3,500 mg choline/day or 50 mg choline/kg-day for a 70 kg person.

Oral RfD = 50 mg/kg-day [choline]

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (50 x 70 x 0.1)/2 = 175 mg/L [choline]

The Australian drinking water guideline value for chloride ions is 250 mg/L based on aesthetics (ADWG, 2011).

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Toxicity Profile

Cinnamaldehyde
(CAS No. 104-55-2)

Acute Toxicity

The oral LD_{50} in rats is 2,220 mg/kg (ECHA) [Kl. score = 2]. The dermal LD_{50} in rats is >2,000 mg/kg (ECHA) [Kl. score = 2].

Irritation

Application of cinnamaldehyde to the skin of rabbits for 4 hours under semi-occlusive conditions was considered a slight-to-moderate irritant. Cinnamaldehyde was severely irritating when applied for 24 hours under occlusive conditions (ECHA) [Kl. score = 2]. Cinnamaldehyde was considered to be a severe skin irritant when tested in a human patch test. Cinnamaldehyde, at doses of 0.02, 0.1%, and 0.8% in ethanol, was applied to the skin over a six-week period (ECHA).

Instillation of 0.1 mL cinnamaldehyde to the eyes of rabbits was considering irritating. The mean of the 24, 48, and 72 hours scores were: 1.00 for corneal opacity, 0.00 for iridial lesions, 2.00 for conjunctival redness, and 1.22 for chemosis. All effects were resolved by Day 14 of the observation period (ECHA) [Kl. score = 1].

Sensitization

Cinnamaldehyde was considered a skin sensitizer when tested in a guinea pig maximization test (ECHA) [Kl. score = 2].

Repeated Dose Toxicity

Male and female F344 rats were given in their diet 0, 4,100, 8,200, 16,500, or 33,000 ppm cinnamaldehyde (microcapsulated) for three months in a study conducted by the National Toxicology Program. The average daily intake was 0, 275, 625, 1,300, and 4,000 mg/kg-day for males, and 0, 300, 570, 1,090, and 3,100 mg/kg-day for females. There was no mortality during the study. Mean body weights were reduced in the ≥16,500 ppm animals as a result of decreased feed consumption from unpalatability of the dosed feed. There was a non-significant increase in serum bile acid concentration at all dose levels suggesting an effect on the liver, but there were no corresponding histopathologic effects. An increase in lesions of the forestomach mucosa was seen in the ≥8,200 ppm animals and included squamous epithelial hyperplasia. There was also chronic active inflammation in the 33,000 ppm males and the ≥16,500 ppm females. The NOAEL was considered to be 4,100 ppm, which corresponds to 275 and 300 mg/kg-day in males and females, respectively (Hooth et al., 2004; ECHA) [Kl. score = 1].

Male and female rats were fed in their diet 0, 1,000, 2,100, or 4,100 ppm cinnamaldehyde for 12 weeks. The average daily intake was 0, 50, 100, or 200 mg/kg-day. There were no significant differences between treated and control animals in urine sugar and albumin, blood hemoglobin levels, growth, food intake, or other physiological criteria. The NOAEL for this

study is 4,100 ppm for males and females, which corresponds to 200 mg/kg-day (ECHA) [Kl. score = 2].

Male and female F344 rats were given in their diet 0, 1,000, 2,100, or 4,100 ppm cinnamaldehyde (microcapsulated) for two years in a study conducted by the National Toxicology Program. The average daily intake was 0, 50, 100, or 200 mg/kg-day. The survival of the 4,100 ppm males was greater than the controls. The mean body weights of the 4,100 ppm animals were generally less than the controls throughout the study. Feed consumption of the ≥2,100 ppm males and the 4,100 ppm females was less than the controls at the beginning and end of the study. There were no non-neoplastic lesions that were considered to be treatment-related. The NOAEL for this study is 4,100 ppm for males and females, which corresponds to 200 mg/kg-day (Hooth et al., 2004; ECHA) [Kl. score = 1].

Male and female B6C3F$_1$ mice were given in their diet 0, 1,000, 2,100, or 4,100 ppm cinnamaldehyde (microcapsulated) for two years in a study conducted by the National Toxicology Program. The average daily intake was 0, 125, 270, or 540 (males) and 570 (females) mg/kg-day. Mean body weights of the ≥2,100 ppm animals were generally less than the controls throughout the study. There were no non-neoplastic lesions that were considered to be treatment-related. Incidences of minimal olfactory epithelial pigmentation was significantly increased in the 4,100 ppm males and the ≥2,100 ppm females. The NOAEL for this study is 1,000 ppm in males and females, which corresponds to 125 mg/kg-day, based on reduced body weights at 270 mg/kg-day (Hooth et al., 2004; ECHA) [Kl. score = 1].

Genotoxicity

Cinnamaldehyde was not mutagenic to *S. typhimurium* strains TA 1535, TA 1537, TA 97, TA 98, or TA 100 in the absence or presence of metabolic activation (ECHA) [Kl. score = 2].

Male and female B6C3F$_1$ mice were administered in their feed 0, 4,100, 8,200, 16,500, or 33,000 ppm cinnamaldehyde (microcapsulated) for three months in a study conducted by the National Toxicology Program. The average daily intake was 650, 1,320, 2,550, and 5,475 mg/kg-day for males, and 0, 625, 1,380, 2,680, and 5,200 mg/kg-day for females. There were no increases in the frequency of micronucleated normochromatic erythrocytes in the peripheral blood in the treated animals compared to the controls (ECHA) [Kl. score = 2].

Carcinogenicity

Male and female F344 rats were administered in their diet 0, 1,000, 2,100, or 4,100 ppm cinnamaldehyde (microcapsulated) for two years in a study conducted by the National Toxicology Program. The average daily intake was 0, 50, 100, or 200 mg/kg-day. The tumor incidences were similar between the treated and control animals (Hooth et al., 2004; ECHA) [Kl. score = 1].

Male and female B6C3F$_1$ mice were administered in their diet 0, 1,000, 2,100, or 4,100 ppm cinnamaldehyde (microcapsulated) for two years in a study by the National Toxicology Program. The average daily intake was 0, 125, 270, or 540 (males) and 570 (females) mg/kg-day. The tumor incidences were similar between the treated and control animals (Hooth et al., 2004; ECHA) [Kl. score = 1].

Reproductive Toxicity

No adequate studies are available.

Developmental Toxicity

Pregnant female CD-1 mice were dosed by oral gavage with 0 or 1,200 mg/kg cinnamaldehyde on gestational days 6 to 13. The dams were allowed to deliver, and the pups were weaned up to postnatal day 3. There was no effect on maternal survival or body weight development and all 34 litters were viable. The number of lifeborns per litter, the survival and birthweight of pups and their weight gain was not affected by treatment. The NOAEL for maternal and developmental toxicity is 1,200 mg/kg-day (ECHA) [Kl. score = 2].

Derivation of Toxicological Reference and Drinking Water Guidance Values

Rat and mouse two-year feeding studies have been conducted on cinnamaldehyde (Hooth et al., 2004; ECHA). The lowest NOAEL from these studies is 1,000 ppm is 125 mg/kg-day, based on reduced body weights in male mice at 270 mg/kg-day. The NOAEL of 125 mg/kg-day will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 125/(10 x 10 x 1 x 1 x 1) = 125/100 = 1.0 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (1.25 x 70 x 0.1)/2 = 4 mg/L

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Toxicity Profile

Diethylene Glycol
(CAS No. 111-46-6)

Acute Toxicity

The oral LD_{50} values in rats are 19,600 mg/kg (Lenk *et al.*, 1989) and 16,500 mg/kg in rats (Laug *et al.*, 1939).

No deaths were reported in rats exposed to a saturated vapor for 6 hours (OECD, 2007). No deaths were also reported in male and female Aplk:AP_fSD (Wistar-derived) rats exposed to 5,080 mg/m^3 diethylene glycol aerosol (MMAD = 2.83 μm, GSD = 2.05) for 4 hours (OECD, 2007).

The dermal LD_{50} in rabbits was reported to be 12,500 mg/kg (OECD, 2007) and 13,300 mg/kg (ECHA).

Irritation

When applied to the skin of rabbits for 24 hours under occlusive conditions, diethylene glycol was essentially non-irritating with a PII score of 0.04 (Guillot *et al.*, 1982) [Kl. score = 2]. In a human repeated irritation patch test, diethylene glycol was minimally irritating to the skin (OECD, 2007).

Instillation of 0.1 mL in the eyes of rabbits produce minor, transient irritation; no corneal lesions were observed (OECD, 2007) [Kl. score = 2]. When instilled into the eyes of rabbits, the ocular irritancy was 11.67 based on a modified Kay Calandra scale of 0 to 110 (Guillot et al., 1982) [Kl. score = 2].

Sensitization

Diethylene glycol was not a skin sensitizer to guinea pigs in a maximization test (OECD, 2007) [Kl. score = 1]. Diethylene glycol was not a skin sensitizer in a human repeat irritation patch test (OECD, 2007).

Repeated Dose Toxicity

Male and female Wistar rats were given in their diet 0, 0.085, 0.17, 0.4, and 2.0% diethylene glycol for 225 days. The corresponding average daily intakes were 0, 51, 105, 234, and 1194 mg/kg-day for males; and 0, 64, 126, 292 and 1462 mg/kg-day for females. In the 0.4% and 2% groups, there were oxalate crystalluria and mild defects of renal function (increased urine volume), as measured by concentration tests. The only finding in the 0.17% group was a 13.2% increase in urinary oxalate excretion in males; no effects were observed in the 0.085% group. The NOAEL and NOEL for this study is considered to be 0.17% (approximately 105 mg/kg-day) and 0.085% (approximately 51 mg/kg-day), respectively (OECD, 2007; ECHA) [Kl. score = 2].

Genotoxicity

The *in vitro* genotoxicity studies on cellulase diethylene glycol are shown in Table 1.

Table 1: *In vitro* Genotoxicity Studies on Diethylene Glycol

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	1	OECD (2007), ECHA
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	1	ECHA
Chromosomal aberration (CHO cells)	-	-	2	OECD (2007), ECHA
Sister chromatid exchange (CHO cells)	-	-	2	OECD (2007), ECHA

*+, positive; -, negative

Micronuclei were not increased in the bone marrow of NMRI mice given a single intraperitoneal injection of 0, 500, 1000 or 2000 mg/kg diethylene glycol (ECHA).

Carcinogenicity

Male and female F344 rats were given 0, 1.25 or 2.5% diethylene glycol (97% purity) in their drinking water for two years. The daily intake was estimated to be 0, 1,210, and 2,630 mg/kg-day for males; and 0, 1,160, and 2,550 mg/kg-day for females. There was increased drinking water consumption in the high-dose animals and increased mortality in the high-dose males. There were no significant differences in the incidence of tumors between treated and control animals (Hiasa *et al.*, 1990; ECHA) [Kl. score = 2].

Male Osborne-Mendel rats were fed diets containing 0, 1, 2, or 4% diethylene glycol for two years. During the first 26 weeks of the study, weight gain was significantly reduced at all dose levels. After the first year, the growth of rats fed the 4% diets was significantly reduced relative to the controls. There were no significant differences in food consumption at any treatment level. Mortality in rats fed the 4% diet was significantly higher than the control group, with all animals dead before the end of the study (most dying during the last 12 months), compared with 7/12 control deaths. The incidence of bladder stones and bladder tumors increased with diethylene glycol exposure, with 0, 0, 6, and 5 bladder tumors observed in the control, 1, 2, and 4% DEG groups, respectively. Bladder stones were observed in 0, 2, 7, and 11 rats in the control, 1, 2, and 4% groups, respectively. In all but one case, bladder stones were present when bladder tumors were observed, suggesting that chronic irritation was a factor in the production of bladder tumors. The severity and incidence of signs of kidney damage (hydronephrosis, hydroureter, focal tubular atrophy, hyalin cast formation, glomerular atrophy) increased in a treatment-related manner, with gross kidney lesions observed in 1/12, 3/12 and 8/12 of the rats in the low-, mid-, and high-dose groups, respectively. Liver damage observed histologically also increased with

the level of diethylene glycol exposure. It cannot be ruled out that this older study, which showed a significant increase in bladder stones and bladder tumors, may have been influenced by the presence of ethylene glycol as an impurity (Fitzhugh and Nelson, 1946) [Kl. score = 3].

Male and female rats were fed diets containing 0, 2, or 4% diethylene glycol (containing 0.031% ethylene glycol) for two years. Rats were either just weaned, 2 months old, or 12 months old at the initiation of the exposure. The dietary concentration of diethylene glycol was adjusted for the food consumption and body weight of each group. For 4% diet, the dosage in weanlings was 5,400 mg/kg-day for the first 28 days, approximately 3,700 mg/kg/day during the next two-week period, gradually declined to about 2,000 mg/kg-day over the next three months and remained at that level for the rest of the study. A study average of 2,300 mg/kg/day for weanlings fed 4% in the diet was calculated from data provided by the authors. None of the 12-month old male rats included in the study survived, whereas all the females in that group survived to termination of the study. Although weanling rats developed more bladder stones than the other groups, the difference was insignificant. The yearling rats developed their bladder stones somewhat earlier. The yearling rats in the 4% groups had the highest stone formation (8 out of 20 rats) and had the only bladder tumor in this dose group; the rat with the bladder tumor also had bladder stones. No bladder stones or tumors were observed in rats of any age in the control or in the 2% groups. The bladder tumors associated with the stones were considered to be the result of mechanical irritation, and diethylene glycol was not considered to be a primary rat carcinogen. The LOAEL and NOAEL for this study were dietary concentrations of 4% and 2% (approximately 2,300 and 1,200 mg/kg), respectively. It cannot be ruled out that this older study, which showed a significant increase in bladder stones and bladder tumors, may have been influenced by the presence of ethylene glycol as an impurity (Weil *et al.*, 1965) [Kl. score = 3].

Reproductive Toxicity

In a two-generation study, male and female rats were dosed by oral gavage with 1 mL/100 g body weight of a 20% aqueous solution of diethylene glycol (approximately 2 mL/kg-day) for 8 weeks. A control group was given daily oral gavage doses of 1 mL/100 g body weight distilled water. Five of the treated females were dosed with diethylene glycol until parturition, the other five until the pups were weaned. Treatment of the P-generation with diethylene glycol for 12 weeks did not impair reproduction. The test animals and the controls became pregnant at almost the same time, litter size averaged 8-10 young, and the young exhibited similar, uniform development. Growth and onset of estrus were not affected by treatment. The endocrine glands investigated showed no differences from the controls with regard to weight and fine structure. The receptiveness and litter size of the untreated F_1 generation were the same as those of the P-generation, and the F_2 generation was normal with regard to weight gain, onset of sexual maturity, and weight as well as histology of the organs examined. The NOAEL for this study was calculated to be 2,200 mg/kg-day (Wegener, 1953; ECHA) [Kl. score = 2].

A continuous breeding protocol (RACB) was used to study the reproductive toxicity of diethylene glycol in mice. Male and female CD-1 mice were administered in their drinking water 0, 0.35, 1.75, or 3.5% diethylene glycol. Mice were exposed for 7

days prior to mating, 98 days during cohabitation of breeding pairs, and a further 23 days after segregation of each pair.

Breeding study: The mice given 1.75% or 3.5% diethylene glycol consumed significantly more drinking water than did the controls. On the basis of water consumption and body weight data, the 0, 0.35, 1.75, and 3.5% dose groups were equivalent to average daily intakes of 0, 612, 3,062, or 6,125 mg/kg-day, respectively. There was no treatment-related mortality. In the 3.5% dose group, there was significant decreases in the number of litters produced per pair, number of live pups per litter, proportion of pups born alive, and the absolute and adjusted pup weights. A significant dose-related trend for reduced absolute pup weights was also observed. Exposure to the 3.55 dose group also resulted in a significant increase in the cumulative days to litter and fewer breeding pairs were able to produce litters: 82%, 76%, and 59% of the pairs exposed to 3.5% in the diet produced the third, fourth or fifth litters, respectively, whereas 97-100% of the control group produced litters.

Crossover mating: The mating index and the fertility of the 3.5% dosed males or females were unaffected compared with the control mice. However, live pup weight was decreased in the highest-dose group, in which a 9% difference was observed for the offspring of the control males and the treated females. At the end of this test the parental animals (F_0 of breeding study) were necropsied. For the male mice there were no significant differences in the body or organ weights, either absolute or adjusted for body weight. Analysis of the cauda epididymal contents of F_0 males at necropsy indicated that there were no effects of diethylene glycol in the highest-doses group on the sperm concentration or the percentage of motile or abnormal sperm. The mean body weight of the 3.5% dosed F_0 females was significantly decreased relative to the control females. The magnitude of this decrease was approximately 7%. These animals also exhibited significantly decreased absolute liver and pituitary weights, but their organ-to body weight ratios were not different from controls. There were no significant treatment-related gross or histopathological lesions in the organs examined from the male and female F_0 mice (Williams *et al.*, 1990) [Kl. score = 2].

Developmental Toxicity

Time-pregnant CD rats were dosed by oral gavage with 0, 1,118, 4,472 or 8,944 mg/kg on gestational days 6-15. In the high-dose females, there were reduced body weight gain, reduced food consumption, increased water consumption, increased liver and kidney weights, and histopathological changes in the kidney. The mid-dose females exhibited only increased water consumption. There were no treatment-related effects on corpora lutea or implantations. Fetal body weights were reduced in the high-dose animals. Total or individual external or visceral variations were similar between treated and control groups; however, individual skeletal variations were significantly increased in the mid- and high-dose groups. The pattern of delayed ossification was considered consistent with reduced fetal body weight. Malformations were similar between treated and control groups. The maternal and developmental NOELs for this study were considered to be 1,118 mg/kg/day (Ballantyne and Snellings, 2005) [Kl. score = 2].

Time-pregnant CD-1 mice were dosed by oral gavage with 0, 559, 2,795, or 11,180 mg/kg/day during gestational days 6-15. In the high-dose females, there was mortality, clinical signs, and increased water consumption; only increased water consumption was observed in the mid-dose females. Fetal body weights were significantly reduced in the high-dose animals. There were no increases in variations or malformations between treated and control animals. The maternal and developmental NOELs were 559 and 2,795 mg/kg/day, respectively (Ballantyne and Snellings, 2005) [Kl. score = 2].

Groups of 15 pregnant Himalayan rabbits were administered oral (gavage) doses of 0, 100, 400, or 1000 mg/kg DEG on gestational days 7-19. No maternal toxicity was observed at any of the DEG doses administered. The fetal and litter incidence of skeletal, soft tissue, and external anomalies or variations were comparable to those of the control and/or historical control groups. The authors set the maternal and developmental toxicity NOEL at greater than 1,000 mg/kg (Hellwig *et al.*, 1995) [Kl. score = 1].

Key Study/Critical Effect for Screening Criteria

The lowest NOAEL reported in the repeat dose toxicity study is 105 mg/kg/day based on the 225-day rat dietary study. Although, there was a 13.2% increase in oxalate excretion at this dose level, this was considered a biomarker and not an indicator of toxicity. At 0.4% (the LOAEL), there were oxalate crystalluria and mild defects of renal function (increased urine volume), as measured by concentration tests. The NOAEL of 105 mg/kg-day will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1

UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 105/(10 x 10 x 1 x 1 x 1) = 105/100 = 1.0 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (1 x 70 x 0.1)/2 = 3.5 mg/L

References

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Toxicity Profile

Distillates, Petroleum, Hydrotreated Light
(CAS No. 64742-47-8)

Distillates, petroleum, hydrotreated light (CAS No. 64742-47-8) is defined as follows:

"A complex combination of hydrocarbons obtained by treating a petroleum fraction with hydrogen in the presence of a catalyst. It consists of hydrocarbons having carbon numbers predominantly in the range of C9 through C16 and boiling in the range of approximately 150ºC to 290ºC. (302ºF to 554ºF)."

There are a hierarchy of considerations in the assignment of CAS registry numbers (CAS RNs) for hydrocarbon substances. These considerations include hydrocarbon type(s), carbon number and/or range, distillation temperature and/or range, and last processing step. Criteria have been developed for assignment of CAS RNs for multi-constituent hydrocarbon substances, and one documented source of criteria is that used by the U.S. Environmental Protection Agency (EPA) for the Toxic Substance Control Act (TSCA) inventory for U.S. chemicals. It should be noted that these criteria may allow the same CAS RN to be applied to differing hydrocarbon and petroleum-derived substances (petroleum streams) that differ somewhat in compositions and applications. Different CAS RNs can also be applied to substances of similar composition and application.

The category C_9-C_{14} Aliphatic [$\leq$2% Aromatics] Hydrocarbon Solvents was developed and reviewed in the OECD-SIDS program (OECD, 2012). Hydrocarbon solvents with CAS RN 64742-47-8 are included in this category. For this category, the hydrocarbons present in CAS RN 64742-47-8 are aliphatic hydrocarbons (typically 30-60% isoparaffins and 40-70% cycloparaffins), with <1% aromatics (OECD, 2012). The typical carbon number range is: ~3% C8, ~26% C9, ~36% C10, ~31% C11, and ~2% C12 (OECD, 2012).

Acute Toxicity

The oral LD_{50} values in rats for two hydrocarbon solvents with CAS RN 64742-47-8 are >5,000 mg/kg (OECD, 2012). The dermal LD_{50} values in rats for the C_9-C_{14} aliphatic [$\leq$2% aromatics] hydrocarbon solvents are >2,000 mg/kg (OECD, 2012). The 4-hour inhalation LC_{50} values in rats for the C_9-C_{14} aliphatic [$\leq$2% aromatics] hydrocarbon solvents are >4,951 mg/m^3 (OECD, 2012).

Irritation

Hydrocarbon solvents with CAS RN 64742-47-8 are slight skin irritants to rabbits under semi-occlusive conditions (OECD, 2012). C_9-C_{14} aliphatic [$\leq$2% aromatics] hydrocarbon solvents produce minimal eye irritation to rabbits (OECD, 2012).

Sensitization

CAS RN 64742-47-8 was not a dermal sensitizer to guinea pigs (OECD, 2012).

Repeated Dose Toxicity

Male and female rats were dosed daily by oral gavage with 0, 100, 500, or 1,000 mg/kg CAS RN 64742-47-8 for 13 weeks. CAS RN 64742-47-8 is composed of hydrocarbons, C_{11}-C_{14}, n-alkanes, isoalkanes, cyclics, <2% aromatics. Additional groups of animals were dosed for 0 or 1,000 mg/kg CAS RN 64742-47-8 for 13 weeks followed by a 4-week recovery period. There were no treatment-related effects. The NOAEL for this study is 1,000 mg/kg-day (OECD, 2012).

Male and female rats were dosed daily by oral gavage with 0, 500, 2,500 or 5,000 mg/kg CAS RN 64742-48-9 for 13 weeks. CAS RN 74742-48-9 is composed of hydrocarbons, C_{10}-C_{13}, n-alkanes, isoalkanes, cycles, <2% aromatics. Additional groups of animals were dosed for 0 or 5,000 mg/kg for 13 weeks followed by a 4-week recovery period. There were dose-related changes in the hematology and serum chemistry parameters which were consistent with changes seen in the liver. Hepatocellular hypertrophy (liver cell enlargement) were seen in both males and females in all dose groups and were reversible. The liver effects were not considered to be an indication of toxicity but an adaptive response due to the metabolism of the hydrocarbons. There were also mucosal thickening and other signs of irritation to the stomach and anus, which appeared to be the direct result of high-dose intubation of a locally irritating material. All treatment-related effects were reversible within the 4-week recovery period. The NOAEL for systemic effects in this study is considered to be 5,000 mg/kg-day (OECD, 2012).

Genotoxicity

Hydrocarbons, C_{10}-C_{12}, n-alkanes, isoalkanes, cyclics, <2% aromatics (CAS RN 64742-48-9) was not mutagenic to *S. typhimurium* strains TA1535, TA1537, TA 98 and TA100 in the absence and presence of metabolic activation (OECD, 2012). CAS RN 64742-47-8 did not increase chromosomal aberrations in human lymphocytes in the absence or presence of metabolic activation (OECD, 2012). Hydrocarbons, C_{10}-C_{13}, n-alkanes, isoalkanes, cyclics, <2% aromatics (CAS RN 64771-72-8) did not increase micronuclei in the bone marrow of mice when dosed by oral gavage up to 5,000 mg/kg (OECD, 2012).

Carcinogenicity

No carcinogenicity studies are available on the C_9-C_{14} Aliphatic [$\leq$2% Aromatics] hydrocarbon solvents.

Reproductive Toxicity

No reproductive toxicity studies are available on the C_9-C_{14} aliphatic [$\leq$2% aromatics] hydrocarbon solvents.

Developmental Toxicity

Hydrocarbons, C_9-C_{11}, n-alkanes, isoalkanes, cyclics, <2% aromatics (CAS RN 64742-48-9) has been tested in a rat pre-natal developmental toxicity study. Pregnant female rats were exposed by inhalation to 0, 300 or 900 ppm for 6 hours/day during

gestation days 6 to 15. There was no evidence of maternal or developmental toxicity at either exposure level. The NOAEL for this study is 900 ppm (OECD, 2012).

Derivation of Toxicological Reference and Drinking Water Guidance Values

No adverse effects were seen in male and female rats dosed by oral gavage with CAS RN 64742-47-8 for 13 weeks. The NOAEL for this study is 1,000 mg/kg-day, the highest dose tested. The NOAEL will be used to derive the oral reference dose and drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 3
UF_D (database uncertainty) = 1

Oral RfD = 1,000/(10 x 10 x 1 x 3 x 1) = 1,000/300 = 3 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (3.33 x 70 x 0.1)/2 = 12 mg/L

References

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

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Toxicity Profile

Ethoxylated C11 Alcohol
(CAS No. 34398-01-1)

Alcohol ethoxylates (AE) are a class of non-ionic surfactants that have the basic structure $C_{x-y}AE_n$. The subscript (x-y) following the 'C' indicates the range of carbon chain units. The hydrocarbon chain can be either linear or branched. AEs also contain an ethylene oxide (E) chain attached to the alcohol. The degree of ethylene oxide polymerization is indicated by the subscript (n) which indicates the average number of ethylene oxide units. In household products the average ethylene oxide chain length commonly ranges between 3 and 12 units.

The toxicity profile of ethoxylated C11 alcohol has been developed from a risk assessment report on ethoxylates ranging from C8 to C18 prepared by the household cleaning product and chemical industry (HERA, 2009).

Acute Toxicity

The oral LD_{50} for $C_{11}AE_9$ is 1,100 mg/kg. The oral LD_{50} of $C9\text{-}11AE_8$ in fasted rats was found to be 1,200 mg/kg. The oral LD_{50} for $C9\text{-}11AE_{2.5}$ in rats was calculated to be >4,000 mg/kg and <10,000 mg/kg.

The dermal LD_{50} for $C_{9\text{-}11}AE_6$ is >2,000 mg/kg. In another study, 5/8 rabbits died after a dermal dose of 5,000 mg/kg $C_{9\text{-}11}AE_6$. The dermal LD_{50} values for AEs with an alkyl chain length of 9 – 11 carbon atoms in three different rat studies were determined to be >2,000 mg/kg and >4,000 mg/kg.

The acute rat 4 hr-LC_{50} of $C9\text{-}11AE_5$ generated as a mist was determined to be >0.22 mg/L. Talmage (1994) reported that alcohol ethoxylates were not acutely toxic to rats at concentrations less than or equal to their saturated vapor concentrations in air. Acute toxic thresholds were reached only when animals were exposed to the undiluted test chemical in the form of a respirable mist or aerosol. Under these conditions, 1- or 4-hour inhalation LC_{50} values ranged from 1.5 to 20.7 mg/L. Some studies reported no mortalities (1-hours LC_{50} -study) occurred at concentrations as high as 52 mg/L.

Irritation

Alcohol ethoxylates with varying alkyl chain lengths and ethoxylation degree were found to be slightly to severely irritating to skin in rabbits and rats. The degree of irritation was dependent on the type of patches used (open application versus full occlusion), the exposure time as well as the concentration of the test material. In humans, AEs are less irritating to skin than in animals. Neat applications of a range AEs in a 4-hr human patch test did not warrant these chemicals to be classified as skin irritants under EU legislation, while the same AEs would have been classified for skin irritation on the basis of animal data.

Alcohol ethoxylates range from mildly to severely irritating to rabbit eyes. Generally, concentration of 0.1% were non-irritating, and concentrations of 1 to 10% ranged

from slight to moderately irritating. No relationship could be established between the chemical structures of the tested AEs and their eye irritation responses.

Sensitization

Alcohol ethoxylates should not be considered as skin sensitizers. A substantial amount of skin sensitization studies in guinea pigs following either the Magnusson-Kligman maximization or the Buehler testing protocol are available to evaluate the skin sensitization potential of AEs. Although a mild skin sensitization reaction was observed in a study following the Magnusson-Kligman protocol, the weight of evidence clearly supports the assessment that AEs should not be considered as skin sensitizers. This is further supported by clinical and market data that demonstrate the absence skin sensitization responses to AEs when tested under the conditions of the HRIPT or when used in AE containing consumer products.

Repeated Dose Toxicity

Rats were given in their diet 0, 125, 250 or 500 mg/kg $C_{10}AE_5$ for 90 days. There were no treatment-related clinical signs, body weight gain, food consumption or feed efficiency. There was a slight increase in absolute liver weights as well as a trend toward a dose-dependent increase in the liver weight/body weight ratio, with a statistically significant increase in the high dose group. However, the histological evaluation did not reveal any indication of hepatotoxicity and therefore the increase in liver weights was not interpreted to be a toxicological effect. It can be considered to be an adaptive response as a result of extensive metabolism of the test compound by the liver. There were no other gross or histopathological changes that were considered treatment-related. The NOAEL for this study is 500 mg/kg-day.

Rats were given in their diet 0, 125, 250, 500, 1,000, or 3,000 ppm $C_{9\text{-}11}AE_6$ for 90 days. There were no signs of toxicity at any dose level. The NOAEL is 3,000 ppm (approximately 150 mg/kg-day).

Rats were given in their diet 0. 0.04, 0.2, or 1.0% $C_{9\text{-}11}AE_8$ for 90 days. Lower body weight gain and decreased food consumption were noted in the 1% males and females and in the 0.2% females from week 1 through the end of the study. Further statistical analyses revealed a significant decrease in the mean body weight gain noted in the 1% females and the decreases in mean food consumption noted in the 1% males and females. The differences noted in the 0.2% females were not statistically significant. The investigators considered these observations to be the result of poor palatability of the test substance. There were no other treatment-related effects. The NOAEL for this study is 1.0% in the diet (about 400 mg/kg-day).

Genotoxicity

The genotoxicity studies conducted on alcohol ethoxylates are reviewed in HERA (2009). In all available *in vitro* and *in vivo* genotoxicity studies, there were no indication of genetic toxicity of a broad range of structurally different alcohol ethoxylates. The results of few of the *in vitro* studies on similar alcohol ethoxylates are presented below in Table 1.

Table 1: *In Vitro* Genotoxicity Studies on Selected Alcohol Ethoxylates

Test Substance	Test System	Results*		Klimisch Score	Reference
		-S9	+S9		
$C_{7-9}AE_6$	Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	HERA, 2009
$C_{14-15}AE_7$	Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	HERA, 2009
$C_{14}AE_{12}$	Chromosomal aberrations (CHO cells)	-	-	2	HERA, 2009

*+, positive; -, negative

In two separate studies, CD-1 mice were given an intraperitoneal dose of 0, 50, or 100 mg/kg $C_{12-15}AE_3$ or $C_{12-14}AE_9$. There were no increases in the micronuclei of bone marrow cells (Talmage, 1994).

Male and female Tunstall rats were given a single oral gavage dose of 0, 250, 500, or 1,000 mg/kg $C_{14-15}AE_7$. There were no increases in chromosomal aberrations in the bone marrow cells.

Carcinogenicity

Alcohol ethoxylates as a class are not carcinogenic by the oral route, based on available oral long-term toxicity/carcinogenicity studies on AEs.

Male and female Sprague-Dawley rats were given in their diet $C_{12-13}AE_{6.5}$ in the diet at doses up to 1% (500 mg/kg-day). Reduced food consumption was noted at the higher dose levels (*i.e.*, 0.5 and 1% for females and 1% for males), resulting in a lower body weight gain compared to the control group. No treatment-related histopathology was found and no increase in tumor incidence was observed.

Male and female Charles River rats were given in their diet 0, 0.1, 0.5 or 1% $C_{14-15}AE_7$ for two years. There were no treatment-related changes in general behavior and appearance. The survival rate of the test animals was comparable if not better than the controls. Body weights of the 0.5% females and the 1% males and females had significantly lower weight gains than the control. There were no treatment-related effects on organ weights and tumor incidence.

Male and female Sprague-Dawley rats were given in their diet $C_{14-15}AE_7$ at 0.1, 0.5 and 1% for two years. A treatment-related body weight depression was observed in females at the two highest treatment levels and in males at the 1% dose level, probably due to the poor palatability of the diet. There was no evidence for any carcinogenic activity.

Reproductive Toxicity

In a two-generation reproductive toxicity study, Charles River rats were given in their diet 0, 0.05, 0.1 and 0.5% (about 0, 25, 50 and 250 mgkg-day) $C_{12}AE_6$ in the diet. There were no treatment related effects in the parents or pups on general behaviour, appearance or survival. Fertility of treated groups was comparable with the controls. The only observation was related to a reduced weight gain of parental rats and pups relative to the control at the 0.5% dose level. The NOAEL for reproduction is 0.5% in the diet, which corresponds to 250 mg/kg-day.

Developmental Toxicity

In a two-generation reproductive toxicity study, Charles River rats were given in their diet 0, 0.05, 0.1 and 0.5% (about 0, 25, 50 and 250 mg/kg-day) $C_{12}AE_6$. General behavior, appearance and survival were unaffected by treatment. At the 0.5% dose level, adults and pups gained less weight than the control rats. In the 0.5% dose group, there was a statistical increase in embryo lethality and soft tissue anomalies and at the 0.1% there was a statistical decrease in mean fetal liver weight. Neither of these effects was considered to be treatment-related by the authors as they showed no dose response characteristics. The NOAEL for maternal toxicity is 50 mg/kg-day. The NOAEL for developmental and teratogenicity is 0.1% in the diet (50 mg/kg-day).

Pregnant rabbits were given by oral gavage 0, 50, 100 or 200 mg/kg $C_{12}AE$ from gestational days 2 to 16. Nine control rabbits and 31 treated rabbits died during the study. Surviving rabbits at the 200 mg/kg dose level generally showed slight losses of body weight. At 100 and 200 mg/kg, ataxia and a slight decrease in body weight was observed in the pregnant animals. In seven treated and two control rabbits, early deliveries were recorded. There were no treatment-related effects on corpora lutea, implantations, number of live fetuses and spontaneous abortions. The NOAEL for maternal toxicity is 50 mg/kg-day; the NOAEL for developmental toxicity is 200 mg/kg-day.

Derivation of Toxicological Reference and Drinking Water Guidance Values

The lowest NOAEL from several rat 90-day oral toxicity studies on alcohol ethoxylates ranging in carbon number from 9 to 11 is 150 mg/kg-day. The NOAEL of 150 mg/kg-day will be used to derive an oral reference dose and drinking water guidance value for the ethoxylated C11 alcohol.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 3
UF_D (database uncertainty) = 1

Oral RfD = 150/(10 x 10 x 1 x 3 x 1) = 150/300 = 0.5 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (0.5 x 70 x 0.1)/2 = 1.8 mg/L

References

ADWG. (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

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Talmage, S.S. (1994). Environmental and Human Safety of Major Surfactants – Alcohol Ethoxylates and Alkylphenol Ethoxylates, pp. 35, The Soap and Detergent Association, Lewis Publishers, Boca Raton, Florida.

Toxicity Profile

Polyoxyethylene-polyoxypropylene Copolymer
(CAS No. 9003-11-6)

The generic CAS RN 9003-11-6 refers to polymers that are synthetic block copolymers of ethylene oxide and propylene oxide. There are over 50 various amphiphilic nonionic block polymers of hydrophobic propylene oxide (PO) and hydrophilic ethylene oxide (EO) (CIR, 2008). These copolymers consist of a central polyoxypropylene molecule, flanked on both sides by two hydrophilic polyoxyethylene chains. These copolymers are also known as Poloxamers. The average molecular weights of several Poloxamer products are as follows: 2,090-2360 for Poloxamer 124; 7,680-9,510 for Poloxamer 188; and 9,840-14,600 for Poloxamer 407 (CIR, 2008).

Acute Toxicity
The oral LD_{50} values in rats for Poloxamer 124, 182, 188, and 235 were 5,000, 5,500, >15,000, and 34,600 mg/kg (Leaf, 1967). No acute dermal or inhalation studies were located.

Irritation
The EO/PO copolymers are not skin irritants to laboratory animals or humans (CIR, 2008).

Sensitization
The EO/PO copolymers are not dermal sensitizer (CIR, 2008).

Repeated Dose Toxicity

Oral
Rats were fed diets containing 0, 3, or 5% Poloxamer 188 for 6 months. During the study, 2 and 14 animals died in the mid- and high-dose groups, respectively. Deaths were attributed to a combination of infection and inanition. There were no histopathologic effects that were considered to be treatment-related (Leaf, 1967).

Rats were fed diets containing Poloxamers 331, 235, or 338 for 90 days. The doses were: 40, 200, or 500 mg/kg Poloxamer 331; 40, 200, or 500 mg/kg Poloxamer 235; 200, 1,000 or 5,000 mg/kg Poloxamer 338. There was no treatment-related mortality. The rats in the 5,000 mg/kg Poloxamer 338 dose group had diarrhea. No other details were given (Leaf, 1967).

Rats were fed diets containing 0, 3, 5, or 7.5% Poloxamer 188 for two years. There was no treatment-related mortality. At the two higher doses, the rats had continuous moderate diarrhea, but not other adverse reactions. A small decrease in growth was seen in the 7.5% group (no statistical analysis and not information on the amount of change), but there were no treatment-related histopathological effects at any dose level. The NOAEL for this study is 5% in the diet. Using 0.05 as the fraction of body weight that rats consume per day as food (U.S. EPA), the NOAEL corresponds to 2,500 mg/kg-day (Leaf, 1967).

Male and female rats were fed diets containing 0, 40, 200, or 500 mg/kg Poloxamer 182 for two years. Deaths occurred in all groups of rats due to chronic respiratory infections unrelated to administration of Poloxamer 182. There were no clinical signs of toxicity, and blood and urine chemistry parameters were comparable across all groups. There were no gross pathological changes noted. It is unclear from the summary in CIR (2008) whether a

histopathologic examination was conducted. The NOAEL for this study is 500 mg/kg-day (Leaf, 1967).

Inhalation

Male SD rats were exposed by inhalation to 0 or 97 mg/m^3 Poloxamer 101 aerosol for 6 hours/day, 5 days/week over a two-week period. A separate group of rats was exposed for two weeks followed by a two-week recovery period. All animals survived until the end of the study. The only adverse effect observed was slight alveolitis in the Poloxamer 101-exposed rats, which subsided by the end of a two-week recovery (Ulrich *et al.,* 1992).

Dermal

New Zealand rabbits were given dermal applications of 0, 100, 300 or 1,000 mg/kg Poloxamer 184 5 days/week for a total of 20 applications. The skin of the treated animals showed slight intradermal inflammatory responses, but no systemic effects (CIR, 2008).

Genotoxicity

Poloxomer 407 was not mutagenic to *S. typhimurium* strains TA97, TA98, TA100, TA1535, and TA1537 in the absence and presence of metabolic activation (CIR, 2008).

Carcinogenicity

No studies are available.

Reproductive/Developmental Toxicity

No studies are available.

Derivation of Toxicological Reference and Drinking Water Guidance Values

EO/PO copolymers have been tested in two chronic rat dietary studies. In the first study, the only effect observed was slightly reduced growth in the rats fed 7.5% (3,750 mg/kg-day) EO/PO copolymer; no effects were seen in the 5% (2,500 mg/kg-day) and lower dose groups. No statistical analysis was provided on whether the change in body weight gain was statistically significant, or whether the change is of sufficient magnitude to be considered an adverse effect. For the purposes of this risk assessment, 3,750 and 2,500 mg/kg-day will be considered a LOAEL and NOAEL, respectively. In the second feeding study, there were no effects seen in the rats at oral doses up to 500 mg/kg-day. The NOAEL of 2,500 mg/kg-day EO/PO copolymer in the diet will be used to derive an oral reference dose (RfD) and a drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 2,500/(10 x 10 x 1 x 1 x 1) = 2,500/100 = 25 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (25 x 70 x 0.1)/2 = 88 mg/L

References

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Cosmetic Ingredient Review [CIR] (2008). Safety Assessment of Poloxamers 101, 105, 108, 122, 123, 124, 181, 182, 183, 184, 185, 188, 212, 215, 217, 231, 234, 235, 237, 238, 282, 284, 288, 331, 333, 334, 334, 338, 401, 402, 403, and 407, Poloxamer 105 benzoate, and Poloxamer 182 dibenzoate as used in cosmetcs. Int. J. Toxicol. 27 (Supppl. 2): 93-128.

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Toxicity Profile

Ethylene Glycol
(CAS No. 107-21-1)

Metabolism

Ethylene glycol is almost completely absorbed in laboratory animals by the oral route (OECD, 2004a and 2004b; Frantz et al., 1996a). A range of 1-51% of ethylene glycol is absorbed by the dermal route based on *in vivo* studies in rodents (Frantz *et al.*, 1996a,b).

The main metabolic pathway for metabolism of ethylene glycol is oxidation via alcohol dehydrogenases and aldehyde dehydrogenases. The main metabolites of ethylene glycol are carbon dioxide, oxalic acid and glycolic acid (OECD, 2004a).

The relevant metabolite for the repeated dose toxicity studies is oxalic acid, which is slowly transported from the liver to the kidneys, where it forms calcium-oxalate crystals (Corley *et al.*, 2005a).

The relevant metabolite for the developmental toxicity seen in rodent, but not rabbit, studies appears to be glycolic acid. This metabolite can be reached at higher concentrations in rats than in rabbits (Carney *et al.*, 1998).

A physiologically-based pharmacokinetic (PBPK) model has been developed for ethylene glycol. When internal dose surrogates were compared in rats and humans over a wide range of exposures, it has been concluded that humans are unlikely to achieve blood levels of glycolic acid necessary for developmental toxicity (Corley *et al.*, 2005b).

Acute Toxicity

The oral LD_{50} in rats was reported to be 7,712 mg/kg (ECHA) [Kl. score = 2]. The 6-hour inhalation LC_{50} value for male and female rats was >2.5 mg/L (Tyl *et al.*, 1995a) [Kl. score = 2]. The dermal LD_{50} for male and female mice is >3,500 mg/kg (Tyl *et al.*, 1995b) [Kl. score = 2].

Following acute ingestion of ethylene glycol, the critical effects in humans in three subsequent stages are central nervous system toxicity, metabolic acidosis, and kidney toxicity (ECHA). The lethal effects of ethylene glycol in human adults occur at oral doses of $\geq$1,600 mg/kg (Hess et al., 2004).

Irritation

Application of 0.5 mL of ethylene glycol to the skin of rabbits for 23 hours under occlusive conditions was not irritating (Guillot *et al.*, 1982) [Kl. score = 2].

In a Human Repeated Insult Patch Test (HRIPT), ethylene glycol was applied to the skin for 24 hours under occlusive or semi-occlusive conditions for nine times during the induction phase. The induction phase was followed by a rest period of two weeks, followed by a 24-hour challenge on the sixth week of the study. Erythema was seen in a small proportion of the 401 subjects that completed the study. Under the conditions of the study, three subjects had

reactions on challenge that were indicative of possible irritation and/or low-level sensitization. These three subjects were re-challenged under occlusive or semi-occlusive conditions one or two weeks later. Re-challenge testing was negative for one subject, but the other two subjects were judged to have irritant reactions to ethylene glycol since their reactions were similar or lesser compared to the skin responses observed during the induction period, and the skin reactions were not greater over time after the challenge or re-challenge (ECHA).

Instillation of 0.05 mL of ethylene glycol into the eyes of rabbits was not irritating (ECHA) [Kl. score = 2].

Sensitization

Ethylene glycol was not a skin sensitizer to guinea pigs in a Magnusson and Kligman test (Kurihara *et al.*, 1996) [Kl. score = 2]. In a HRIPT, ethylene glycol was considered to have a low potential for dermal sensitization in humans (ECHA).

Repeated Dose Toxicity

Male and female Fischer 344 rats were given in their feed 0, 0.32, 0.63, 1.25, 2.5, or 5% ethylene glycol for 13 weeks. Mortality was seen in the 5% males, but not in females. Mean weight gain was significantly decreased in the 2.5 and 5% males; there was no significant differences in female rats. Feed consumption was similar across all groups. A significant increase was seen in the left kidney weight in the 2.5 and 5% dose groups (both sexes); this was not seen in the right kidneys. Mean thymus ratio to terminal body weight was significantly decreased in the 5% males. Serum urea nitrogen levels were significantly increased in the 2.5 and 5% males, and significantly increased in the $\geq$0.32% females. Creatinine levels were decreased in the 0.32% groups and significantly increased in the 2.5 and 5% groups. The 2.5% and 5% male rats had kidneys that were rough, granular and/or pitted appearances. The 5% females showed nephrosis, and the 5% males had clusters of crystals in the brain. The NOAEL for this study is 1.25%, which was estimated to be 600 to 1,000 mg/kg-day (Melnick, 1984) [Kl. score = 2].

Male and female Sprague Dawley rats were given in their drinking water ethylene glycol for 90 days. The concentrations for females were 0, 0.5, 1.0, 2.0 or 4.0% (0, 597, 1,145, 3,087 or 5,744 mg/kg-day). The concentrations for males were 0, 0.25, 0.5, 1.0 or 2.0% (0, 205, 407, 947 or 3,134 mg/kg-day). In the 4% groups, there was mortality and decreased body weights (males only). Significant organ weights were noted only in males. Kidney weights were significantly increased in the 1% and 2% males; heart, liver, and lung were significantly decreased in the 2% males. The 4% males also had a significant increase in the brain and gonads relative to body weights. Leukocyte levels were significantly decreased in the 0.5, 2 and 4% females, but not in males. Significant differences were noted in LDH, creatinine, ALT, calcium and glucose in the 1% males; and phosphorus, BUN, and creatinine in the 2% males. There were significant increases in phosphorus in the 1% females and glucose in the 0.5 and 4% females. Kidney lesions were seen in the $\geq$2% females and in the $\geq$1% males, with the lesions more prominent in males than in females. The kidney changes consisted of tubular dilation, tubular degeneration, acute inflammation, birefringent crystals in tubules and pelvic epithelium. The NOAEL for this study is 407 mg/kg-day for males. The LOAEL for females is 597 mg/kg-day; a NOAEL was not established (Robinson *et al.*, 1990) [Kl. score = 2].

Male and female B6C3F$_1$ mice were given in their feed 0, 0.32, 0.63, 1.25, 2.5, or 5.0% ethylene glycol for 13 weeks. There was no mortality and no treatment-related effect on mean weight gain and feed consumption. Organ/body weight ratios were similar across all groups. Serum urea nitrogen and creatinine levels were unaffected. Kidney effects were seen in the male, but not female, mice. Kidney lesions were observed in half of the 5% male mice and one mouse in the 2.5% dose level. Lesions were tubular dilation, cytoplasmic vacuolization, and regenerative hyperplasia of tubular cells. There was no evidence of crystal formation in the tubules. These changes were focal, randomly distributed, and of minimal to mild severity. Hyaline degenerative of the liver was present in the centrilobular hepatocytes in all of the 2.5% and 5% males. These cells showed cytoplasmic accumulations of non bifringent, eosinophilic (hyaline), globular, or crystalline material which resembled erythrocytes in size, shape, and tinctorial properties. The NOAEL for this study is 1.25%, which was estimated to be 600 to 1,000 mg/kg-day (Melnick, 1984) [Kl. score = 2].

Male Fischer 344 and Wistar rats were given in their feed 0, 150, 500 or 1,000 mg/kg ethylene glycol for 16 weeks. At 1000 mg/kg, the following effects were seen: mortality in Wistar strain (2/10) with prior clinical observations of emaciation and dermal atonia and macroscopic findings of changes in kidneys (pale, calculi) and small seminal vesicles in these animals; mean body weight losses, lower mean body weights and mean cumulative body weight changes in Wistar strain (weeks 2 – 16); lower mean food consumption in Wistar strain; higher mean water consumption in both F344 and Wistar strains; lower mean specific gravity and higher mean total urine volume in both F344 and Wistar strains; macroscopic findings of pale kidneys, presence of calculi, rough surface and dilated pelvis; higher mean absolute and relative kidney weights in both F344 and Wistar strains; renal macroscopic findings of crystal nephropathy in Wistar and F-344 rats, with more severe nephropathy in Wistar strain than in the F344 strain. At 500 mg/kg, the following effects were seen: lower mean body weights (study weeks 3, 6-8, and 10-12) and mean cumulative body weight changes in the Wistar strain throughout the study with slightly lower mean food consumption throughout the study; higher mean water consumption in the Wistar strain; lower mean urine specific gravity and higher mean total urine volume in the Wistar strain; macroscopic findings in the Wistar strain consisting of predominantly pale kidneys, presence of calculi, rough surface, and dilated pelvis; higher mean absolute and relative kidney weight in the Wistar strain; renal macroscopic findings of crystal nephropathy in Wistar and F-344 strains, with more severe nephropathy in the Wistar strain than in the F344 strain. The NOAEL in both the F344 and Wistar rats is 150 mg/kg-day (Cruzan *et al.*, 2004) [Kl. score = 2].

Male Wistar rats were given in their feed 0, 50, 150, 300 or 400 mg/kg ethylene glycol for 12 months. There was mortality in the 300 and 400 mg/kg dose groups (5/20 and 4/20, respectively); the remaining 400 mg/kg animals were euthanized early (day 203) due to excessive weight loss. The 300 mg/kg animals had increased water consumption and urine volume with decreased specific gravity, most likely due to osmotic diuresis. Calculi (calcium oxalate crystals) were found in the bladder and kidney pelvis in the $\geq$300 mg/kg animals. The $\geq$300 mg/kg rats that died prematurely had transitional cell hyperplasia with inflammation and hemorrhage of the bladder wall. Crystal nephropathy (basophilic foci, tubule or pelvic dilatation, birefringent crystals in the pelvic fornix, or transitional cell hyperplasia) was seen in all of the 400 mg/kg and most of the 300 mg/kg rats. These effects were not seen in the 50 or 150 mg/kg rats. Kidney oxalate levels, the metabolite responsible for the kidney toxicity, was not increased in the 50 and 150 mg/kg animals compared to the controls. The NOAEL for this study is 150 mg/kg/day (Corley *et al.*, 2005b) [Kl. score = 1].

Male and female Sprague-Dawley rats were given in their feed 0, 0.1, 0.2, 0.5, 1.0 or 4.0% ethylene glycol for two years. There was significant reduction in growth in the 4% males after week 16, and in the 1% males after week 70. The 4% females did not gain any weight past the first year of the study. Water consumption was double that of the controls in the 4% males that initiated soon after the start of the study. The 1% males had significant increases in water consumption after 6 months and some increase was observed in the 0.5% males. Females only showed increased water consumption in the 4% group. There was 100% mortality in the 1 and 4% males, while mortality of additional dose levels was below that of the controls. There was 100% mortality in the 4% females, while the 1% females were similar to the controls; the 0.1, 0.2 and 0.5% females were increased compared to the controls. Since the 1 and 4% males and the 4% females all died before the study termination date, there are no data for these groups on terminal organ weight. For males, the terminal organ weights were decreased in all dose levels compared to the controls. For females, the organ weights were similar to the controls. The 1 and 4% males and females had kidneys with stones and crystals. The NOAEL for this study is 0.2% (data was insufficient to calculate the dose) (Blood, 1965) [Kl. score = 2].

Male and female Fischer 344 rats were given in their feed 0, 40, 200 or 1,000 mg/kg ethylene glycol for 24 months. There were numerous adverse effects in the 1,000 mg/kg males and, to a lesser degree, in the 1,000 mg/kg females. The most remarkable effect was the production of urinary calculi in the kidneys, ureters, and urinary bladders of the 1,000 mg/kg males, along with the presence of high levels of calcium oxalate in the urine. Increased incidences of tubular cell hyperplasia, tubular dilation, peritubular nephritis, and focal granulomatous nephritis occurred in the 1,000 mg/kg males. Other significant findings in these males were markedly lower body weight gain, increased absolute and relative kidney weights, decreased absolute and relative liver weights, various hematopoietic changes, and increased water consumption (likely a result of impaired kidney function). Histopathological changes in the 1,000 mg/kg males were mineralization of the heart, lungs, stomach, and vas deferens being the most noteworthy. The various adverse effects in these males resulted in reduced survival; there was increased mortality which became apparent by 8 months, with all males in this group died by month 16. Although calcium oxalate crystals were found in the urine of the 1,000 mg/kg females, no urinary calculi were seen. Absolute and relative kidney weights were increased in these rats. The most significant histopathologic finding in the 1,000 mg/kg females was fatty metamorphosis of the liver. There were transient changes in organ weights, erythroid parameters, water consumption rates, and urine specific gravity in the 200 and 40 mg/kg rats; these effects were considered to be statistical artifacts attributable to chance. Focal soft mineralization was observed in certain organs of the 200 and 40 mg/kg rats, which were considered to be the result of altered calcium metabolism associated with ingestion of ethylene glycol. The NOAEL for this study is considered to be 200 mg/kg-day (DePass *et al.,* 1986a; ECHA) [Kl. score = 2].

Male and female B6C3F$_1$ mice were given in their feed 0, 6,250 ppm (males only), 12,500 and 25,000 ppm (males and females) or 50,000 ppm (females only) for 103 weeks. These concentrations are approximately equivalent to 0, 1,500, 3,000, 6,000 or 12,000 mg/kg-day. Survival, mean body weights, and feed consumption was similar across all groups. There were no treatment-related clinical signs of toxicity. Liver lesions (males only) and arterial hyperplasia (females only) were observed at 12,500 ppm, but no adverse effects were observed at 6,250 ppm. The NOAEL for this study is 6,250 ppm in males, which corresponds to 1,500 mg/kg-day (NTP, 1993) [Kl. score = 2].

Genotoxicity

The *in vitro* genotoxicity studies on ethylene glycol are presented in Table 1.

Table 1: *In vitro* Genotoxicity Studies on Ethylene Glycol

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* and *E. coli* strains)	-	-	1	ECHA
Bacterial reverse mutation (*S. typhimurium* and *E. coli* strains)	-	-	2	ECHA
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	+/-	-	2	McGregor et al. (1991)
Chromosomal aberration (CHO cells)	-	-	2	ECHA

*+, positive; -, negative

A dominant lethal study was conducted in F344 rats given 0, 40, 200, or 1,000 mg/kg-day ethylene glycol in feed. There were slight increases in the dominant lethal mutation index in the high-dose and low-dose groups; these appear to be random occurrences and were not considered to be treatment-related. It was concluded that ethylene glycol was not genotoxic in this study (DePass et al., 1986b) [Kl. score = 2].

Carcinogenicity

Male and female Fischer 344 rats were given in their feed 0, 40, 200 or 1,000 mg/kg ethylene glycol for 24 months. There was increased mortality in the 1,000 mg/kg males, starting at 8 months and resulting in all males in this group dead by 16 months. Survival for the 1,000 mg/kg females and the 200 and 40 mg/kg males and females were similar to the controls. The incidence of mononuclear cell leukemia was statistically significantly higher in the 200 mg/kg males compared to the male controls, but not when compared to the pooled controls (males and females). Evaluation of the data by the method of Thomas et al. (2007), however, showed no treatment-related effect. It was concluded that ethylene glycol was not carcinogenic to rats in this study (DePass et al., 1986a and 1986b) [Kl. score = 2].

Male and female B6C3F_1 mice were given in their feed 0, 6,250 ppm (males only), 12,500 and 25,000 ppm (males and females) or 50,000 ppm (females only) ethylene glycol. These concentrations were approximately equivalent to 0, 1,500, 3,000, 6,000 or 12,000 mg/kg-day. Body weights, survival, and incidence of tumors were similar between treated and control mice (NTP, 1993) [Kl. score = 2].

Reproductive Toxicity

Ethylene glycol was assessed in a Reproductive Assessment by Continuous Breeding (RACB) protocol. The parental mice were administered ethylene glycol via drinking water during pre-mating exposure, cohabitation, pregnancy, and lactation. The F_1 generation received prenatal

exposure via maternal exposure during gestation, with the exposure continuing during lactation, weaning, and mating of F_1 animals and production of an F_2 litter. The doses were 0, 0.25, 0.5 or 1% ethylene glycol, which corresponded to approximately 0, 410, 840 or 1,640 mg/kg-day. No adverse effects were noted in the parental animals at doses up to 1%. There was a small, but statistically significant, effects on the numbers of litters per fertile pair, the number of live pups per litter, and live pup weight in the 1% dose group. Neither the 0.25 nor 0.5% dose groups were significantly affected. The number of live pups per litter was lower in the treated groups, but differences were not statistically significant. Unusual facial features (*i.e.*, shorter snout and wide-set eye) and skeletal defects (shortened frontal, nasal, and parietal bones; fused ribs abnormally shaped or missing sternebrae, abnormally shaped vertebrae; and twisting of the spine) were noted on some of the offspring of the treated mice in the 1% group, but not in the controls. The parental NOAEL is 1% (approximately 1,640 mg/kg-day), and the NOAEL for reproductive toxicity is 0.5% (approximately 840 mg/kg-day (Lamb *et al*., 1985) [Kl. score = 2].

In a three-generation reproductive toxicity study, Fischer 344 rats were given in their diet 0, 40, 200 or 1,000 mg/kg-day ethylene glycol. There were no treatment-related effects on clinical signs of toxicity or survival in the parental animals. There were no significant effects on fertility index, gestation index, gestation survival for all three generations. Mean pup weights in all three generations were similar between treated and control animals. The NOAEL for parental and reproductive toxicity is 1,000 mg/kg/day (DePass *et al.*, 1986b) [Kl. score = 2].

Developmental Toxicity

Pregnant Sprague-Dawley rats were dosed by oral gavage with 0, 50, 150, 500, 1,000 or 2,500 mg/kg ethylene glycol during gestational days (GD) 6-15. Maternal toxicity was observed in the 2,500 mg/kg group and consisted of significantly decreased body weights, increased water consumption, decreased uterine weights, increased kidney weights, and increased relative liver weights. At 500 mg/kg, there were developmental effects, which included reduced fetal body weights, extra or missing ribs, missing arches, and poor ossification in thoracic and lumbar centra. In the 2500 mg/kg group, in addition to skeletal malformations, there was gastroschisis, hydrocephaly, lateral ventricle dilated (tissue depressed), umbilical hernia, and atelectasis. The NOAELs for maternal and developmental toxicity are 1,000 and 500 mg/kg-day, respectively (Neeper-Bradley *et al.*, 1995) [Kl. score = 2].

Pregnant CD rats were dosed by oral gavage with 0, 1,250 2,500 or 5,000 mg/kg ethylene glycol during GD 6-15. In the $\geq$2,500 mg/kg groups, the dams had increased relative kidney weights, decreased gravid uterine weight, and increased water consumption. Maternal body weight gain was significantly decreased in the 1,250 mg/kg group. Live litter size was significantly decreased in the 5,000 mg/kg group, and fetal body weights were decreased in the 1,250 and 5,000 mg/kg groups. Litters with malformed fetuses were observed in the $\geq$1,250 mg/kg groups. The LOAELs for maternal and developmental toxicity are 1,250 mg/kg/day; NOAELs were not established (Price *et al.*, 1985) [Kl. score = 2].

Pregnant Fischer 344 rats were given by oral gavage 0, 40, 200 or 1,000 mg/kg ethylene glycol during GD 6-15. No maternal toxicity was observed at any dose level. There were no significant effects on preimplantation loss, fetal length, fetal weight, total implantations or litter size. There was an increased incidence of skeletal alterations in the 1,000 mg/kg group, which consisted of poorly ossified and unossified vertebral centra. No significant increases in the

incidence of major malformations were observed. The NOAELs for maternal and developmental toxicity are 1,000 and 400 mg/kg/day (Maronpot *et al.*, 1983) [Kl. score = 2].

Pregnant CD-1 mice were dosed by oral gavage with 0, 50, 150, 500 or 1,500 mg/kg ethylene glycol during gestational days (GD) 6 to 15. There was no maternal toxicity. At 1,500 mg/kg, there were reduced fetal body weights, fused ribs and arches, poor ossification in thoracic and lumbar centra, and increased occurrence of an extra 14th rib. At 500 mg/kg, there was slight reductions in fetal body weight and increased incidences of extra ribs. The NOAELs for maternal and developmental toxicity were 1,500 and 150 mg/kg/day, respectively (Neeper-Bradley et al., 1995) [Kl. score = 2].

Pregnant CD-1 mice were dosed by oral gavage with 0, 750, 1,500 or 3,000 mg/kg ethylene glycol during GD 6 to 15. There was a significant decrease in maternal gain, gravid uterine weights, and liver weights in the 1,500 mg/kg group. A decreased number of implantation sites per litter was observed in the 1,500 mg/kg group. Significant decrease in liver litter size was observed in the 3,000 mg/kg group and decreased fetal body weights were seen at $\geq$750 mg/kg. Litters with a significant increase in malformed fetuses were observed in the $\geq$750 mg/kg groups. There was a significant dose-related increase in postimplantation loss per litter, though there were no significant pairwise comparisons. The NOAEL for maternal toxicity is 750 mg/kg-day. The LOAEL for developmental toxicity is 750 mg/kg-day; the NOAEL was not established (Price *et al.*, 1985) [Kl. score = 2].

In a short-term reproductive and developmental toxicity screen test, male and female Swiss Crl:CD-1 mice were allowed to mate over a three-day period. The males were dosed by oral gavage from study day 3 to study day 20. The Group A females were exposed throughout the 21-day test period; the Group B females were exposed during GD 8-14. The doses were 0, 250, 700 or 2,500 mg/kg ethylene glycol. The Group A females were sacrificed after 19 days of treatment, and the Group B females were allowed to litter and rear to postnatal day (PND) 4. There was no maternal or paternal toxicity. The 2,500 mg/kg females in Group A had significantly fewer liver implants and more dead implants. The 2,500 mg/kg in Group B had significantly lower total litter weights on PND 1 and 4. The NOAELs for parental and developmental toxicity are 2,500 and 700 mg/kg/day (Harris *et al.*, 1992) [Kl. score = 2].

In a Chernoff/Kavlock assay, pregnant CD-1 mice were dosed by oral gavage with 0 or 11,090 mg/kg ethylene glycol during GD 7-14. The females were allowed to litter and rear to PND 3. Ten percent of the maternal animals died. The number of surviving pups per litter (40% survived), birth weight and pup weight gain were reduced. The LOAELs for maternal and developmental toxicity are 11,090 mg/kg; NOAELs were not established (Schuler *et al.*, 1984; Hardin *et al.*, 1987) [Kl. score = 2].

Pregnant female New Zealand White rabbits were dosed by oral gavage with 0, 100, 500, 1,000, or 2,000 mg/kg ethylene glycol on GD 6 to 19. At 2,000 mg/kg, eight of the 17 does (42.1%) died. Maternal body weights and body weight gain were similar across all groups. There was no developmental toxicity. The NOAEL for maternal toxicity is 1,000 mg/kg-day. The NOAEL for developmental toxicity is 2,000 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 2].

Pregnant female CD rats were dosed by oral gavage with 0, 250, 1,250, or 2,250 mg/kg ethylene glycol on GD 6 to 20. At 2,250 mg/kg, maternal body weight, body weight gain, kidney weight, and postpartum uterine weight were significantly reduced. At 1,250 mg/kg, the gestational

period was lengthened and maternal kidney histopathological effects were noted. Developmental toxicity was noted in the 2,250 mg/kg group and included reduced pup weight, reduced viability, and increased malformations (primarily hydrocephaly and abnormalities of the axial skeleton). No developmental toxicity was seen in the 1,250 mg/kg group. The NOAEL for maternal and developmental toxicity is 250 mg/kg-day (ECHA) [Kl. score = 2].

Inhalation

Pregnant female CD rats were exposed by inhalation (whole-body) to 0, 150, 1,000, or 2,500 mg/m^3 ethylene glycol aerosol 6 hours/day on gestational days 6 to 15. There was no treatment-related mortality; a dose-related increased in clinical signs (red fur discoloration on the head and neck) was noted, which was considered to be a non-specific indication of stress. Body weights and body weight gain were unaffected by treatment. There was some evidence of treatment-related reductions in ossification of the fetal skeleton at 1,000 and 2,500 mg/m^3 (considered as fetotoxicity). The NOAECs from inhalation exposure cannot be determined due to confounding oral exposure during whole-body exposure. However, there was no maternal or embryotoxicity at 150 mg/m^3 and no teratogenicity at any aerosol concentration tested (Tyl et al., 1995a) [Kl. score = 2].

Pregnant female CD-1 mice were exposed by inhalation (whole-body) to 0, 150, 1,000, or 2,500 mg/m^3 ethylene glycol aerosol 6 hours/day on gestational days 6 to 15. Reduced maternal body weight was observed in the 2,500 mg/m^3 group on GD 12,15, and 18 and in the 1,000 mg/m^3 group on GD 18. Reduced maternal weight gain was also seen during GD 6-12, 6-15, and GD 6-18 for the $\geq$1000 mg/m^3 groups, and for GD 5-18 for the 2,500 mg/m^3 group. Terminal body weights were reduced in the $\geq$1,000 mg/m^3 groups. Gravid uterine weight was also reduced in the $\geq$1,000 mg/m^3 groups, so that body weight corrected for gravid uterine weight was unaffected. The number of viable implantations per litter was reduced at 2,500 mg/m^3. The number of non-viable implantations per litter was elevated at $\geq$1,000 mg/m^3 because of a significant increase in late resorptions at 1,000 mg/m^3, and a significant increase in late resorptions and in dead fetuses at 2,500 mg/m^3. The number of early resorptions at 2,500 mg/m^3 was also elevated but not statistically. Fetal body weights per litter (male, female, and total) were reduced at $\geq$1,000 mg/m^3. There was a significant increase in the incidence of a number of external, visceral, and skeletal malformation, as well as skeletal variations, at $\geq$1,000 mg/m^3. There was no observable maternal or developmental toxicity at 150 mg/m^3. However, a NOAEC cannot be determined because of the amount of ethylene glycol that may have been ingested from the presence of ethylene glycol on the fur (Tyl et al., 1995a) [Kl. score = 2].

Pregnant female CD-1 mice were exposed by inhalation (nose-only) to 0, 500, 1,000, or 2,500 mg/m^3. The study also included a group exposed to 2,100 mg/m^3 (not discussed here). Reduced maternal body weight gain were seen in the 2,500 mg/m^3 for GD 9-12, 12-15, 6-15, and 0-18. Absolute kidney weights were increased in the $\geq$1,000 mg/m^3 groups. Fetal body weights per litter were significantly reduced for the 2,500 mg/m^3. In the 2,500 mg/m^3, there was a significant increase in one skeletal malformation (fusion of the ribs) and an increased incidence of skeletal variations. No other teratogenic effects were observed. The NOECs for maternal and developmental toxicity are 500 and 1,000 mg/m^3, respectively (Tyl et al., 1995c) [Kl. score = 2].

Dermal

Pregnant CD-1 mice were administered by dermal applications of 0, 400, 1,677 or 3,549 mg/kg ethylene glycol 6 hours/day on GD 6-15. There was minimal, if any, treatment-related maternal toxicity. Copora lutea, total implants, percentage of live fetuses per litter, fetal body weights, and incidence of external or visceral malformations were unaffected by treatment. There was, however, a significant increase in two skeletal variations in the 3,549 mg/kg group. The NOAELs for maternal and developmental toxicity were considered to be 3,549 mg/kg-day (Tyl *et al.*, 1995b) [Kl. score = 2].

Derivation of Toxicological Reference and Drinking Water Guidance Values

The NOAEL from a 24-month rat dietary study was reported to be 200 mg/kg-day based on kidney lesions in male F344 rats at 1,000 mg/kg-day (Depass et al., 1986b). A subsequent 12-month rat dietary study using male Wistar rats reported a NOAEL of 150 mg/kg-day also based on kidney toxicity at 300 mg/kg-day and higher (Corley et al., 2008). The Wistar rat strain was shown to be more sensitive (approximately three-fold) to the kidney toxicity of ethylene glycol than F344 rats (Cruzan et al., 2004). The NOAEL of 150 mg/kg-day will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Snellings et al. (2013) derived an oral reference dose for ethylene glycol using benchmark dose modeling, with toxicokinetic (PBPK modeling) and toxicodynamic data. The human equivalent dose ($[BMDL_{05}]_{HED}$) was calculated to be 150 mg/kg-day.

Oral RfD = $[BMDL_{05}]_{HED}$ / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 1
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 150/(1 x 10 x 1 x 1 x 1) = 150/10 = 15 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (15 x 70 x 0.1)/2 = 53 mg/L

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Toxicity Profile

Formic acid
(CAS No. 64-18-6)

Acute Toxicity

The oral LD_{50} in rats is 730 mg/kg (ECHA) [Kl. score = 1]. The 4-hour LC_{50} in rats is 7.85 mg/L (ECHA) [Kl. score = 1]. The dermal LD_{50} in rats is >2,000 mg/kg (ECHA) [Kl. score = 1].

Irritation

No valid animal skin irritation studies are available. Formic acid has been reported to be corrosive to human skin (ECHA). Instillation of 122 mg formic acid into the eyes of rabbits was severely irritating (ECHA) [Kl. score = 4].

Sensitization

Formic acid was not considered a skin sensitizer in a guinea pig Buehler test (ECHA) [Kl. score = 1].

Repeated Dose Toxicity (oral)

Male and female Crl:HanWist(Glx:BRL)BR rats were fed in their diet 0, 40, 400, or 2,000 mg/kg-day potassium formate for 52 weeks. The high-dose animals showed a statistically significant reduced body weight gain and basal cell hyperplasia or foveolar epithelium hyperplasia of the stomach. The NOAEL is 400 mg/kg-day, which equates to 220 mg formic acid/kg-day (ECHA) [Kl. score = 1].

Genotoxicity

The results of the *in vitro* genotoxicity studies on formic acid are presented below in Table 1.

Table 1: *In Vitro* Genotoxicity Studies on Formic Acid

Test System	**Results***		**Klimisch Score**	**Reference**
	-S9	**+S9**		
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	1	ECHA
Sister chromatid exchange (V79 cells)	-	-	1	ECHA
Sister Chromatid Exchange (human lymphocytes)	-	-	1	ECHA
Mammalian cell gene mutation HPRT (CHO cells)	-	-	1	ECHA

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Chromosomal aberrations (CHO cells)	-**	-**	1	ECHA

*+, positive; -, negative; NA, not applicable
**It was concluded that formic acid was not itself clastogenic to CHO cells but that the acidic conditions were responsible for the chromosomal aberrations observed.

Formic acid and sodium formate did not induce a mutagenic response in a Drosophila sex-linked recessive lethal test (ECHA) [Kl. score = 1].

Carcinogenicity

Male and female Crl:HanWist(Glx:BRL)BR rats were fed in their diet 0, 40, 400, or 2,000 mg/kg-day potassium formate for 52 weeks. The incidence of tumors was similar between the treated and control groups (ECHA) [Kl. score = 1].

Reproductive Toxicity

A two-generation reproductive toxicity study was conducted on sodium formate. Male and female Wistar rats were fed in their diet 0, 100, 300, or 1,000 mg/kg-day sodium formate. There was no evidence of reproductive, developmental, or systemic toxicity. The NOAEL for reproductive, developmental, and parental systemic toxicity is 1,000 mg/kg-day, which equates to 676 mg formic acid/kg-day (ECHA) [Kl. score = 1].

Developmental Toxicity

Pregnant female Wistar rats were dosed by oral gavage with 0, 59, 236, or 945 mg/kg sodium formate during gestational days 6 to 19. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity is 945 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 1].

Pregnant female Himalayan rabbits were dosed by oral gavage with 0, 100, 300, or 1,000 mg/kg sodium formate during gestational days 6 to 28. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity is 1,000 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 1].

Derivation of Toxicological Reference and Drinking Water Guidance Values

In a 52-week dietary study on potassium formate, reduced body weights were observed in male and female at 2,000 mg/kg-day (ECHA). There were no other effects that were indicative of systemic toxicity. The NOAEL is 400 mg/kg-day, which equates to 220 mg formic acid/kg-day, will be used to derive an oral reference value and drinking water guidance value for formic acid.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 220/(10 x 10 x 1 x 1 x 1) = 220/100 = 2 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (2 x 70 x 0.1)/2 = 7 mg/L

References

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

Toxicity Profile

Glutaraldehyde
(CAS No. 111-30-8)

Toxicokinetics

Dermal Absorption

[1,5-^{14}C]-glutaraldehyde was applied to the skin of male and female F344 rats (ECHA). Doses were 0.75% and 7.5%: this corresponds to approximately 6.5 and 63 mg/kg for males; and approximately 8.7 and 102 mg/kg for females. The dermal absorption data are presented below in Table 1. The results indicate that glutaraldehyde has a low rate of absorption by the dermal route.

Table 1: Dermal Absorption Data in Rats on Glutaraldehyde (ECHA)

Sex	Absorption rate constant/hr		% of applied dose	
	Low Dose	High Dose	Low Dose	High Dose
Males	1.5	0.7	0.7	1.3
Females	1.8	0.9	0.3	2.1

An *in vitro* percutaneous absorption study was conducted on glutaraldehyde using excised skin from rats, rabbits, mice, guinea pigs, and humans (ECHA; Frantz et al., 1993). The skin samples were placed in a flow-through skin penetration chamber, and [^{14}C]-glutaraldehyde was added at doses of 0.75% and 7.5%. The results are presented below in Table 2. Glutaraldehyde did not penetrate any of the skin samples to a significant degree, suggesting that only minimal amounts of glutaraldehyde may be available for systemic uptake and distribution after skin exposure. The results also show that skin absorption was greater for the animal species used in toxicity tests than human skin.

Table 2: *In vitro* Percutaneous Absorption (mg/cm^2) of Glutaraldehyde (ECHA; Frantz et al., 1993)

Species	Low Dose	High Dose
Animal*	0.006	0.08
Human	0.002	0.02

*Percutaneous absorption in rats, mice, guinea pigs, mice and rabbits were similar to each and were reported as a single value.

Acute Toxicity

The oral LD_{50} values are: 123 to 820 mg/kg in rats; 100 to 352 mg/kg in mice; and 50 mg/kg in guinea pigs (NICNAS, 1994).

The dermal LD_{50} values are: 640 to 2,000 mg/kg in rabbits; >2,500 mg/kg in rats; and >4,500 mg/kg in mice (NICNAS, 1994).

The inhalation 4-hour LC_{50} values for glutaraldehyde are listed in Table 3 below:

Table 3: Acute inhalation LC_{50} values for Glutaraldehyde

Test Material	LC_{50} (males)	LC_{50} (females)	LC_{50} (both sexes)	Reference
50% aq. aerosol	0.52 mg/L	0.45 mg/L	-	OECD, 1995
25% aq. aerosol	-	-	0.8 mg/L	OECD, 1995
50% aq. aerosol	0.35 mg/L	0.28 mg/L	-	OECD, 1995
5% soln. vapour	0.096 mg/L	0.164 mg/L	-	OECD, 1995

During the exposure period, the animals showed signs of eye and respiratory irritation, as indicated by laboured and audible breathing, and wetness and encrustation around the nose and eyes.

Irritation

Glutaraldehyde is corrosive to the skin and eyes of rabbits (NICNAS, 1994; ECHA). Signs of irritation occurred at a concentration of 2% for skin and 0.2% for eyes (NICNAS, 1994). In the acute inhalation studies, rats exposed to aerosols or vapours of glutaraldehyde showed signs of eye and respiratory irritation (OECD, 1995).

Sensitization

Glutaraldehyde is a skin sensitiser to guinea pigs and humans. Information on the individual studies can be found in NICNAS (1994) and in the ECHA REACH database (ECHA).

Asthmatic symptoms, such as wheezing, coughing, chest tightness, breathing difficulties and non-specific hyper-responsiveness have been reported to occur in humans occupationally exposed to glutaraldehyde (NICNAS, 1994). It is unclear whether the asthma is an allergic hypersensitivity response or a result of the aggravation of pre-existing asthma due to the irritating properties of glutaraldehyde. Nevertheless, glutaraldehyde should be considered a respiratory sensitiser, although one of low potency.

Repeated Dose Toxicity

Oral

Male and female Wistar rat were given in their drinking water 0, 100, 500 or 2,000 ppm glutaraldehyde for 90 days. The approximate daily intakes were 0, 3, 15 or 53 mg/kg-day for males, and 0, 4, 19 or 72 mg/kg-day for females. There were no signs of neurotoxicity at any dose level. There was slight impairment of food consumption in the 2,000 ppm animals, as well as slight impairment of body weight and body weight gain. Impaired water consumption was seen in the 100 and 500 ppm females. The NOAEL for males is 500 ppm (15 mg/kg-day). The NOAEL for females is 100 ppm (4 mg/kg-day), since the impaired water consumption in the 100 ppm females was considered a palatability problem and not an adverse effect (ECHA). [Kl. score = 1]

Male and female F344 rats were given in their drinking water 0, 50, 250 or 1,000 ppm glutaraldehyde for 13 weeks. Additional groups of animals were given in their drinking water 0 or 1000 ppm glutaraldehyde for 13 weeks followed by a 4-week recovery period. The approximate daily intakes were 0, 5, 25 or 100 mg/kg-day for males; and 0, 7, 35 or 120 mg/kg-day for females. Water consumption was reduced in a dose-dependent manner in the ≥250 ppm males and 1,000 ppm females, which was attributed to an aversion to the taste and/or odour of glutaraldehyde in the water. There was also a reduction in food consumption in the 1,000 ppm animals with a parallel reduction in body weights. It is unclear whether the reduction in food consumption was related to the decreased water consumption. Urine volume was decreased with an increase in specific gravity, along with a slight increase in protein and ketone concentration, in the ≥250 ppm animals, which was probably related to the decreased water consumption. There were no treatment-related changes in the haematology parameters measured. Blood urea nitrogen was increased in a dose-related manner in the ≥250 ppm females at the 6-week time point, but at the 13-week or 17-week time points. Relative kidney weights were increased in a dose-related manner in the ≥250 ppm males and females, and increased absolute kidney weights in the females. Histopathological examination showed no treatment-related effects. The NOAEL is 50 ppm (5 and 7 mg/kg-day for males and females, respectively) based on dose-related increase in kidney weights at ≥250 ppm (ECHA). [Kl. score = 2]

Male and female Wistar rats were given in their drinking water 0, 100, 500 or 2000 ppm glutaraldehyde for 12 months. The approximate daily intakes were: 0, 6.4, 30.5 or 116.6 mg/kg-day for males; and 0. 9.6, 46 or 153 mg/kg-day for females. There was no treatment-related mortality. At 2,000 ppm, treatment-related effects included respiratory sounds (both sexes), decrease in body weight (males), decrease in body weight gain (both sexes), decrease in food consumption (both sexes), reduced water consumption (both sexes), lesions within the glandular stomach (both sexes showed erosion/ulceration of the glandular stomach), increased incidence of clear cell foci in the liver (males), and a single case of slight diffuse squamous metaplasia in the epithelium of the larynx (male). At 500 ppm, water consumption was reduced in males which was considered to be a palatability (bad taste) problem and not an adverse effect. No effects were seen in the 100 ppm animals. The NOAEL for this study is 500 ppm, which corresponds to 30.5 and 46 mg/kg-day for males and females, respectively (ECHA). [Kl. score = 1]

Male and female Fischer 344 rats were given in their drinking water 0, 50, 250 or 1000 ppm glutaraldehyde for 104 weeks. The mean glutaraldehyde consumption was 0, 4, 17 and 64 mg/kg-day for males and 0, 6, 25 and 86 mg/kg-day for females. There were no treatment-related mortalities or clinical symptoms of toxicity. In the 250 and 1,000 ppm groups, there was reduction in body weight and body weight gain; reduction in food and water consumption; increased statistically significant incidence of nucleated erythrocytes and of large monocytes; decreases in alanine aminotransferase (ALT), aspartate aminotransferase (AST), and glutamate dehydrogenase; dose-related decrease in urine volume accompanied by a dose-related increase in osmolality; changes in absolute and relative kidney weight; gastric irritation; increases in bone marrow hyperplasia; and increased incidence of renal tubular pigmentation. The decreased water consumption was considered to be due to the bad taste, smell and/or irritancy of the test substance in the drinking water; therefore, it is of no toxicological relevance. As a result of reduced water intake, there are renal physiological adaptation, such as decreased urine, increased osmolality and changes in kidney weight. The haematological and clinical chemistry parameter changes were marginal and were considered to be of no toxicological relevance. The main haematological finding seen at the end of the study and which consisted of the appearance of nucleated erythrocytes and large monocytes in all treated groups (statistically significant for

the ≥250 ppm males) was related to the incidence of large granular lymphocytic leukaemia (LGLL) in the spleen. The bone marrow hyperplasia and renal tubular pigmentation are related to the occurrence/incidence of LGLL, and were considered by the authors of the study as being secondary to a low grade haemolytic anaemia in animals with LGLL. The NOAEL for this study is 50 ppm which corresponds to 4 and 6 mg/kg-day for males and females, respectively (Van Miller *et al.* 2002). [Kl. score = 2]

Inhalation

Male and female F344 rats were exposed by inhalation to 0, 0.0625, 0.125, 0.25, 0.5 or 1.0 ppm (0, 0.26, 0.5, 1, 2, or 4.1 mg/m^3) glutaraldehyde for 6.5 hours/day, 5 days/week for 13 weeks. The study focused on the respiratory tract, using histopathology and epithelial cell labelling index as end points. Histopathological lesions in the nasal passages and turbinates were seen at ≥0.25 ppm. Treatment-related effects were primarily the respiratory mucosa (nasal cavity and tips of the turbinates) and the olfactory epithelium (dorsal meatus). Hyperplasia, squamous metaplasia, olfactory degeneration, squamous exfoliation (accumulation of keratin, cell debris and bacteria in the lumen of the nasal vestibule) and focal erosions were reported for both sexes, and the severity and incidence of the findings increased with increasing concentration of glutaraldehyde. The NOAEL for this study is 0.125 ppm (Gross et al., 1994). [Kl. score = 1]

Male and female B6C3F$_1$ mice were exposed by inhalation to 0, 0.0625, 0.125, 0.25, 0.5 or 1.0 ppm (0, 0.26, 0.5, 1, 2, or 4.1 mg/m^3) glutaraldehyde for 6.5 hours/day, 5 days/week for 13 weeks. The study focused on the respiratory tract, using histopathology and epithelial cell labelling index as end points. Histopathologic lesions in the nasal passages and turbinates were seen at all exposure concentrations (≥0.0625 ppm). Treatment-related lesions were primarily the respiratory mucosa (nasal cavity and tips of the turbinates) and the olfactory epithelium (dorsal meatus). Hyperplasia, squamous metaplasia, olfactory degeneration, squamous exfoliation (accumulation of keratin, cell debris and bacteria in the lumen of the nasal vestibule) and focal erosions were reported for both sexes, and the severity and incidence of the findings increased with increasing test concentration. Furthermore, neutrophilic inflammation was seen at ≥0.062 ppm, and squamous metaplasia as well as necrosis were seen in the larynx at 1 ppm). The LOAEL for this study is 0.0625 ppm; a NOAEL was not established (Gross et al*.,* 1994). [Kl. score = 1]

Male and female B6C3F$_1$ mice were exposed by inhalation to 0 or 0.1 ppm (o or 0.41 mg/m^3) glutaraldehyde for 6 hours/day, 5 days/week for 52 and 78 weeks. Survival was similar between treated and control groups. Hyperplasia of the squamous epithelium lining of the dorsal wall of the nasal passages and the lateral aspect of the atrioturbinate was seen in a greater number of exposed females than in controls. Epidermal erosion and ulceration as well as squamous and inflammatory exfoliation were also seen in the nasal lumens. All of these changes were dependent on the length of glutaraldehyde exposure. The authors concluded that, since the induced lesions occurred in the more anterior part of the nasal passages, that they were likely the result of an irritation mechanism (Zissu et al., 1998). [Kl. score = 2]

Male and female Fischer 344 rats were exposed by inhalation to 0, 0.25, 0.5, or 0.75 ppm (0, 1, 2, or 3.1 mg/m^3) glutaraldehyde for 6 hours/day, 5 days/week for two years. Survival in the mid- and high-dose females was statistically significantly decreased compared to controls. Mean body weights of all exposed males and the mid- and high-dose females were generally less than those of the controls. Non-neoplastic lesions were limited primarily to the most

anterior region of the nasal cavity. Effects included hyperplasia and inflammation of the squamous epithelium; hyperplasia, goblet cell hyperplasia, inflammation, and squamous metaplasia of the respiratory epithelium; and hyaline degeneration of the olfactory epithelium. The LOAEL for this study is 0.25 ppm based on hyperplasia and inflammation of the squamous epithelium of the nose in both sexes. A NOAEL was not established (van Birgelen et al., 2000). [Kl. score = 2]

Male and female B6C3F$_1$ mice were exposed by inhalation to 0, 0.0625, 0.125, or 0.25 ppm (0, 0.26, 0.5, or 1 mg/m^3) glutaraldehyde for 6 hours/day, 5 days/week for two years. Survival of the treated animals was similar to controls. Mean body weights of the high-dose females were generally lower than the controls. Non-neoplastic lesions were limited primarily to the anterior region of the nasal cavity; the effects were qualitatively similar to those seen in the rats (see accompanying summary on the two-year rat study by van Birgelen et al., 2000). Squamous metaplasia of the respiratory epithelium was observed in both sexes of mice while female mice also had inflammation and hyaline degeneration of the respiratory epithelium. The incidence and severity grade (in parentheses) of the hyaline degeneration were: 16/50 (1.4), 35/49 (1.4), 32/50 (1.3), and 30/50 (1.1) for the 0, 0.0625, 0.125, and 0.25 ppm dose groups, respectively. The LOAEL for this study is 0.0625 ppm based on hyaline degeneration of the respiratory epithelium in female mice. A NOAEL was not established (van Birgelen et al., 2000). [Kl. score = 2]

Dermal

Applications of a 50% solution of glutaraldehyde was applied to the skin of male and female SD rats for 13 weeks. The doses were 0, 50, 100, and 150 mg/kg glutaraldehyde. At the application site, there were signs of irritation (scabs, desquamation and very slight or well-defined erythema). There was no treatment-related mortality, clinical signs, body weights, feed consumption, and ophthalmoscopic effects. There were no changes in the haematology and clinical chemistry parameters that were considered to be biologically or toxicologically relevant. Organ weights were similar between treated and control animals. Histopathological examination showed a treatment-related effects in the skin associated with chronic irritation; no other changes were noted that were considered to be treatment-related. The NOAEL for this study is 150 mg/kg, the highest dose tested (ECHA). [Kl. score = 1]

Genotoxicity

Glutaraldehyde may exhibit weak genotoxic effects in some *in vitro* tests. The bacterial reverse mutation assays have been the most consistent. Variable results have been reported for the forward gene mutation tests; and for sister chromatid exchange (SCE), chromosomal aberration and Unscheduled DNA Synthesis (UDS) tests (Vergnes and Ballantyne, 2002).

The in vivo studies conducted on glutaraldehyde are presented below in Table 4. All of the studies show that glutaraldehyde is not mutagenic or genotoxic.

Table 4: *In Vivo* Genotoxicity Studies on Glutaraldehyde

Test System	Results*	Klimisch Score	Reference
Rat bone marrow (chromosomal aberration)	-	1	ECHA

Rat bone marrow (chromosomal aberration)	-	2	ECHA
Mouse bone marrow (micronucleus)	-	1	ECHA
Rat bone marrow (chromosomal aberration)	-	2	ECHA
Rat germ cell cytogenetic assay (alkaline elution)	-	2	ECHA
Drosophila SLRL Test	-	2	ECHA
Rat liver UDS Assay	-	1	ECHA
Rat germ cell cytogenetic assay (alkaline elution)	-	2	ECHA
Mouse peripheral blood micronucleus study	-	2	Vergnes and Ballantyne (2002)
Rat liver UDS Assay	-	2	Mirsalis *et al.* (1989)

* = +, positive; -, negative

Carcinogenicity

Oral

Male and female Fischer 344 rats were given in their drinking water 0, 50, 250 or 1,000 ppm glutaraldehyde for 104 weeks. The mean glutaraldehyde consumption was 0, 4, 17 and 64 mg/kg-day for males and 0, 6, 25 and 86 mg/kg-day for females. Mortality rates were 25-30% and 19-23% for males and females, respectively, with no dose-related increase. The major cause of death in all dose groups including the controls was LGLL. There was an increased incidence of LGLL in the liver and spleen in all treated females (≥50 ppm). The incidence of LGLL was not significantly increased in the treated males compared to the controls. No other treatment-related increased incidence of tumours was seen (Van Miller et al., 2002). [Kl. score = 2]

Male and female Wistar rats were given in their drinking water 0, 100, 500 or 2,000 ppm glutaraldehyde for two years. The mean daily intake of glutaraldehyde was as follows: 0, 6.1, 31.9, and 120.7 mg/kg-day for males; and 0, 10.5, 48.5 and 176.4 mg/kg-day for females. In the high-dose animals, there was mortality (2 males and 9 females) from asphyxia and mean terminal body weights were significantly decreased compared to the controls. There were no treatment-related neoplastic effects (ECHA). [Kl. score = 1]

Inhalation

Male and female $B6C3F_1$ mice were exposed by inhalation to 0 or 0.1 ppm (0 or 0.4 mg/m^3) glutaraldehyde for 6 hours/day, 5 days/week for 52 and 78 weeks. No exposure-related neoplastic lesions were observed in either males or females (Zissu et al., 1998). [Kl. score = 2]

Male and female Fischer 344 rats were exposed by inhalation to 0, 0.25, 0.5, or 0.75 ppm (0, 1, 2, or 3.1 mg/m^3) glutaraldehyde for 6 hours/day, 5 days/week for two years. Survival in the

mid- and high-dose females was statistically significantly decreased compared to controls. Survival of the treated males was similar to controls. No exposure-related neoplastic lesions were observed in either males or females (van Birgelen et al., 2000). [Kl. score = 2]

Male and female B6C3F$_1$ mice were exposed by inhalation to 0, 0.0625, 0.125, or 0.25 ppm (0, 0.26, 0.5, or 1 mg/m^3) glutaraldehyde for 6 hours/day, 5 days/week for two years. Survival of the treated animals was similar to controls. No exposure-related neoplastic lesions were observed in either males or females (van Birgelen et al., 2000). [Kl. score = 2]

Reproductive Toxicity

A two-generation reproductive toxicity study was conducted in Wistar rats given 0, 100, 500 and 2000 ppm glutaraldehyde in their drinking water. The approximately mean daily intake is 0, 12, 58 and 199 mg/kg-day for the parental males and females of the F_0 and F_1 generation during premating. There were no adverse effects on reproductive performance or fertility. Oestrous cycle data, mating behaviour, conception, gestation, parturition, lactation and weaning as well as sperm parameters, sexual organ weights, gross and histopathological findings of these organs were similar between treated and control groups. In the high-dose animals, there was decreased water and/or food consumption; and decreased body weights and/or reduced body weight gains during the premating periods in the F_0 and F_1 parental females during premating, gestation and/or lactation. The high-dose F_1 parental females also had increased the number of erosions/ulcers with microscopic erosion(s) or inflammatory oedema in the mucosa/submucosa of the glandular stomach. There were no adverse effects in the 500 ppm animals except for slight decreases in water consumption due to a palatability (bad taste) problem. Treatment-related signs of developmental toxicity were seen in the progeny of the high-dose F_0 and F_1 parental generation, and included impairment in body weight and consequently in organ weights in the respective F1 and F2 pups. The NOAEL for reproductive toxicity is 2,000 ppm (199 mg/kg-day), the highest dose tested. The NOAEL for parental systemic toxicity is 500 ppm (58 mg/kg-day). The NOAEL for developmental toxicity is 500 ppm or 58 mg/kg-day (ECHA). [Kl. score = 1]

A two-generation reproductive toxicity study was conducted in Crj: CD(SD) rats given 0, 50, 250 and 1,000 ppm glutaraldehyde in their drinking water. Mean daily intake was not calculated. Parental body weights and body weight gains were significantly reduced at 1,000 ppm at some periods, particularly during pre-mating. Food consumption was significantly reduced at 1,000 ppm for the F_0 and F_1 parental animals during pre-mating and gestation, and F_1 females during lactation. Water consumption was reduced throughout the pre-mating period for the F_0 and F_1 250 and 1,000 ppm parental animals. There was no indication of adverse effects on reproductive performance or fertility at any dose level. For the F_1 1,000 ppm offspring, body weights were reduced from lactation days 21-28. The NOAEL for reproductive toxicity is 1,000 ppm, the highest dose tested. The NOAEL for parental systemic toxicity is 50 ppm. The NOAEL for developmental toxicity is 250 ppm (Neeper-Bradley and Ballantyne, 2000). [Kl. score = 2]

Developmental Toxicity

Pregnant Wistar rats were given in their drinking water 0, 50, 250 or 750 ppm (0, 5, 26 or 68 mg/kg) glutaraldehyde from GD 6 to 16. Water consumption was reduced in a dose-related manner in the $\geq$250 ppm dams, and was considered not to be a toxic response, but due to the palatability (bad taste) of the drinking test solution. No other maternal effects were seen in the

study. There were no significant differences between treated and controls in the sex distribution, placental weights, fetal weights, malformations or variations. The NOAELs for maternal and developmental toxicity in this study are 68 mg/kg-day, respectively (ECHA). [Kl. score = 1]

Pregnant Wistar rats were dosed by oral gavage with 0, 25, 50, or 100 mg/kg glutaraldehyde on GD 6 to 15. Mortality was significantly increased in the high-dose group (5/26); there were 2/21 deaths in the mid-dose group. Clinical signs (piloerection) occurred in all treated groups in a dose-dependent manner. Maternal body weight gain and feed consumption were significantly reduced in the high-dose dams, but not at the lower doses. The necropsy findings showed evidence of stomach irritation in almost all of the animals that died during the study and in 12/21 of the surviving dams in the high-dose group. The number of implantations per litter, resorptions and dead foetuses per litter, live foetuses per litter, and incidence of post-implantation loss per litter was similar across all groups. The mean foetal body weights for male and female foetuses were significantly reduced in the high-dose group; this was attributed to the reduced food consumption of the dams during gestation rather than a direct effect of treatment. There was no evidence of a treatment-related teratogenic effect. The NOAELs for maternal and developmental toxicity are 50 mg/kg-day, respectively (Ema et al., 1992). [Kl. score = 2]

Pregnant Himalayan rabbits were dosed by oral gavage with 0, 5, 15 or 45 mg/kg glutaraldehyde on GD 7 to 19. In the high-dose group, 5/15 died on GD 9-11. Food consumption and body weight gain were also significantly reduced in the high-dose group. Clinical observations in 12/15 high-dose does included soft faces, diarrhoea, and blood in the bedding. The mean gravid uterus weight was significantly reduced in the high-dose group. Post-implantation loss was greatly increased (94.3%) in the high-dose group: no viable foetuses in 9/15 of the high-dose does, only early resorptions; only one female gave 4 alive foetuses on the scheduled date. There were reduced placental and foetal body weights in the only four foetuses. No significant maternal or developmental effects were seen in the mid- and low-dose groups. The NOAELs for maternal and developmental toxicity in this study are 15 mg/kg-day (ECHA). [Kl. Score = 2]

Derivation of Toxicological Reference and Drinking Water Guidance Values

Non-Cancer (Oral)

The lowest NOAEL values from key toxicity studies on glutaraldehyde are listed below in Table 5.

Table 5: Lowest NOAEL Values from Key Toxicity Studies on Glutaraldehyde by the Oral Route

Species/Sex	Study Duration	mg/kg-day	Endpoint	Reference
Rats, female	90-days	4	Decreased body weights, food and water consumption	ECHA
Rats, male	13-wk (drinking water)	5	Increased kidney weights	ECHA

Species/Sex	Study Duration	mg/kg-day	Endpoint	Reference
Rats, male	12-months (drinking water)	30.5	Clinical signs; decreased body weights and food consumption; increased clear cell foci in liver	ECHA
Rats, male	2-yr (drinking water)	4	Reduced body weight, body-weight gain, and food consumption	Van Miller *et al.* (2002)
Rats	2-generation (drinking water)	58	Systemic toxicity	ECHA
Rats	GD 6-16 (drinking water)	68	Developmental toxicity	ECHA
Rats	GD 6-15 (oral gavage)	50	Developmental toxicity	Ema *et al.* (1992)
Rabbits	GD 7-19 (oral gavage)	15	Developmental toxicity	ECHA

The lowest NOAEL from these studies is 4 mg/kg-day based on reduced body weights, body weight gain, and feed consumption in male rats from the two-year drinking water study (Van Miller et al., 2002). The NOAEL of 4 mg/kg-day will be used for determining the oral Reference Dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

$$\text{Oral RfD} = \text{NOAEL} / (UF_A \times UF_H \times UF_L \times UF_{Sub} \times UF_D)$$

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

$$\text{Oral RfD} = 4/(10 \times 10 \times 1 \times 1 \times 1) = 4/100 = \underline{0.04 \text{ mg/kg-day}}$$

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)

Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2 L (ADWG, 2011)
Drinking water guidance value = (0.04 x 70 x 0.1)/2 = 0.14 mg/L

Cancer

Increased incidence of large granular cell lymphatic leukaemia (LGLL) was observed in all groups of male and female Fischer 344 rats given glutaraldehyde in their drinking water, including the controls (Van Miller *et al.,* 2002). For the males, the incidence of LGLL was not statistically significantly increased. However, for the females, the incidence of LGLL was significantly increased in all treated females (≥50 ppm). Inhalation exposure of Fischer 344 rats to glutaraldehyde did not result in an increased incidence of tumours, including LGLL.

LGLL, also known as mononuclear cell leukaemia, is an extremely common spontaneous neoplastic disease of the ageing F344 rat (Stromberg, 1985; Ward *et al.,* 1990; Thomas et al., 2007). Consistent features are splenomegaly, anaemia, thrombocytopenia and leukemic infiltration of the spleen, liver lung, and in an advanced stage, of several other organs. The incidence is variable but has been increasing progressively with time and can exceed 70% in controls in some studies. This compares with background incidence of less than 1% in other strains of commonly used laboratory rats (Haseman et al., 1998; Thomas et al., 2007). The incidence in F344 rats is modulated by a variety of factors not clearly related to carcinogenicity. Corn oil gavage, for example, has been shown consistently to reduce the incidence of MCL in male, but not female, controls (reviewed in Thomas et al., 2007).

The neoplastic mononuclear cells appear to be derived from large granular lymphocytes (LULs) (reviewed in Thomas et al., 2007). The tumour cell is of the NK type in most, if not all, cases. LGL leukaemia, although uncommon, does occur in humans. There are two types: T-LGL leukaemia which has a chronic course characterised by neutropenia, recurrent infections, splenomegaly and accompanying rheumatoid arthritis, and the much rarer NK-LGL leukaemia which has an acute course, more pronounced splenomegaly, and thrombocytopenia. The latter type appears to resemble more closely the disease in the F344 rat than the former. The aetiology of human LGL leukaemia is unknown. There is some evidence that viral infection may play a role but no evidence that a chemically-related increased of LGLL in the F344 rat is indicative of the potential to induce LGL leukaemia in humans.

To extrapolate results from an animal model that has a clear predisposition (high spontaneous rates) to a tumour type to humans, of which this is not the case, seems inappropriate if the mechanism(s) for LGLL formation in that strain is not understood. Although that rat strain may be useful for understanding the disease process in humans, it does not seem reasonable to use the results from that rat strain for risk assessment purposes. There should be confirmation of a putative leukemogenic effect in the F344 rat in another strain before any conclusions are made about the use of this tumour type for human health risk assessment purposes.

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Toxicity Profile

Glycerol
(CAS No. 56-81-5)

Toxicokinetics/Metabolism

Glycerol is an intermediate in carbohydrate and lipid metabolism in living organisms.

Acute Toxicity

The oral LD_{50} values are >5,000 to 58,400 mg/kg in rats, 4,250 to 38,000 mg/kg in mice, 7,750 and 10,000 mg/kg in guinea pigs (OECD, 2002). The oral LD_{50} value of 4,250 mg/kg in mice is not consistent with the range of values found in the available literature and is considered unreliable because of the lack of documentation of the study (OECD, 2002).

All rats died following a 2-hour exposure to saturated vapors of glycerol, while there was no mortality when the exposure was for only one hour (ECHA) [Kl. score = 2].

No deaths were seen in rabbits following dermal application for 8 hours under occlusive conditions. The dermal LD_{50} is >18,700 mg/kg (Hine *et al.*, 1953).

Irritation

Application of 0.5 ml glycerol to the skin of rabbits for 24 hours under occlusive conditions was not irritating (Weil and Scala, 1971; ECHA). [Kl. score = 2]

Instillation of 0.1 ml glycerol into the eyes of rabbits was non-irritating (Weil and Scala, 1971; ECHA).

Sensitization

Male guinea pigs were given ten 0.1 mL injections of a 0.1% solution of synthetic or natural glycerol in isotonic saline every other day over 20 days. Following a two-week period, an 0.05 mL injection was given of the 0.1% glycerol solution. There was no sensitizing response (Hine *et al.*, 1953).

Repeated Dose Toxicity

Oral

Male and female rats were given in their feed 0, 5, or 20% glycerol for 90 days. Glycerol samples from different companies were compared in separate groups of animals. Body weight gain was higher in the treated rats compared to the controls. The 20% males had increased liver weights relative to body weights with histopathologic changes of generalized cloudy swelling and hypertrophy of the parenchymal cells. The 20% females showed increased relative liver weights, but had generalized cloudy swelling in the liver. For the liver changes, there were no differences between the three glycerol samples. Relative heart weights were significantly reduced in the 20% females from one glycerol sample, and relative kidney weights

were increased in the 20% females from another glycerol sample; these changes were not accompanied by histopathological changes. The NOAEL for this study is 5% glycerol in the diet, which corresponds to an estimated daily intake of 4,580 and 6,450 mg/kg-day for males and females, respectively (ECHA). [Kl. score = 2]

Male and female Long-Evans rats were given in their feed 0, 5, 10, or 20% glycerol for two years (the 20% group were for 1 year only). The estimated daily intakes are 0, 2,000, 4,000, and 8,000 mg/kg-day for males; and 0, 2,500, 5,000, and 10,000 mg/kg-day for females. Treatment was discontinued after one year for the 20% animals for reasons that were not stated in the report. Data on mortality and clinical observations were not reported. There was a slight increase in food consumption in the ≥5% group males. No adverse effects were reported in males or females at any dose level. The NOAEL is 20% glycerol in the diet, which corresponds to 8,000 and 10,000 mg/kg-day for males and females, respectively (Hine et al., 1953; ECHA). [Kl. score = 2]

Female rats were given in their drinking water 0, 5% synthetic glycerol, or 5% natural glycerol for 6 months. There was no difference between the two glycerol samples. The treated rats gained more weight over the treatment period than the controls. There were no treatment-related hematological changes, and there were mild treatment-related kidney effects, as indicated by calcified masses in tubules near the junction of the cortex and medulla (Anderson et al., 1950; ECHA). [Kl. score = 2]

Inhalation

Male and female SD rats were exposed by inhalation (nose-only) to 0, 33, 165, or 660 mg/m^3 of aerosolized glycerol 6 hours/day, 5 days/week for 13 weeks. The mass median aerodynamic diameter (MMAD) was <2.0 μm (respirable). The only effect seen was localized irritation of the upper respiratory tract. The NOAEC for systemic toxicity is 660 mg/m^3, the highest exposure concentration tested. The NOAEC for localized effects (irritation) is 167 mg/m^3 (Renne, 1992; ECHA). [Kl. score = 2]

Dermal

Rabbits were given dermal applications of 0.5 to 5.4 ml/kg glycerol 8 hours/day for 45 weeks. No effects including irritation were noted. The NOAEL is 5.4 ml/kg, which is calculated to be 5,040 mg/kg-day (ECHA). [Kl. score = 2]

Genotoxicity

The results of the *in vitro* studies on glycerol are presented below in Table 1.

Table 1: *In Vitro* Genotoxicity Studies on Glycerol

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	Haworth *et al.*, 1983; ECHA
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	Doolittle *et al.*, 1988; ECHA
Mammalian cell gene mutation (CHO cells)		-	2	Doolittle *et al.*, 1988; ECHA
Sister chromatid exchange (human lymphocytes)	-	-	2	Doolittle *et al.*, 1988; ECHA
Unscheduled DNA synthesis (rat hepatocytes)	-	-	2	Doolittle *et al.*, 1988; ECHA
Chromosomal aberrations (CHO cells)	-	-	2	Doolittle *et al.*, 1988; ECHA

*+, positive; -, negative

There are no in vivo genotoxicity studies available on glycerol.

Carcinogenicity

Male and female Long-Evans rats were given in their feed 0, 5, 10, or 20% glycerol for two years (the 20% group were for 1 year only). The estimated daily intakes are 0, 2,000, 4,000, and 8,000 mg/kg-day for males; and 0, 2,500, 5,000, and 10,000 mg/kg-day for females. Treatment was discontinued after one year for the 20% animals for reasons that were not stated in the report. Data on mortality and clinical observations were not reported. The tumor incidences were similar between treated and control animals (Hine et al., 1953; ECHA). [Kl. score = 2]

Reproductive Toxicity

In a two-generation reproductive toxicity study, male and female rats were dosed by oral gavage with 0 or 20% glycerol solution (in water). There were no treatment-related effects on growth, reproductive performance, fertility, and no histopathological changes in the tissues examined. The NOAEL for this study is 20% glycerol in water, which the daily intake was estimated to be 2,000 mg/kg-day (OECD, 2002; ECHA). [Kl. score = 2]

Developmental Toxicity

Pregnant female Wistar rats were dosed by oral gavage with 0, 13.1, 60.8, 282, or 1,310 mg/kg-day glycerol during gestational days 6 to 15. There was no maternal or developmental toxicity.

The NOAEL for maternal and developmental toxicity is 1,310 mg/kg-day, the highest dose tested (ECHA). [Kl. score = 2]

Pregnant female CD-1 mice were dosed by oral gavage with 0, 12.8, 59.4, 276, or 1,280 mg/kg-day glycerol during gestational days 6 to 15. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity is 1,280 mg/kg-day, the highest dose tested (ECHA). [Kl. score = 2]

Pregnant female Dutch rabbits were dosed by oral gavage with 0, 11.8, 54.8, 254.5, or 1,180 mg/kg-day glycerol during gestational days 6 to 18. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity is 1,280 mg/kg-day, the highest dose tested (ECHA). [Kl. score = 2]

Derivation of Toxicological Reference and Drinking Water Guidance Values

Liver effects were seen in male and female rats in a 90-day dietary study, with a NOAEL of 5% glycerol in the diet. This dose corresponds to an estimate daily intake of 4,580 and 6,450 mg/kg-day for males and females, respectively (ECHA). In a two-year dietary study, no effects were seen in male or female rats at a dose of 20% glycerol in the diet. It should be noted, however, that the treatment at the dietary level of 20% was for only one year, while the lower doses (5 and 10%) were for two years. No liver effects were noted at any dose level. The NOAEL for the two-year dietary study is the 20% dietary level which corresponds to estimated daily intakes of 8,000 and 10,000 mg/kg-day, for males and females, respectively (Hine et al., 1953; ECHA).

The NOAEL of 4,580 mg/kg-day from the male rats in the 90-day dietary study will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 3
UF_D (database uncertainty) = 1

Oral RfD = 4,580/(10 x 10 x 1 x 3 x 1) = 4,580/300 = 15 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (15 x 70 x 0.1)/2 = 53 mg/L

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Toxicity Profile

Guar Gum
(CAS No. 9000-30-0)

Guar gum (CAS No. 9000-30-0) is a resinous material derived from milled endosperm from guar beans of the legume *Cyamopsis tetragonolobus*. Structurally, it is a galactomannan (high molecular weight carbohydrate polymer) consisting of a main chain of D-mannose with a side chain of D-galactose at approximately every second mannose unit. The mannose units are β-(l-4) linked, and the single D-galactose units are joined to the main chain by α-(1-6) linkages. The molecular weight is 200,000 to 300,000 daltons (Glicksman, 1969.)

Acute Toxicity

The oral LD_{50} in rats was reported to be 7,060 mg/kg (Graham *et al.*, 1981). [Kl. score = 2]

Irritation

Guar gum is non-irritating to the skin and minimally irritating to the eyes (McCarty *et al.*, 1990).

Sensitization

There were reports of workers sensitized to guar gum in a carpet-manufacturing plant. Immediate skin reactivity to guar gum was observed in 8 out of 162 employees, and 11 of 133 participants had serum IgE antibodies to guar gum. These findings are difficult to interpret since carbohydrates, such as guar gum, are generally not associated with allergenicity (Maio, 1990).

Repeated Dose Toxicity

Male and female Osborne-Mendel rats were given diets containing 0, 1, 2, 4, 7.5, or 15% guar gum for 91 days. The average daily intakes are: 0, 580, 1,187, 2,375, 4,561, and 10,301 mg/kg-day for males; and 0, 691, 1,362, 2,762, 5,770, and 13,433 mg/kg-day for females. There were no deaths during the study. Body weights were significantly decreased in the ≥1% females and the ≥7.5% males; biologically significant changes (>10%) were seen in the 7.5% females and the 15% males. Liver weights were decreased in the ≥1% dietary groups. Kidney weights were decreased in the ≥7.5% dietary groups and were borderline significant in the 4% group. The 15% group males had reduced bone marrow cellularity; although the level was within normal limits, several of the rats were at the lower end of the normal range. The NOAEL for this study is 4% in the diet or 2,762 mg/kg-day based on reduced body weights in the female rats (Graham *et al.*, 1981). [Kl. score = 2].

Male and female F344 rats and $B6C3F_1$ mice were given diets containing 0, 6,300, 12,500, 25,000, 50,000 or 100,000 ppm guar gum for 13 weeks. Mean body weights were decreased in the 100,000 ppm male rats and in the ≥50,000 ppm female mice. A dose-related decrease in feed consumption was observed for male and female rats; male and female mice were comparable or higher than that of controls. There were no compound-related clinical signs or histopathological effects. The NOAELs for this study is 50,000 and 25,000 ppm for rats and mice, respectively. Using the fraction of body weight that rats and mice consume per day as

food (0.05 and 0.13, respectively; U.S. EPA), the NOAELs corresponds to 2,500 mg/kg-day for rats and 3,250 mg/kg-day for mice (NTP, 1982). [Kl. score = 2]

Male and female F344 rats and B6C3F$_1$ mice were given diets containing 0, 25,000 ppm or 50,000 ppm guar gum for 103 weeks. Mean body weights of the high-dose females were lower than those of the controls after week 20 for mice and week 40 for rats. No compound-related clinical signs or adverse effects on survival were observed. Feed consumption by dosed rats and mice of either sex was lower than that of controls. There were no non-neoplastic histopathological effects in either rats or mice that were treatment-related. The NOAEL for both rats and mice is 25,000 ppm. Using the fraction of body weight that rats and mice consume per day as food (0.05 and 0.13, respectively; U.S. EPA), the NOAELs corresponds to 1,250 mg/kg-day for rats and 3,250 mg/kg-day for mice (NTP, 1982). [Kl. score = 2]

Genotoxicity

Guar gum was not mutagenic to *S. typhimurium* strains TA 97, TA 98, TA 100, TA 102, TA 104, TA 1535, TA 1537, and TA1538 in the presence or absence of metabolic activation (Zeiger *et al.*, 1992) [Kl. score = 2].

Guar gum was inactive in a rat bone marrow cytogenetic assay at doses up to 5,000 mg/kg (CIR, 2015) [Kl. score = 4]. In a rat dominant lethal mutation test, rats were dosed by oral gavage with either a single or multiple doses of up to 5,000 mg/kg guar gum. There was no indication of a mutagenic effect by guar gum (Lee *et al.*, 1983) [Kl. score = 2].

Carcinogenicity

Male and female F344 rats were given diets containing 0, 25,000 ppm, or 50,000 ppm guar gum for 103 weeks in a NTP chronic bioassay. There were increased incidences of adenomas of the pituitary in male rats and pheochromocytomas of the adrenal medulla in female rats that were statistically significant, but these differences were considered to be unrelated to guar gum administration. When pituitary adenomas or carcinomas and when pheochromocytomas or malignant pheochromocytomas were combined, the statistical differences disappeared. NTP concluded that, under conditions of this bioassay, guar gum was not carcinogenic for F344 rats (NTP, 1982). [Kl. score = 2]

Male and female B6C3F$_1$ mice were given diets containing 0, 25,000, or 50,000 ppm guar gum for 103 weeks in a NTP chronic bioassay. Hepatocellular carcinomas occurred in treated male mice at incidences that were significantly lower than that in controls. The combined incidence of male mice with either hepatocellular adenomas or carcinomas was also significantly lower in the high-dose group. NTP concluded that, under conditions of this bioassay, guar gum was not carcinogenic for B6C3F$_1$ mice (NTP, 1982). [Kl. score = 2]

Reproductive Toxicity

Male and female Osborne-Mendel rats were fed diets containing 0, 1, 3, 4, 7.5, or 15% guar gum for 13 weeks before mating, during mating and throughout gestation. The daily intakes for the female rats during gestation were 0, 700, 1,400, 2,700, 5,200, or 11,800 mg/kg-day. Fertility was unaffected by treatment. There were slightly fewer corpora lutea and

implantations in the 15% dietary group, but implantation efficiency was unaffected. The NOAEL for reproductive toxicity is 5,200 mg/kg-day (Collins *et al.*, 1987). [Kl. score = 2]

Developmental Toxicity

Male and female Osborne-Mendel rats were fed diets containing 0, 1, 3, 4, 7.5, or 15% guar gum for 13 weeks before mating, during mating and throughout gestation. The daily intake for the female rats during gestation were 0, 700, 1,400, 2,700, 5,200, or 11,800 mg/kg-day. There were no deaths during the study. In the 15% group, the number of viable fetuses per litter were slightly reduced but was not statistically significantly different from controls. The authors indicated that the reduction may have been an effect of the decreased number of corpora lutea because the number of resorptions was unaffected in this treatment group. There was no treatment-related effect on fetal development or sex distribution, and there were no teratogenic effects (Collins *et al.*, 1987). [Kl. score = 2]

Pregnant female rats were dosed by oral gavage with 0, 9, 42, 200, or 900 mg/kg guar gum on GD 6 to 15. There was no maternal or developmental toxicity at any dose level. The NOAEL for maternal and developmental toxicity is 900 mg/kg-day (FDRL, 1973). [Kl. score = 2]

Pregnant female CD-1 mice were dosed by oral gavage with 0, 8, 37, 170, or 800 mg/kg guar gum on GD 6 to 15. A significant number of deaths (6 out of 29) occurred in the 800 mg/kg dose group. There were indications of maternal toxicity in the surviving high-dose dams. There was no developmental toxicity at any dose level. The NOAELs for maternal and developmental toxicity are 170 and 800 mg/kg-day, respectively (FDRL, 1973). [Kl. score = 2]

Derivation of Toxicological Reference and Drinking Water Guidance Values

In a two-year NTP chronic bioassay, female rats and mice given 50,000 ppm guar gum in their feed had lower body weights. There were no treatment-related non-neoplastic lesions in either rats or mice. The NOAEL for this study is 25,000 ppm for rats and mice, which corresponds to 1,250 mg/kg-day for rats and 3,250 mg/kg-day for mice. The NOAEL of 1,250 mg/kg-day will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 1,250/(10 x 10 x 1 x 1 x 1) = 1,250/100 = 13 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (13 x 70 x 0.1)/2 = <u>46 mg/L</u>

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Toxicity Profile

Hemicellulase
(CAS No. 9025-56-3)

Hemicellulases are a group of enzymes that break down hemicellulose, which are polysaccharides that are present in cell walls of all terrestrial plants. These polysaccharides have a β-(1→4)-linked backbone and are composed of pentoses (xylose, arabinoses), hexoses (mannose, glucose, galactose), and sugar acids. Unlike cellulose which are polysaccharides consisting of linear chains of several hundred to over ten thousand β-(1→4) linked D-glucoses, hemicelluloses are not chemically homogeneous. The best characterized hemicellulases are the 1,4- β -D-xylanases and, in particular, those derived from fungal sources presumably because their substrates, xylans, constitute the largest proportion of hemicelluloses in pasture plants.

No toxicity information could be located on hemicellulases; however, mammalian toxicity information was found on the cellulase enzymes (HERA, 2005). Cellulases cleave the ß-1,4-glycosidic bonds in cellulose, and are used in the pulp and paper industry, the textile industry, and in detergents to remove deposits and stains. The molecular weight of cellulase is 20,000 to 80,000 daltons.

Enzymes are catalytic proteins or polypeptides and consist of amino acid residues coupled via peptide bonds. They are primarily characterized by their biocatalytic or enzymatic activity. There is a broad range of detergent cellulases used both from fungal as well as from bacterial origin; all are characterized by ß-1,4-endoglucanase activity. For the purposes of risk assessment, the structure of hemicellulases would be expected to be similar to that of cellulases, given that hemicellulases and cellulases are both enzyme families that hydrolyze polysaccharides, although differing in their substrates. Thus, the toxicity data on cellulases will be used as read-across to hemicellulases.

Acute Toxicity

The oral LD_{50} of a cellulase enzyme was calculated to be 8,000 mg/kg for mice and >10,000 mg/kg for rats (HERA, 2005) [Kl. score = 4]. The oral LD_{50} in rats for a cellulase enzyme was >2,880 mg/kg, measured as total organic solids (ECHA). [Kl. score = 1]

The inhalation LC_{50} of a cellulase enzyme in rats was >3.48 mg/L. The mass mean aerodynamic diameter (MMAD) was 7.8 µm with a geometric standard deviation of 2.1 µm (HERA, 2005) [Kl. score = 4]. The 4-hour inhalation LC_{50} of a cellular enzyme in rats was >4.86 mg/L, which corresponds to 4.44 mg total organic solids/L). The respirable fraction was 80% (44.8% of the particles were <6 µm (ECHA). [Kl. score = 1]

No dermal toxicity studies are available.

Irritation

Application of 0.5 ml of a cellulase enzyme to the skin of rabbits for 4 hours under semi-occlusive conditions was minimally irritating (ECHA). [Kl. score = 1]

Instillation of 0.1 ml of a cellulase enzyme to the eyes of rabbits was non-irritating (ECHA). [Kl. score = 1]

Sensitization

A cellulase enzyme was not a skin sensitizer to guinea pigs in a Buehler sensitization test (HERA, 2005). [Kl. score = 2]

Although there are no specific studies on cellulase enzyme, a number of enzymes from bacteria, plants, and fungi have the potential to cause occupational respiratory allergy, even asthma (Basketter et al., 2015).

Repeated Dose Toxicity

Male and female rats were dosed by oral gavage with 0, 300, 1,000 or 3,000 mg/kg of a cellulase enzyme for 4 weeks. There were no treatment-related clinical signs, but a slight dose-related increase in body weight gain (approx. 7%) was seen in the males. No treatment-related changes were noted in the hematology or clinical chemistry. There were no gross or histopathologic changes that were considered treatment-related. The NOAEL is 3,000 mg/kg-day (HERA, 2005). [Kl. score = 2]

Male and female rats were fed a diet containing 0, 120, 600 or 3,000 mg/kg of a cellulase enzyme for 13 weeks. There were no treatment-related clinical signs. A reduction in body weight gain was seen in both sexes at the 3,000 mg/kg dose level (10% in males and 20% in females). A slight reduction in food consumption was also noted for the 3,000 mg/kg rats. Alkaline phosphatase was increased in the 600 and 3,000 mg/kg females in a dose-dependent manner. There were no gross or histopathologic changes that were considered treatment-related. The NOAEL for this study is 600 mg/kg-day (HERA, 2005). [Kl. score = 2]

Male and female Wistar rats were dosed by oral gavage with 0, 100, 300, or 1,000 mg/kg β-glucanase (measured as total organic solids) for 13 weeks. There were no treatment-related effects on mortality, clinical signs, body weights, food or water consumption, ophthalmoscopic findings, hematology, clinical chemistry, neurobehavior (functional observation battery), organ weights, gross or microscopic pathology. The NOAEL is 1,000 mg/kg-day expressed as total organic solids (ECHA). [Kl. score = 1]

Genotoxicity

The *in vitro* genotoxicity studies on cellulase enzymes are shown in Table 1.

Table 1: *In vitro* Genotoxicity Studies on Cellulase Enzyme

Test System	**Results***		**Klimisch Score**	**Reference**
	-S9	**+S9**		
Bacterial reverse mutation (*S. typhimurium* and *E. coli* strains)	-	-	1	ECHA

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	HERA (2005)
Chromosomal aberration (human lymphocytes)	-	-	1	ECHA

*+, positive; -, negative

Male and female SD rats were dosed by oral gavage with 0, 300, 1,000, or 3,000 mg/kg of a cellulase enzyme for five consecutive days. Chromosomal aberrations, excluding gaps, were not significantly increased at any dose level compared to controls. Chromosomal aberrations including gaps were increased in females from all dose groups, but there was no clear dose-response relationship and the difference was only statistically significant at 3,000 mg/kg. There was no treatment-related effect on the mitotic capacity of the bone marrow. It was concluded that the cellular enzyme was not genotoxic under the conditions of the assay (HERA, 2005). [Kl. score = 2]

Carcinogenicity

No studies are available.

Reproductive/Developmental Toxicity

No studies are available.

Derivation of Toxicological Reference and Drinking Water Guidance Values

There are two 13-week rat studies on cellulase enzyme. In a dietary study, rats were given 0, 120, 600, or 3,000 mg/kg cellulase enzyme. The LOAEL for this study is 3,000 mg/kg based on significant reduction in body weight gain in both sexes; the NOAEL is 600 mg/kg-day (HERA, 2005). In an oral gavage study, rats were dosed with 0, 100, 300, or 1,000 mg/kg β-glucanase. There were no treatment-related effects and the NOAEL for this study is 1,000 mg/kg-day, the highest dose tested (ECHA). The NOAEL of 1,000 mg/kg-day from the 13-week rat oral gavage study will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 3
UF_D (database uncertainty) = 1

Oral RfD = 1,000/(10 x 10 x 1 x 3 x 1) = 1,000/300 = 3.0 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (3 x 70 x 0.1)/2 = 11 mg/L

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Toxicity Profile

1,6-Hexanediol
(CAS No. 629-11-8)

Acute Toxicity

The oral LD_{50} in rats is approximately 3,000 mg/kg (ECHA) [Kl. score = 2]. The 8-hour LC_{50} in rats is >3.3 mg/L (ECHA) [Kl. score = 2]. The dermal LD_{50} in rabbits is >2,500 mg/kg (ECHA) [Kl. score = 2].

Irritation

Application of 1 mL to the skin of rabbits for 20 hours under occlusive conditions was not irritating. The mean of the 24, 48, and 72-hour scores were 0.00 for both erythema and edema (ECHA) [Kl. score = 2].

Instillation of 0.1 mL into the eyes of rabbits was not irritating. The mean of the 24, 48, and 72-hour scores were: 0.00 for corneal opacity; 0.00 for iridial lesions; 1.70 for conjunctival redness; and 1.00 for chemosis (ECHA) [Kl. score = 1].

Sensitization

1,6-Hexanediol was not considered a skin sensitizer when tested in a guinea pig maximization test (ECHA) [Kl. score = 1].

Repeated Dose Toxicity

Male and female Wistar rats were dosed by oral gavage with 0, 100, 400, or 1,000 mg/kg 1,6-hexanediol for 28 days. There were no substantial treatment-related effects regarding feed consumption, body weight, body weight gain, clinical chemistry parameters, clinical signs, gross pathology, or histopathology. The NOAEL for this study is 1,000 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 1].

Male and female Wistar rats were dosed by oral gavage with 0, 100, 400, or 1,000 mg/kg 1,6-hexanediol for 90 days. The 1,000 mg/kg males had reduced body weights and body weight gain. There were no other treatment-related effects. The NOAEL for this study is 400 mg/kg-day (ECHA) [Kl. score = 1].

Genotoxicity

The *in vitro* genotoxicity studies on 1,6-hexanediol are presented below in Table 1.

Table 1: *In vitro* Genotoxicity Studies on 1,6-Hexanediol

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* strains	-	-	2	ECHA
Bacterial reverse mutation (*S. typhimurium* strains	-	-	2	ECHA
Mammalian cell gene mutation (HGPRT, Chinese hamster V79 cells)	-	-	1	ECHA
Chromosomal aberrations (Chinese hamster V79 cells)	-	-	1	ECHA

*+, positive; -, negative

Carcinogenicity

No studies are available.

Reproductive/Developmental Toxicity

A reproductive/developmental toxicity screening (OECD TG 421) study has been conducted on 1,6-hexanediol. Male and female Wistar rats were dosed by oral gavage with 0, 100, 400, or 1,000 mg/kg-day. There was no indication of reproductive or developmental toxicity. The 1,000 mg/kg males had reduced body weights and body weight gain. The NOAEL for reproductive and developmental toxicity is 1,000 mg/kg-day, the highest dose tested. The NOAEL for parental toxicity is 400 mg/kg-day (ECHA) [Kl. score = 1].

Male and female Wistar rats were dosed by oral gavage with 0, 100, 400, or 1,000 mg/kg 1,6-hexanediol for 90 days. There were no treatment-related effects on estrous cycle length and the number of cycles that were obtained. Sperm motility, the incidence of abnormal sperm in the cauda epididymis, and the sperm head counts in the testis and cauda epididymis were similar between treated and control males. The NOAEL for reproductive endpoints is 1,000 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 1].

Derivation of Toxicological Reference and Drinking Water Guidance Values

In a 90-day oral toxicity study, the 1,000 mg/kg male rats had reduced body weights and body weight gain; there were no other treatment-related effects (ECHA). The NOAEL for this study is 400 mg/kg-day, which will be used to derive the oral reference and drinking water guidance values.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 3
UF_D (database uncertainty) = 1

Oral RfD = 400/(10 x 10 x 1 x 3 x 1) = 400/300 = 1 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (1.33 x 70 x 0.1)/2 = 4.7 mg/L

References

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

Toxicity Profile

Hydrochloric acid
(CAS No. 7647-01-0)

Hydrochloric acid can exist in a gaseous phase at room temperature and pressure. Hydrochloric acid is also very soluble in water and is a strong acid that dissociates completely in water to hydrogen (H^+) and chloride (Cl^-) ions.

Acute Toxicity

The oral LD_{50} values in rats were reported to be 238 to 277 mg/kg and 700 mg/kg (OECD, 2002a,b) [Kl. scores = 2 and 4, respectively].

The lethal dose by dermal exposure is >5,010 mg/kg for rabbits (OECD 2002a,b) [Kl. score = 4].
The LC_{50} values in rats for HCl gas are 40,989 and 4,701 ppm for 5 and 30 minutes, respectively (ECHA) [Kl. score = 2]. The LC_{50} values in rats for HCl aerosol are 31,008 and 5,666 ppm (45.6 and 8.3 mg/L) for 5 and 30 minutes, respectively (ECHA) [Kl. score = 2].

Irritation

Application of a 37% aqueous solution of HCl for 1 or 4 hours was corrosive to the skin of rabbits (OECD, 2002a,b) [Kl. score = 2). Application of 0.5 mL of a 17% solution of aqueous solution of HCl for 4 hours was corrosive to the skin of rabbits (OECD, 2002a,b) [Kl. score = 3]. Moderate skin irritation was observed in rabbits following an application of 0.5 mL of a 3.3% aqueous solution of HCl for five days; no irritation was observed with 0.5 mL of a 1% aqueous solution (OECD, 2002a,b) [Kl. score = 2]. In humans, an aqueous solution of 4% of HCl was slightly irritating, while a 10% solution was sufficiently irritating to be classified as a skin irritant (OECD, 2002a,b).

Instillation of 0.1 mL of a 10% aqueous solution of HCl to the eyes of rabbits resulted in severe eye irritation (ECHA) [Kl. score = 2]. Instillation of 0.1 mL of a 5% solution of HCl produced corneal opacity, iridial lesions, conjunctival redness and chemosis in 3/3 animals at 1 hour and at day one post-instillation. There was no recovery in any animal and the study was terminated on day two (ECHA) [Kl. score = 1].

Sensitization

Hydrochloric acid was not a skin sensitiser in a guinea pig maximisation test (ECHA). [Kl. score = 2]

Repeated Dose Toxicity

Oral

No adequate studies were located.

Inhalation

Male and female SD rats and F344 rats were exposed by inhalation to 0, 10, 20, or 50 ppm 6 hours/day, 5 days/week for up to 90 days. Clinical signs were mainly indicative of the irritant/corrosive nature of HCl. Body weights were significantly decreased in the 50-ppm male F344 rats. There were no treatment-related effects on the haematology or clinical chemistry parameters or urinalysis. At study termination, heart, kidney and testes weights were increased in the 100 and/or 50 ppm groups; these changes were considered to be mainly related to the treatment-related effect on body weight. Histopathological examination showed minimal to mild rhinitis in the ≥20 ppm dose groups of both strains of rats (both sexes). The NOAELs for systemic toxicity and localised irritation (site-of-contact) are 20 and 10 ppm, respectively (ECHA) [Kl. score = 1].

Male and female B6C3F$_1$ mice were exposed by inhalation to 0, 10, 20, or 50 ppm HCl, 6 hours/day, 5 days/week for up to 90 days. Clinical signs were mainly indicative of the irritant/corrosive nature of HCl. Body weights were significantly decreased in the 50 ppm groups. At study termination, absolute liver weights were decreased in the 50 ppm males. Histopathologic examination showed only eosinophilic globules in the nasal epithelium in the 50 ppm animals. The NOAEL for this study is 20 ppm (ECHA) [Kl. score = 1].

Male SD rats were exposed by inhalation to 0 or 10 ppm HCl 6 hours/day, 5 days/week for 128 weeks. Survival and body weights were similar between treated and control groups. There was a higher incidence of hyperplasia of the larynx compared to control, but no serious irritating effects of the nasal epithelium (ECHA) [Kl. score = 2].

Genotoxicity

Table 1 presents the *in vitro* genotoxicity studies on hydrochloric acid.

Table 1: In Vitro Genotoxicity Studies on Hydrochloric Acid

Test System	Results[a]		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* and *E. coli* strains)	-	-	2	ECHA
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	-	+	2	ECHA
Chromosomal aberration (CHO cells)	+	+	2	ECHA
Saccharomyces cerevisiae (mitotic recombination	-	-	2	ECHA
E. coli W3110 (pol A+) and P3078 (pol A-) repair assay	-	-	2	ECHA

[a]+, positive; -, negative.

In the mouse lymphoma assay, the mutant frequency increased as the pH was lowered to 6.5 to 6.0 (from increased HCl) in the presence of metabolic activation. A decrease in pH from the addition of HCl to the medium also resulted in clastogenic effects to CHO cells in the absence or presence of metabolic activation. The positive findings in these two studies are considered to be the result of the pH change in the test media.

No adequate in vivo genotoxicity studies are available.

Carcinogenicity

Oral

No studies were located.

Inhalation

Male SD rats were exposed by inhalation to 0 or 10 ppm HCl 6 hours/day, 5 days/week for 128 weeks. Survival and body weights were similar between treated and control groups. There was a higher incidence of hyperplasia of the larynx compared to control, but no serious irritating effects of the nasal epithelium. There was no increased incidence of tumours in the HCl-treated rats compared to controls (ECHA) [Kl. score = 2].

Reproductive Toxicity

No studies were located.

Developmental Toxicity

No adequate studies were located.

Derivation of Toxicological Reference and Drinking Water Guidance Values

Repeated dose, reproductive, and developmental toxicity studies by the oral route have not been conducted on hydrochloric acid. These toxicity studies would have questionable usefulness because of the corrosive/irritating nature of hydrochloric acid, which would limit the amount of absorbed HCl. Hydrochloric acid dissociates to hydrogen and chloride ions in bodily fluids, and a significant amount of these ions are already ingested in foods. Furthermore, both ions are present in the body and are highly regulated by homeostatic mechanisms. Thus, an oral toxicological reference and drinking water guidance values were not derived from hydrochloric acid.

The Australian drinking water guideline values for pH (6.5 to 8.5) and chloride (250 ppm, aesthetics) may be applicable (ADWG, 2011).

References

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

De Groot, W.A., and van Dijk, N.R.M. (2002). Addition of hydrochloric acid to a solution with sodium bicarbonate to a fixed pH. Solvay Pharmaceuticals, Study No. A SOL.S.027; cited in OECD 2002a,b.

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances

OECD (2002a). IUCLID Data Set for Hydrogen chloride (CAS No. 7647-01-0), UNEP Publications.

OECD (2002b). Screening Information Dataset (SIDS) Initial Assessment Report for Hydrogen chloride (CAS No. 7647-01-0), UNEP Publications.

Toxicity Profile

Isopropanol
(CAS No. 67-63-0)

Acute Toxicity

The acute oral LD_{50} of isopropanol has been reported as 4,700 mg/kg, 5,300 mg/kg, 5,500 mg/kg, and 5,8400 mg/kg in rats; 4,500 mg/kg in mice; and 5,030 mg/kg, 7,800 mg/kg, and 7,900 mg/kg in rabbits (Kimura et al., 1971; WHO, 1990; Smyth and Carpenter, 1948; Lehman and Chase, 1944; Munch and Schwartze, 1925; Munch, 1972).

The acute dermal LD_{50} in rabbits has been reported to be 12,900 mg/kg (Smyth and Carpenter, 1948).

The acute inhalation 8-hour LC_{50} in rats was 19,000 ppm in females and 22,500 ppm in males (Laham *et al.*, 1980). Exposure of rats to 16,000 ppm for 8 hours resulted in four deaths out of six animals (Smyth and Carpenter, 1948).

In an acute neurotoxicity study, male and female F344 rats were exposed to 0, 500, 1,500, 5,000, or 10,000 ppm isopropanol for 6 hours. A spectrum of behavioral effects indicative of narcosis, defined as a generalized loss of neuromotor and reflex function, was observed in animals of the 10,000 ppm group and to a lesser extent in the 5,000 ppm animals. Recovery from these effects was observed by 24 hours for the 10,000 ppm animals and by 6 hours for the 5,000 ppm animals. A concentration-dependent decrease in motor activity was observed for the 1,500 ppm males and the 5,000 ppm females. The results show that exposure of rats to isopropanol vapor produces transient, concentration-related narcosis and/or central nervous system sedation. The NOAEL for acute neurotoxicity is 500 ppm (Gill et al., 1995).

Irritation

Isopropanol applied to the intact or abraded skin of rabbits and guinea pigs produced negligible irritation (Nixon *et al.*, 1975). Liquid isopropanol is moderately irritating to the eyes of rabbits (Griffith *et al.*, 1980; WHO, 1990). Isopropanol produced little irritation when tested on the skin of six human subjects (Bevan, 2012). [Kl. score = 1]

Sensitization

There have been reports of isolated cases of dermal irritation and/or skin sensitization (Bevan, 2012). Except for three case reports, the positive reactions were observed on patch testing patients with contact dermatitis due to ethanol. These patients also had a positive reaction to ethanol.

Repeated Dose Toxicity

Oral

In a drinking water study, rats ingested 0.5 to 10% of isopropanol for 27 weeks and showed decreased body weight gain but no gross or microscopic tissue abnormalities (Lehman and

Chase, 1944) [Kl. score = 3]. Increased formation of hyaline droplets in the proximal tubules was reported in male rats given 1–4% isopropanol in drinking water for 12 weeks (Pilegaard and Ladefoged, 1993) [Kl. score = 3].

A two-generation reproductive toxicity study has been conducted in rats given isopropanol by oral gavage. Pre-mating exposures were for at least 10 weeks for both generations. The results from this study are presented in the Reproductive Toxicity section (Bevan *et al.*, 1995). [Kl. score = 1]

Inhalation

F344 rats and CD-1 mice (both sexes) were exposed to 0, 100, 500, 1,500, or 5,000 ppm isopropanol for 6 hours/day, 5 days/week for 13 weeks. There were no deaths during the study. During and immediately following exposure to 5,000 ppm, ataxia, narcosis, hypoactivity, and a lack of startle reflex were observed in some rats and mice. Narcosis was not observed in rats during exposure following week 2, suggesting some adaptation to isopropanol. During exposures to 1,500 ppm, narcosis, ataxia, and hypoactivity were observed in some mice, whereas only hypoactivity was observed in rats. Immediately following exposures, ataxia and/or hypoactivity were observed in a few rats or mice exposed to 5,000 ppm. Overall, the 1,500 and 5,000 ppm rats and the 5,000 ppm female mice showed increased body weights and/or body weight gain during the study. Liver weights relative to body weight were observed in rats of both sexes and the 5,000 ppm female mice; however, no corresponding microscopic changes were noted in the liver. Histopathological evaluation showed a slight increase in the size and frequency of hyaline droplets in the kidneys of the isopropanol-exposed rats. Excluding the clinical signs of CNS depression, which will be discussed in the next study, the NOAEL for this study is 5,000 ppm (Burleigh-Flayer *et al.*, 1994). [Kl. score = 1]

In a subchronic neurotoxicity study, male and F344 rats were exposed by inhalation to 0, 100, 500, 1,500, or 5000 ppm for 13 weeks. Neurobehavioral evaluations included a functional observation battery (FOB), motor activity, and neuropathology. Effects of narcosis were observed in the 5,000 ppm groups only. There were no changes in FOB, but increased motor activity was noted in 5,000 female rats at weeks 9 and 13. Neuropathological examination revealed no exposure-related lesions in the nervous system. The NOAEL for acute effects is 500 ppm, and the NOAEL for subchronic neurotoxicity is 1,500 ppm (Burleigh-Flayer *et al.*, 1994). [Kl. score = 1]

An additional subchronic neurotoxicity study was conducted to clarify the increased motor activity findings in the previous study by Burleigh-Flayer et al. (1994). Female F344 rats were exposed to 0 or 5,000 ppm of isopropanol vapor for 6 hours/day, 5 days/week. Half of the animals in each group were exposed for 9 consecutive weeks and the other half for 13 consecutive weeks. After 9 weeks of exposure, the motor activity effect was reversible within 2 days after the last exposure. Subtle differences in the shape of the motor activity versus test session time curve were noted in both the 9-week and the 13-week exposed animals, although it was unclear whether these changes were treatment-related. Complete reversibility of these changes did not occur until 1 and 6 weeks after the last exposure in the 9- and 13-week exposure groups, respectively (Burleigh-Flayer *et al.*, 1998). [Kl. score = 2]

Male and female CD-1 mice were exposed by inhalation to 0, 500, 2,500, or 5,000 ppm isopropanol vapor 6 hours/day, 5 days/week for 18 months. An additional group of mice (all exposure levels) were assigned to a recovery group which were exposed to isopropanol for 12

months and then retained until study termination at 18 months. Survival was similar across all groups. Clinical signs were noted in the 5,000 ppm animals and included hypoactivity, lack of a startle reflex, ataxia, prostration, and narcosis. Some of the animals in the 2,500 ppm group also showed hypoactivity, lack of a startle reflex, and narcosis. Ataxia was the only exposure-related clinical sign that was noted for the 5,000 ppm animals following exposure. There was a concentration-related increase in body weights and body weight gain in both the 2,500 and 5,000 ppm animals (both sexes). There were no exposure-related changes in the hematological parameters at the 12- and 18-month time points. At study termination, there was a concentration-related increase in liver weights in the females, with the 5,000 ppm females being statistically significant. Nonneoplastic lesions were limited to the testes (males) and the kidney. In the testes, enlargement of the seminal vesicles occurred in the absence of associated inflammatory or degenerative changes. The kidney effects included tubular proteinosis and/or tubular dilatation. The incidence of testicular and kidney effects was not increased in the isopropanol-exposed recovery animals. The NOAEL is 500 ppm (Burleigh-Flayer *et al.*, 1997).

Male and female Fischer 344 rats were exposed to 0, 500, 2,500, or 5,000 ppm isopropanol vapor 6 hours/day, 5 days/week for 24 months. The mortality rates for all male rats were 82, 83, 91, and 100% for the 0, 500, 2500, and 5000 ppm groups, respectively. The corresponding values for the female rats were 54, 48, 55, and 69%. The main cause of death for the 5000 ppm rats (both sexes), as well as for much of the mortality of the 2500 ppm male rats, was chronic progressive nephropathy. Clinical signs were seen in the 5,000 ppm animals and included hypoactivity, lack of a startle reflex, and narcosis. Some of the 2,500 ppm animals also showed a lack of a startle reflex. Body weight of the 5,000 ppm animals showed an initial decrease; from Weeks 6-72, body weights and body weight gain were increased. A similar pattern was seen in the 2,500 ppm males. Liver weights were increased in the $\geq$2,500 ppm male at 18 months, in the 2,500 ppm males at 24 months, and in the 5,000 ppm females at 24 months. Kidney weights were increased in the 5,000 ppm males at 18 months and in the 5,000 ppm females at 24 months. Isopropanol exposure resulted in impaired kidney function, as indicated by various urine chemistry changes in male (2500 and 5000 ppm) and female (5000 ppm) rats. Animals in these groups also exhibited histopathological effects in the kidneys which appeared to be an exacerbated form of chronic progressive nephropathy. The NOAEL is 500 ppm (Burleigh-Flayer *et al.*, 1997). [Kl. score = 1]

Genotoxicity

The results of the *in vitro* genotoxicity studies on isopropanol are presented below in Table 1.

Table 1: *In Vitro* Genotoxicity Studies on Isopropanol

Test System	**Results***		**Klimisch Score**	**Reference**
	-S9	**+S9**		
Bacterial reverse mutation (*S. typhimurium* TA98, TA100, TA1535, TA1537)	-	-	2	Abbondandolo *et al.* (1980)
Bacterial reverse mutation (*S. typhimurium* TA97, TA98, TA100,	-	-	2	Zeiger *et al.* (1992)

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
TA102, TA104, TA1535, TA1537, TA1538)				
Sister Chromatid Exchange (V79 cells)	-	-	2	Von der Hude *et al.* (1987)
Mammalian cell gene mutation (CHO/HGPRT)	-	-	1	Kapp, Jr. *et al.* (1993)
Adenovirus (SA7) cell transformation (Syrian hamster embryo cells)	NA	-	2	Heidelberger *et al.* (1983)

*+, positive; -, negative; NA, not applicable

Male and female ICR mice were given a single intraperitoneal injection of 0, 350, 1,173, or 2,500 mg/kg isopropanol. There were no increases in micronuclei in the bone marrow polychromatic erythrocytes at the 24, 48, or 72 hour post-dosing time points at any dose level (Kapp, Jr. *et al.*, 1993). [Kl. score = 1]

Carcinogenicity

Oral

No studies are available.

Inhalation

The carcinogenic potential of isopropanol was evaluated via inhalation using three strains of mice. Male mice were exposed to 7.5 ppm of isopropanol for 3 to 7 hours/day, 5 days/week for 5 to 8 months. Animals were killed at either 8 or 12 months. There was no significant increase in the number of lung tumors observed (Weil *et al.*, 1952). [Kl. score = 3]

Male and female CD-1 mice were exposed by inhalation to 0, 500, 2,500, or 5,000 ppm isopropanol vapor for 6 hours/day, 5 days/week for 18 months. An additional group of mice (all exposure levels) were assigned to a recovery group which were exposed to isopropanol for 12 months and then retained until study termination at 18 months. There was no increased frequency of neoplastic lesions in any of the isopropanol-exposed animals (Burleigh-Flayer *et al.*, 1997). [Kl. score = 1]

Male and female Fischer 344 rats were exposed to 0, 500, 2500, or 5000 ppm of isopropanol vapor for 6 h/day, 5 days/week for 24 months. The mortality rates for all male rats were 82, 83, 91, and 100% for the 0, 500, 2,500, and 5,000 ppm groups, respectively. The corresponding values for the female rats were 54, 48, 55, and 69%, respectively. The main cause of death for the 5000 ppm rats (both sexes), as well as for much of the mortality of the 2500 ppm male rats, was chronic progressive nephropathy. The only neoplastic lesion noted was increased interstitial (Leydig) cell adenomas in male rats. The frequency of these tumors, although

elevated above the control animals, was within the historical control range of the testing facility and within the range reported for control animals from the National Toxicology Program carcinogenicity studies (Burleigh-Flayer *et al.*, 1997). [Kl. score = 1]

Reproductive Toxicity

In a two-generation reproductive toxicity study, Sprague–Dawley rats were dosed by oral gavage with 0, 100, 500, or 1,000 mg/kg isopropanol. There were seven parental deaths that were considered treatment-related: two high-dose F_0 females, two F_1 high-dose females, one mid-dose F_0 female, and two low-dose F_1 males. Lactation body weight gain was increased in the 500 and 1000 mg/kg females in both generations, and liver and kidney weights were increased in the 500 and 1,000 mg/kg groups in both sexes. Centrilobular hepatocyte hypertrophy was noted in some 1,000 mg/kg F_1 males. There were some kidney effects in the 500 and 1000 mg/kg F_0 males and in all treated F_1 male rats. The kidney effects were characterized by an increased number of hyaline droplets in the convoluted proximal tubular cells, epithelial degeneration and hyperplasia, and proteinaceous casts. Increased mortality occurred in the high-dose F_1 offspring during the early postnatal period; no other clinical signs of toxicity were observed in the offspring from either generation. Offspring body weight, however, in the 1,000 mg/kg group was reduced during the early postnatal period. There was significant mortality in the F_1 weanlings (18/70) before the selection of the F_1 adults. A statistically significant reduction was observed in the F_1 male mating index of the 1,000 mg/kg group (73 versus 97% in the controls). There were no other treatment-related effects on reproduction, including fertility and gestational indices, or histopathology of the reproductive organs. Allen et al. (1998) calculated a benchmark dose level of 420 mg/kg-day (lower bound) on dose associated with a 5% response rate for the decrease in the male mating index (Bevan *et al.*, 1995). [Kl. score = 1]

In a one-generation reproductive/embryotoxicity study, male and female Wistar rats were given 0, 0.5, 1.0, or 2.0% isopropanol in their drinking water. The calculated intakes for males were 383, 686 and 1107 mg/kg-day (pre-mating) and 347, 625 and 1030 mg/kg-day (18 weeks of treatment). The calculated intakes for females were 456, 835 and 1206 mg/kg-day (premating); 668, 1330 and 1902 mg/kg-day (gestation); and 1053, 1948 and 2768 mg/kg-day (postpartum). An immediate, statistically significant dose-dependent decrease occurred in water intake in the male rats. Intake was reduced ~5-14% (1% group; premating period) and ~30% (2% group; days 7-11 to end of study). Overall mean feed consumption was significantly lower in treated versus control animals. Male body weights (2% only) were reduced throughout the study. Water consumption was initially reduced in the 1% and 2% females, but the 2% group recovered to only ~70% of the control values (premating); it continued to be reduced during the gestation and lactation period. Mean maternal body weights were reduced (all treated groups) at the start of gestation, with partial recovery during the gestation period except for the 2% group. Overall weight gain during gestation in these groups were similar to the controls. Following parturition from PND 4 onward, the 2% dams had significantly lower body weights. There were no infertile males in any group, and no treatment-related effect on female fertility or on length of gestation. The number of pups/litter on GD 1 was reduced in the 2% group; because it was not replicated in the embryotoxicity portion, an increase in pup mortality during parturition or GD 0, followed by cannibalism of the dead pups by the dam was suggested. No macroscopic abnormalities were seen in females; nor was there any treatment-related histopathological changes seen in the reproductive tissue in the 2% parental animals. Absolute kidney weight and relative kidney, liver, and spleen weights were increased in the 2% F_0 males; increased absolute liver and kidney weights and relative liver weights in the 2% F_0 females. In

the embryotoxicity portion, there was a statistically significant increase in the total number of pre-implantation losses in the 2% animals. Whole body edema was seen in 40% of the fetuses in 3/8 litters in the 2% group. No macroscopic abnormalities of the viscera of these fetuses were detected, and the incidence of edema was not related to gender. In the one-generation portion, postnatal pup survival and in the average pup weight (by PND 7) were decreased in the 2% group. F_1 generation animals of both sexes showed increased relative liver weights at all dose levels, and the 2% males had higher relative kidney weights. A slight but significant decrease in absolute brain weight and increase in relative empty cecum weights in both sexes of the 2% F_1 generation group. No treatment-related gross abnormalities were observed in the F_1 generation animals at necropsy. The NOAEL for reproductive toxicity is 2% in drinking water, the highest dose tested (BIBRA, 1988). [Kl. score = 1]

The effects of isopropanol (2.5% in drinking water) on the reproduction and growth of rats was assessed in a multigenerational study. No reproductive toxicity was observed. The NOAEL for reproductive toxicity is 2.5% isopropanol in drinking water (Lehman *et al.*, 1945). [Kl. score = 4]

Isopropanol was administered as a 3% solution in drinking water to Wistar rats. Reduced parental body weight gain, food, and water consumption was observed in the treated animals compared with the controls. Fertility, litter size, and pup weights at postnatal days 4 and 21 were reduced in treated animals compared with the controls. In the second generation, the isopropanol concentration was reduced to 2%, and there were essentially no effects (Gallo *et al.*, 1977). [Kl. score = 4]

Developmental Toxicity

Oral

Isopropanol was given at concentrations of 0, 0.5, 1.25, or 2.5% in the drinking water to female Wistar rats on GD 6 to 16. The calculated intakes of isopropanol during GD 6-16 were 596, 1242 and 1605 mg/kg-day. There was an immediate reduction in water intake in the 2.5% dose group, and this was statistically significant throughout the treatment period when compared to controls. A smaller reduction in water intake was also seen in the 1.25% females (statistically significant during GD 6-9), with no change in the 0.5% females. Palatability of the drinking water may have been the problem since water intake significantly increased the first day following the end of the treatment period for all dose groups. Feed consumption patterns paralleled the water consumption during and after treatment in the mid- and high-dose groups. Overall, mean body weights of the 2.5% females were lower than the controls from GD 7 to termination. Effects on weight gain in the 0.5% and 1.25% females were limited to a failure to gain weight during the first (0.5%) and second (1.25%) day of treatment. There were no treatment-related effects in post-implantation loss, mean number of implantation sites or live fetuses. There was a slight dose-dependent decrease in mean litter weight and a significant decrease in mean fetal weight in the 1.25% and 2.5% groups. A statistically significant increase in variations was observed, indicative of a lower degree of ossification in the treated animals There was a dose-dependent decrease in the number of fetuses with the 4^{th} sacral arch and a dose-dependent increase in the number of fetuses with less than 2 caudal arches. The sternum also showed reduced ossification because there were increased numbers of fetuses with small, absent, or incompletely ossified sternebrae. The NOAEL for maternal and developmental toxicity is 596 mg/kg-day (BIBRA, 1987). [Kl. score = 1]

In a rat developmental study, female Sprague–Dawley rats were dosed by oral gavage with either 0, 400, 800, or 1200 mg/kg of isopropanol during gestational days 6 to 15. Two dams (8%) died at 1200 mg/kg and one dam (4%) died at 800 mg/kg. At 1200 mg/kg, maternal body weights were reduced throughout gestation (GS 0-20; 89.9% of control value), associated with reduced gravid uterine weight. There were no other treatment-related effects on the dams. Fetal body weights per litter were also significantly reduced at the 800 and 1200 mg/kg dose levels, but there were no teratogenic effects. The NOAEL for maternal and developmental toxicity is 400 mg/kg-day, respectively (Tyl *et al.*, 1994). [Kl. score = 1]

In a rabbit developmental study, female New Zealand white rabbits were dosed by oral gavage with either 0, 120, 240, or 480 mg/kg of isopropanol during gestational days 6 to 18. At 480 mg/kg, isopropanol was unexpectedly toxic to pregnant female rabbits, resulting in the deaths of four does (26%). Maternal body weights were significantly reduced during treatment (gestational days 6–18) and were associated with reduced maternal food consumption during this period. Profound clinical signs were noted at 480 mg/kg and included flushed and/or warm ears, cyanosis, lethargy, and labored respiration. No adverse maternal effects were noted at 120 or 240 mg/kg. There were no developmental or teratogenic effects at any dose tested. The NOAELs for maternal and developmental toxicity are 240 and 480 mg/kg-day, respectively (Tyl *et al.*, 1994). [Kl. score = 1]

Isopropanol was given by oral gavage to Sprague–Dawley rats from gestational days 6 to 21 in doses of 0, 200, 700, or 1200 mg/kg. The dams were allowed to deliver, litters were culled on postnatal day (PND) 4, pups were weaned on PND 22, and their dams were killed. Weaned pups were assessed for day of testes descent or vaginal opening, motor activity, auditory startle, and active avoidance. The pups were killed on PND 68. Some of the pups were taken from each dose group and were perfused in situ for pathological examination of the central nervous system. There were no biologically significant findings in the behavioral tests, no changes in organ weights, and no pathological findings of note. Thus, there was no evidence of developmental neurotoxicity from isopropanol exposure (Bates *et al.*, 1994). [Kl. score = 1]

Inhalation

Pregnant female Sprague Dawley rats were exposed to 0, 3,500, 7,000, or 10,000 ppm isopropanol for 7 hours/day during gestational days 1–19. The animals showed unsteady gait and narcotization during initial exposures in the mid- and high-dose groups; reduced food consumption and reduced weight gain were also noted in both the mid- and high-dose groups. Fetal body weights per litter were reduced in all dose groups. Exposure to 10,000 ppm also resulted in failure of implantation, fully resorbed litters, increased resorptions per litter, and increased incidence of cervical ribs. The NOAEL for maternal toxicity is 3,500 ppm. The LOAEL for developmental toxicity is 3,500 ppm; a NOAEL was not established (Nelson et al., 1988). [Kl. score = 2]

Derivation of Toxicological Reference and Drinking Water Guidance Values

The repeated-dose toxicity studies on isopropanol by the oral route are inadequate for the purposes of risk assessment. There is, however, a well-conducted two-generation reproductive toxicity study, in which rats were dosed by oral gavage up to 1,000 mg/kg-day (Bevan *et al.*, 1995). Allen *et al.* (1998) calculated a benchmark dose level of 420 mg/kg-day (lower bound on dose associated with a 5% response rate for the decrease in the male mating index). The

Point of Departure (POD) of 420 mg/kg-day will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 10
UF_D (database uncertainty) = 1

Oral RfD = 420/(10 x 10 x 1 x 10 x 1) = 420/1000 = <u>0.4 mg/kg-day</u>

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (0.4 x 70 x 0.1)/2 = <u>1.4 mg/L</u>

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Toxicity Profile

Methanol
(CAS No. 67-56-1)

Toxicokinetics/Metabolism

Several reviews on the metabolism and pharmacokinetics of methanol are available (Kavet and Nauss, 1990; Liesivuori and Savolainen, 1991; Tephly, 1991; IPCS, 1997; OECD, 2004a,b). Methanol is first oxidized to formaldehyde. This initial metabolic step involves different enzymes in rats than in primates and humans, although the rates are similar. A catalase–peroxidase system is primarily responsible for the initial step in rats, whereas alcohol dehydrogenase plays a major role in humans and monkeys. Methanol oxidation can also occur via hepatic microsomal oxidation involving the cytochrome P450 system.

Formaldehyde is converted to formic acid, which is converted to formate and a hydrogen ion. Conversion to formic acid is a two-step process, the second step is irreversible. In the first reaction, formaldehyde combines with reduced glutathione (GSH) to form S-formylglutathione. This is mediated by an NAD-dependent formaldehyde dehydrogenase. In the second reaction, thiolase catalyzes the hydrolysis of S-formylglutathione to form formic acid and GSH. A folate-dependent pathway in the liver is responsible for formate metabolism in both rats and primates. Formate first forms a complex with tetrahydrofolate (THF) that is sequentially converted to 10-formyl-THF (by formyl-THF synthetase) and then to CO2 (by formyl-THF dehydrogenase). THF is derived from folic acid in the diet and is also regenerated in the folate pathway. Although the folate pathway metabolizes formate in both rats and monkeys, rats use the pathway more efficiently.

The dermal uptake rate of liquid methanol applied to the forearm of human volunteers was 11.5 $mg/cm^2/hr$ (Dutkiewicz et al., 1980). The dermal flux for methanol in human skin (epidermis) *in vitro* is 8.29 $mg/cm^2/hr$ (Schueplein and Blank, 1971). When 12 human volunteers immersed one hand into a vessel containing neat methanol for up to 16 min, the maximum methanol concentration in blood was reached 1.9 $\pm$ 1.0 hr after exposure. Delivery rates from the skin into blood lagged exposure by 0.5 hours, and methanol continued to enter the blood for 4 hours following exposure. The average derived dermal absorption rate absorption rate was 8.1 $\pm$ 3.7 $mg/cm^2/hr$. The authors calculated that the maximum concentration of methanol in blood following immersion of one hand in methanol for approximately 20 min is comparable to that reached following inhalation exposures to 200 ppm methanol (Batterman and Franzblau, 1997).

Acute Toxicity

The acute oral LD_{50} for rats range from 6,200 to 13,000 mg/kg (Kimura et al., 1971; Welch and Slocum, 1943; Deichman and Mergard, 1948; Smyth et al., 1941). The acute dermal LD_{50} for rabbits was reported to be 20 mL/kg (Rowe and McCollister 1982). The inhalation 4- and 6-hour LC_{50} values in rats are 128.2 and 87.5 mg/L, respectively (BASF, 1980a,b). Sublethal doses, however, produce CNS effects and ocular injury that may result in blindness. This effect has been seen in primates, but not in rodents, and has been attributed to the differences in blood levels of the metabolite, formic acid.

Methanol is metabolized to formate, which is considered to be the ultimate toxicant in acute methanol intoxication in humans. Acute methanol toxicity in humans is characterized by CNS depression, followed by acidosis and ocular injury. Generally, transient CNS effects appear above methanol levels of 200 mg/L and serious ocular symptoms appear above 500 mg/L (OECD, 2004a,b). This blood concentration can transiently be achieved in an adult person (70 kg) by ingestion of 0.4 ml methanol/kg (approximately 0.32 mg/kg). The minimal acute methanol dose to humans that can result in death is considered to be 300 to 1,000 mg/kg by ingestion, and fatalities have occurred in untreated patients with initial methanol blood levels in the range of 1500-2000 mg/L (OECD, 2004a,b). However, such high blood methanol levels able to cause death are not likely to be achieved through inhalation exposure.

Irritation

Methanol is not irritating to the skin of rabbits (BASF, 1975), but it is slightly irritating to the eyes of rabbits (BASF, 1975).

Sensitization

Methanol was not considered a skin sensitiser to guinea pigs (BASF, 1979).

Repeated Dose Toxicity

Oral

Male and female Sprague–Dawley rats were dosed by oral gavage with 0, 100, 500, or 2,500 mg/kg of methanol for 90 days. There were no differences in body weight gain and food consumption between treated and control animals. Brain weights were decreased in both sexes in the 2,500 mg/kg dose group. Elevated serum glutamic pyruvate transaminase and alkaline phosphatase were noted in the 2,500 mg/kg dose group, but there were no adverse treatment-related effects in the gross pathology and histopathological evaluation. The NOAEL is 500 mg-kg-day (USEPA, 1986).

Sprague-Dawley rats were given in their drinking water 0, 500, 5,000 or 20,000 ppm methanol for 104 weeks, and then the animals were maintained until natural death. The study was conducted by the Ramazzini Foundation which uses their own testing guideline for carcinogenicity studies and not an internationally accepted guideline. Treatment with methanol did not decrease survival. However, there was considerable early mortality; by 18 months, 30% of the male controls had died. In females, there were no differences in survival between controls and treated groups. There was still more early mortality in the females than expected, but it was less pronounced than the males. There was no obvious effect of methanol exposure on water consumption. The 20,000 ppm males and females weighed more than the controls (up to 14% and 7%, respectively) throughout the study. The 5,000 ppm females also weighed more (4%) than the controls at 24 months, but not at earlier time points. There were no body weight differences between the remaining treatment groups and the controls. The calculated methanol doses based on water intake were: 0, 55, 542, and 1,840 mg/kg-day for males; and 0, 67, 630, and 2,250 mg/kg-day for females. Nearly all rats in all dose groups had some pathology in the lung. The finding of lung pathology was consistent regardless of the age at death (not an old age response). The lung pathology included inflammation, dysplasia, or tumours). Lung pathology was present in 70-100% of the first 10% of deaths in each group, including controls (70, 80, 80, 100% in males; and 90, 90, 100, 100% in females at 0, 500, 5,000, and 20,000

ppm). The degree of inflammation in the lungs is difficult to assess because no other lung information was recorded for the rats when a neoplasm in the lung was recorded (Soffritti et al., 2002; Cruzan, 2009; USEPA, 2013a). [Kl. score = 3]

Inhalation

Cynomolgus monkeys or Sprague–Dawley rats were exposed by inhalation to 0, 500, 2,000, or 5,000 ppm (0, 660, 2,620, or 6,552 mg/m3) methanol for 6 h/day, 5 days/week for 4 weeks. There was no mortality and no clinical signs of toxicity among the monkeys, but there a few signs of eye and nose irritation in the rats. No differences were seen between treated and control groups in body weight gain and organ weights, with the exception being decreased absolute adrenal weight in the 5,000 ppm female monkeys and increased relative spleen weights in the 2,000 ppm female rats. These changes were not considered by the authors to be of biological significance. There were no treatment-related effects on the ophthalmoscopy, gross pathology or histopathology. The NOAEL for this study is 5,000 ppm (6,552 mg/m^3) (Andrews et al., 1987). [Kl. score = 4]

Groups of four male rats were exposed by inhalation to 0, 200, 2000, or 10,000 ppm (0, 262, 2,621, or 13,104 mg/m3) methanol for 6 hours/day, 5 days/week for 1, 2, 4, or 6 weeks. Additional groups of animals were exposed for 6 weeks followed by a 6-week recovery period. Evaluation of a number of parameters including lung weights, surfactant levels, and enzyme activities did not reveal any adverse effects on the lung. No histopathological examinations were performed (White et al. 1983). [Kl. score = 2]

Male and female F344 rats were exposed by inhalation to 0, 10, 100, or 1,000 ppm methanol 19.5 hours/day, 7 days/week for 104 weeks. The average methanol doses were: 0, 3.7, 37, and 369 mg/kg-day in males; and 0, 5.9, 60, and 599 mg/kg-day for females. There were no treatment-related clinical signs and no effect on survival or food consumption. Lower body weights were seen in the 1,000 ppm females beginning around day 259, but after day 574, there was no difference from controls. Body weights in males were similar across all groups. There were no treatment-related effects on urinalysis, hematology, or clinical biochemistry, nor was there any treatment-related effects on organ weights or gross lesions. Histopathologic examination showed no statistically significant differences between treated and control animals (NEDO, 1985a). [Kl. score = 2]

Male and female B6C3F1 mice were exposed by inhalation to 0, 10, 100, or 1,000 ppm methanol 19.5 hours/day, 7 days/week for 78 weeks. The average methanol doses were: 0, 9.8, 95, and 947 mg/kg-day in males; and 0, 8.1, 106, and 1,071 mg/kg-day for females. There were no treatment-related clinical signs and no effect on survival or body weight. Food consumption was decreased slightly between months 7 and 12 in the 1,000 ppm females. Urinalysis, hematology, and clinical biochemistry were similar across all groups. No differences were seen in organ weights, gross lesions, or histopathology between treated and control mice. (NEDO, 1985b). [Kl. score = 2]

Genotoxicity

In Vitro Studies

Methanol was not mutagenic to *Salmonella* strains TA97, TA98, TA100, TA1535, TA1537, and TA1538 in *in vitro* bacterial mutation assays with or without metabolic activation (De

Flora et al., 1984a, b; Florin et al., 1980; Gocke et al.,1981). Equivocal results were obtained with *Salmonella* strain TA102 in the presence of metabolic activation (De Flora et al. 1984b). Methanol was not mutagenic in a DNA-repair test using various strains of *Escherichia coli* WP2 (De Flora et al. 1984a) and in a forward mutation assay using *Schizosaccharomyces pombe* (Abbondandolo et al. 1980).

Methanol did not induce micronuclei in Chinese hamster lung V79 cells in vitro (Lasne et al., 1984). Methanol was mutagenic in the mouse lymphoma assay in the presence of metabolic activation (McGregor et al., 1985), but it was not mutagenic in a Basc test or in a Drosophila, sex-linked, recessive lethal mutation assay (Gocke et al., 1981). Treatment of primary cultures of Syrian golden hamster embryo cells with methanol did not lead to cell transformation (Heidelberger et al., 1983).

In Vivo Studies

Male C57BL/6J mice were exposed by inhalation 0, 800 or 4,000 ppm methanol, 6 hours/day for five days. There were no increased frequencies of micronuclei in blood cells; sister chromatid exchanges, chromosomal aberrations, or micronuclei in lung cells; or synaptosomal complex damage in spermatocytes (Campbell et al., 1991).

Normal or folate-deficient mice were given four daily intraperitoneal injections of up to 2,500 mg/kg of methanol. There was no increase in micronucleated erythrocytes in the treated mice compared to the controls (O'Loughlin et al., 1992).

Male and female NMRI mice were given a single intraperitoneal injection of 0, 1,920, 3,200, or 4,480 mg/kg methanol. There was no increase in micronuclei was observed in the bone marrow at any dose level (Gocke et al., 1981).

Carcinogenicity

The carcinogenicity studies conducted on methanol were reviewed by Cruzan (2009) and by the USEPA (2013a).

Oral

Male and female SD rats were given in their drinking water 0, 500, 5,000, or 20,000 ppm methanol for 104 weeks. This study was conducted by the Ramazzini Foundation, which uses a unique methodology and not the standardized international testing guidelines. There was excessive early mortality, and lung pathology (inflammation, dysplasia, or tumours) was present in 87 to 94% of those dying anytime during the study. An increase in lympho-immunoblastic lymphomas was reported (Soffritti et al., 2002; Cruzan, 2009; USEPA, 2013a). [Kl. score = 3]

Inhalation

Male and female F344 rats were exposed by inhalation to 0, 10, 100, or 1,000 ppm methanol 19.5 hours/day, 7 days/week for 104 weeks. The average methanol doses were: 0, 3.7, 37, and 369 mg/kg-day in males; and 0, 5.9, 60, and 599 mg/kg-day for females. There was no increase in tumours in the methanol-exposed rats and mice (NEDO, 1985a). [Kl. score = 2]

Male and female B6C3F1 mice were exposed by inhalation to 0, 10, 100, or 1,000 ppm methanol 19.5 hours/day, 7 days/week for 78 weeks. The average methanol doses were: 0, 9.8, 95, and 947 mg/kg-day in males; and 0, 8.1, 106, and 1,071 mg/kg-day for females. There was no increase in tumours in the methanol-exposed mice (NEDO, 1985b). [Kl. score = 2]

Reproductive/Developmental Toxicity

The reproductive and developmental toxicity studies were reviewed by the NTP Centre for Evaluation of Risks to Human Reproduction (NTP-CERHR, 2003). Conflicting results have been obtained concerning the effect of methanol on testicular hormones in rats; nevertheless, methanol does not appear to a male reproductive toxicant. The primate data indicates that methanol is unlikely to be a reproductive hazard in females. Methanol causes developmental effects at very high exposure levels in both rats (≥ 10,000 ppm) and mice (≥ 2000 ppm); there is also some evidence that it is a developmental neurotoxicant in rodents, but not in primates.

NICNAS concluded in their human health Tier II assessment for methanol: "Based on the data available, [methanol] is not considered to have reproductive or developmental toxicity in humans."

Derivation of Toxicological Reference and Drinking Water Guidance Values

A 90-day oral gavage rat study showed elevated serum enzymes and decreased brain weights in the 2,500 mg/kg-day dose group with a NOAEL of 500 mg/kg-day (USEPA, 1986). The NOAEL of 500 mg/kg-day will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 10
UF_D (database uncertainty) = 1

Oral RfD = 500/(10 x 10 x 1 x 10 x 1) = 500/1000 = 0.2 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD: Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)

Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2 L (ADWG, 2011)

Drinking water guidance value = (0.5 x 70 x 0.1)/2 = 1.8 mg/L

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Toxicity Profile

N-benzyl-alkylpyridium chloride
(CAS No. 68909-18-2)

Acute Toxicity

The oral LD_{50} in rats is 50.1 mg/kg (HPVIS) [Kl. score = 2]. There are no acute inhalation or dermal toxicity studies on N-benzyl-alkylpyridium chloride.

Irritation

No studies are available. However, N-benzyl-alkylpyridium chloride is considered corrosive based on its pH of 1.2 (ECHA).

Sensitization

No studies are available.

Repeated Dose Toxicity

No studies are available.

Genotoxicity

The *in vitro* genotoxicity studies on N-benzyl-alkylpyridium chloride are presented below in Table 1.

Table 1: *In vitro* Genotoxicity Studies on N-benzyl-alkylpyridium chloride

Test System	**Results***		**Klimisch Score**	**Reference**
	-S9	**+S9**		
Bacterial reverse mutation (*S. typhimurium* strains	-	-	1	ECHA
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	-	-	1	ECHA
Chromosomal aberrations (human lymphocytes)	-	-	1	ECHA

* - negative, + positive

Carcinogenicity

No studies are available.

Reproductive/Developmental Toxicity

No studies are available.

Derivation of Toxicological Reference and Drinking Water Guidance Values

No data are available on N-benzyl-alkylpyridium chloride to derive oral toxicological reference and drinking water guidance values.

References

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

HPVIS. The U.S. EPA High Production Volume Information System: https://iaspub.epa.gov/oppthpv/public_search.html_page.

Toxicity Profile

Pine oil
(CAS No. 8002-09-3)

Acute Toxicity

The oral LD_{50} in rats is 2,700 mg/kg (EPA, 2006). The inhalation LC_{50} in rats is >3.67 mg/L (EP, 2006). The dermal LD_{50} in rats is >2,000 mg/kg (EPA, 2006).

Irritation

Pine oil is irritating to the skin and eyes of rabbits. (EPA, 2006).

Sensitization

No studies are available.

Repeated Dose Toxicity

A 90-day dermal toxicity study has been conducted on pine oil, but the details are unavailable (EPA, 2006).

Genotoxicity

Pine oil was not mutagenic or genotoxic in a bacterial reverse mutation assay and a mouse micronucleus assay (EPA, 2006).

Carcinogenicity

No studies are available.

Reproductive/Developmental Toxicity

In a rat developmental toxicity study, the maternal LOAEL was 600 mg/kg based on clinical observations of toxicity and decreased body weight, body weight gain and food consumption. The developmental LOAEL was 600 mg/kg based on decreased fetal weight, fetal malformations, and retardation of ossification. The NOAEL for maternal and developmental toxicity is 50 mg/kg-day (EPA, 2006).

Derivation of Toxicological Reference and Drinking Water Guidance Values

The only study available for the derivation of an oral reference dose and a drinking water guidance value is a rat developmental toxicity study (EPA, 2006). The NOAEL of 50 mg/kg-day for maternal and developmental toxicity will be used for determining the oral reference dose.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 3
UF_D (database uncertainty) = 1

Oral RfD = 50/(10 x 10 x 1 x 3 x 1) = 50/300 = 0.17 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (0.17 x 70 x 0.1)/2 = 0.6 mg/L

References

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

U.S. EPA (2006). Reregistration Eligibility Decision for Pine Oil, Office of Prevention, Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Available at: https://www3.epa.gov/pesticides/chem_search/reg_actions/reregistration/red_PC-067002_2-Oct-06.pdf.

Toxicity Profile

Polyoxyethylene Nonylphenol Ether
[Nonylphenol, ethoxylated]
(CAS No. 9016-45-9)

Acute Toxicity

The oral LD_{50} in the mouse is 4,290 mg/kg (ECHA) [Kl. score = 2]. No acute inhalation or dermal toxicity studies are available.

Irritation

Nonylphenol ethoxylates are moderately to severely irritating. However, nonylphenol ethoxylates with an ethylene oxide (EO) chain of $\geq$ 30 are slightly irritation or non-irritating (Talmage, 1994).

In studies involving the instillation of 0.1 mL of an undiluted nonylphenol ethoxylate solution to the eyes of rabbits, nonylphenol ethoxylates with chains of 2 to 15 were moderately to severely irritating. Nonylphenol ethoxylates with EO chains of $\geq$30 were non-irritating (ECHA) [Kl. score = 2].

Sensitization

Nonylphenol ethoxylate with an EO chain of 6 was not considered a skin sensitizer in a guinea pig maximization test (ECHA) [Kl. score = 2].

Repeated Dose Toxicity

No data are available.

Genotoxicity

Nonylphenol ethoxylates with EO chains of 9 and 30 were not mutagenic to *S. typhimurium* strains TA 1535, TA 1537, TA 98, and TA 100 in the absence or presence of metabolic activation (ECHA) [Kl. score = 2].

Carcinogenicity

No studies are available.

Reproductive Toxicity

No studies are available.

Developmental Toxicity

No studies are available.

Derivation of Toxicological Reference and Drinking Water Guidance Values

An oral reference dose and a drinking water guidance value were not derived because of lack of data.

References

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

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Toxicity Profile

Potassium carbonate
(CAS No. 584-08-7)

Acute Toxicity

The oral LD_{50} in rats is >2,000 mg/kg (ECHA) [Kl. score = 2].

The inhalation 4.5-hr LC_{50} is >4.96 mg/L. Approximately 3% of the particles were <1 μm and 38% <1 μm. The mass median aerodynamic diameter (MMAD) was approximately 3.6 1 μm (ECHA) [Kl. score = 2].

The dermal LD_{50} in rabbits is >2,000 mg/kg (ECHA) [Kl. score = 2].

Irritation
Application of 0.5 g. potassium carbonate to the skin of rabbits for 24 hours under occlusive conditions was not irritating (ECHA) [Kl. score = 2].

Instillation of 0.1 mL into the eyes of rabbits was irritating (ECHA) [Kl. score = 2].

Sensitization

Potassium carbonate was not considered to be a skin sensitizer in a guinea pig Buehler test (ECHA) [Kl. score = 2].

Repeated Dose Toxicity

There are no repeated dose toxicity studies on potassium carbonate. However, there are repeated dose toxicity studies on potassium hydrogencarbonate ($KHCO_3$, CAS No. 298-14-6).

Male and female Wistar rats were fed in their diet 0, 2, or 4% potassium hydrogencarbonate for 4 weeks. The estimated daily intakes are 0, 2,944, and 6,054 mg/kg-day for males; and 0, 2,902, and 6,137 mg/kg-day for females. The few treatment-related effects were considered to be due to the physiological adaptation to a very high ion intake and were considered to be of no toxicological significance. The NOAEL is 4% in the diet, which corresponds to 6,054 and 6,137 mg/kg-day for males and females, respectively (Lina et al., 1994; Lina and Kuijpers, 2004; ECHA) [Kl. score = 2].

Male and female Wistar rats were fed in their diet 0, 2, or 4% potassium hydrogencarbonate for 13 weeks. The estimated daily intakes are 0, 2,046, and 4,326 mg/kg-day for males; and 0, 2,294, and 4,879 mg/kg-day for females. The few treatment-related effects were considered to be due to the physiological adaptation to a very high ion intake and were considered to be of no toxicological significance. The NOAEL is 4% in the diet, which corresponds to 4,326 and 4,879 mg/kg-day for males and females, respectively (Lina et al., 1994; Lina and Kuijpers, 2004; ECHA) [Kl. score = 2].

Male and female Wistar rats were fed in their diet 0, 2, or 4% potassium hydrogencarbonate for 30 months. The estimated daily intakes are 0, 1,285, and 2,667 mg/kg-day for males; and

0, 1,576, and 3,331 mg/kg-day for females. The rats adapted relatively easily to the feeding of these very high doses and were free of treatment-related adverse effects that are relevant to humans. Most treatment-related changes seen were an expression of the physiological adaptation to the very high ion intake and is regarded as of no toxicological relevance. The NOAEL is 4% in the diet, which corresponds to 2,667 and 3,331 mg/kg-day for males and females, respectively (Lina et al., 1994; Lina and Kuijpers, 2004; ECHA) [Kl. score = 2].

Genotoxicity

The *in vitro* genotoxicity studies on potassium carbonate are presented below in Table 1.

Table 1: *In vitro* Genotoxicity Studies on Potassium Carbonate

Test System	**Results***		**Klimisch Score**	**Reference**
	-S9	**+S9**		
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	ECHA
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	ECHA
Chromosomal aberrations (Chinese hamster lung cells)	-	-	2	ECHA

*, - negative, + positive

Carcinogenicity

Male and female Wistar rats were fed in their diet 0, 2, or 4% potassium hydrogencarbonate for 30 months. The estimated daily intakes are 0, 1,285, and 2,667 mg/kg-day for males; and 0, 1,576, and 3,331 mg/kg-day for females. In the urinary bladder, significant pre-neoplastic and neoplastic histopathologic epithelial alterations were seen, which are common findings in rats after long-term high-dose alkali intakes. The relevance to humans of pre-neoplastic or neoplastic urinary bladder findings in rats induced by high-dose alkali intakes (e.g., as counterions in food additives like artificial sweetener or flavor enhancer) and associated by alkalinization of the urine, elevated urine volumes, altered urine electrolytes composition with or without renal pelvic mineralization of urine precipitation which leads to a cytotoxic effect on the bladder epithelium with consequent regenerative proliferation and ultimately tumors (Lina et al., 1994; Lina and Kuijpers, 2004; ECHA) [Kl. score = 2].

Reproductive Toxicity

No studies are available.

Developmental Toxicity

Pregnant female Wistar rats were dosed by oral gavage with 0, 1.8, 8.4, 38.8, or 180 mg/kg potassium carbonate on gestational days 6 to 15. There was no indication of maternal or developmental toxicity at any dose level. The NOAEL for maternal and developmental toxicity is 180 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 2].

Derivation of Toxicological Reference and Drinking Water Guidance Values

Potassium carbonate is used in many countries (e.g., U.S. and EU) as a food additive. It is regarded as a Generally Recognized as Safe (GRAS) substance in food with no limitation other than current good manufacturing practice (OECD, 2004a,b).

Therefore, a toxicological reference value was not derived for potassium carbonate.

The Australian drinking water guideline values for pH may be applicable (ADWG, 2011).

References

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

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OECD (2004b). SIDS Initial Assessment Report on the Ethylene Glycol Category: Ethylene Glycol (CAS No. 107-21-1), Diethylene Glycol (CAS No. 111-46-6), Triethylene Glycol (CAS No. 112-27-6), Tetraethylene Glycol (CAS No. 112-60-7), Pentaethylene glycol (CAS No. 4792-15-8).

Toxicity Profile

Potassium chloride
(CAS No. 7747-40-7)

Potassium chloride (KCl) dissociates completely in aqueous solutions to potassium (K^+) and chloride (Cl^-) ions. Potassium chloride and its dissociated ions are ubiquitous in the environment.

Toxicokinetics/Metabolism

Potassium chloride dissociates completely in aqueous solutions to potassium (K^+) and chloride (Cl^-) ions. Potassium is an essential nutrient: it has a number of critical roles, one of which is that it is the principal cation involved in maintaining the osmotic balance of bodily fluids (Ganong, 1995). Both potassium and chloride ions are involved in regulating the acid-base balance of the body (Ganong, 1995).

Acute Toxicity

The oral LD_{50} in rats was reported to be 3,020 mg/kg (Boyd and Shanas, 1961) [Kl. score = 2]. No acute toxicity studies by the dermal or inhalation route were identified.

Irritation

Potassium chloride did not produce an irritant response in an *in vitro* skin irritation (OECD TG 439) test (ECHA). [Kl. score = 1]

Potassium chloride did not produce an irritant response in an *in vitro* eye irritation test (ECHA). [Kl. score = 2]

Sensitization

No studies are available.

Repeated Dose Toxicity

Male F344/Slc rats were given 0, 0.25, 1, 5, or 5% potassium chloride in their feed for two years. The mean daily intake was calculated to be 0, 110, 450, or 1,820 mg/kg-day, respectively. At the end of the study, survival rates were 48%, 64%, 58%, and 84% in the respective dose groups. Nephritis was predominant in all groups, including the controls. The only treatment-related effect was gastritis (inflammation of the stomach lining). The incidence of gastritis and ulcers were 6%, 18%, 18%, and 30% in the 0, 110, 450, and 1,820 mg/kg-day groups, respectively. The gastritis was thought to be indicative of a localised effect due to the irritating nature of the test material. The NOAEL for systemic effects is 1,820 mg/kg-day, the highest dose tested. (Imai et al., 1986; OECD 2001a,b). [Kl. score = 2]

Male and female Wistar rats were fed diets containing 0 or 3% potassium chloride over a total period of 30 months. Due to the reduction of feed intake the mean test substance intake and mean body weight decreased in time. The mean daily intake of potassium chloride was not

calculated. There was hypertrophy of the zona glomerulosa in the adrenals (24/50 treated rats versus 4/50 in controls); and cystitis in the urinary bladder (males: 3/59; females 3/50) and single epithelial hyperplasia of the bladder (males 3/50; females 2/50) (Lina and Kuijpers, 2004). [Kl. score = 2]

Genotoxicity

Potassium chloride was not mutagenic to *Salmonella typhimurium* strains TA100, TA 1535, TA 1537 and TA 98 strains in an *in vitro* bacterial mutation assay in the absence or presence of metabolic activation (Mortelmans et al., 1986).

Potassium chloride was weakly mutagenic in two separate L5178Y mouse lymphoma assays (Myhr and Caspary,1988; Mitchell et al., 1988). It was mutagenic at 4,000 and 5,000 µg/ml in the presence of metabolic activation in one study, and mutagenic at 7,000 µg/ml in the absence of metabolic activation. The authors stated that these responses are due to high salt concentrations which affect the ionic balance and osmotic pressure of the medium, inducing mutations in cells surviving the treatment.

Potassium chloride induced a significant increase in chromosomal aberrations in Chinese Hamster lung fibroblasts (V79) cells only at the highest test dose (12,000 µg/ml) in the absence of a metabolic activation system. Measurements of the osmotic pressure of the medium showed a two-fold increase at this test compound concentration when compared to the normal medium (530 mOsmol/kg versus 253 mOsmol/kg) (OECD, 2001b).

There are two other reports on the effect of potassium chloride on the formation of chromosome aberrations in Chinese hamster ovary cells (CHO). In these studies potassium chloride concentrations of 75 and 80 mM (approximately 5,500 and 6,000 µg/ml) resulted in 19% and 28% aberrant cells, respectively. An increased number of chromosome aberrations was observed with potassium chloride concentrations that reduced cell survival of 40% or more. The increases in mutagenicity and chromosome aberrations observed in these studies have been considered to be related to cytotoxicity resulting from the high potassium chloride concentrations used (Brusick, 1988).

The reported mutagenic effect of potassium chloride most probably results from a disruption of the osmotic balance of cells with a subsequent interference with chromosomal stability. This may result in the clastogenic effects (DNA breakage and chromosome structural instability) due to K^+ effects on sequestering of Mg^{++} ions required for normal maintenance of chromatin integrity (OECD, 2001b).

No *in vivo* genotoxicity studies on potassium chloride were located.

Carcinogenicity

F344/Slc male rats were given 0, 110, 450, or 1,820 mg/kg-day potassium chloride in feed for two years. At the end of the study, survival rates were 48%, 64%, 58%, and 84% in the 0, 110, 45, and 1,820 mg/kg/day groups. There was no increased incidence of tumours that were considered to be treatment-related (Imai et al., 1986). [Kl. score = 2]

Male and female Wistar rats were fed diets containing 0 or 3% potassium chloride over a total period of 30 months. There were no treatment-related differences in tumour response among the groups (Lina and Kuijpers, 2004). [Kl. score = 2]

Reproductive Toxicity

No studies are available.

Developmental Toxicity

Pregnant Wistar rats were given doses of 3.1 to 310 mg/kg potassium chloride by oral gavage during gestation days 5 through 15. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity is 310 mg/kg-day, the highest dose tested (OECD, 2001a,b). [Kl. score = 2]

Pregnant CD-1 mice were given doses of 2.35 to 235 mg/kg potassium chloride by oral gavage during gestation days 5 through 15. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity is 235 mg/kg-day, the highest dose tested (OECD, 2001a,b). [Kl. score = 2]

Derivation of Toxicological Reference and Drinking Water Guidance Values

Two chronic rat feeding studies have been conducted on potassium chloride: only the study by Imai et al. (1986) was conducted with multiple doses and provided mean daily intake values. In this study, the only treatment-related effects were associated with chronic irritation in the gastrointestinal tract (gastritis and ulcers), a localised effect due to the irritating properties of the test material. No systemic toxicity was observed at any of the doses tested. The NOAEL for systemic toxicity in this study is 1,820 mg/kg-day, the highest dose tested. The NOAEL of 1,820 mg/kg-day will be used for determining the oral Reference Dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:

UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subacute to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 4(10 x 10 x 1 x 1 x 1) = 1,820/100 = 18 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD:

Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (18 x 70 x 0.1)/2 = 63 mg/L

Australian Drinking Water Guidelines

The Australian drinking water guideline value for chloride is 250 mg/L based on aesthetics (ADWG, 2011).

References

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Toxicity Profile

Potassium hydroxide
(CAS No. 1310-58-3)

Potassium hydroxide (KOH) is a strong alkaline substance that dissociates completely in water to potassium (K^+) and hydroxyl (OH^-) ions.

Toxicokinetics/Metabolism

Potassium hydroxide dissociates completely in aqueous solutions to potassium (K^+) and hydroxyl (OH^-) ions. Potassium is an essential nutrient involved in fluid and electrolyte balance and is required for normal cellular function (Ganong, 1995). Potassium is a major extracellular cation in the body; the total body content is tightly regulated (Ganong, 1995).

Acute Toxicity

The oral LD_{50} values in rats was determined to be 333 mg/kg by the conventional method and 388 mg/kg by the up-and-down method (Bruce, 1987; ECHA) [Kl. score = 2]. In another study, the oral LD_{50} in fasted rats was 365 mg/kg (Johnson et al., 1975; ECHA) [Kl. score = 2]. Acute toxicity studies were not identified for the inhalation and dermal route.

Irritation

No adequate skin irritation studies are available for potassium hydroxide; potassium hydroxide is expected to be similar to sodium hydroxide (NaOH). Animal studies have shown that an 8% NaOH solution is corrosive to the skin. In humans, 0.5 to 4% NaOH concentrations produced skin irritation; and, based on the results of two different human patch tests, a NaOH solution that is slightly less than 0.5% would be non-irritating to human skin (OECD, 2002).

In rabbit eye tests, a 5-minute exposure to 5% KOH was extremely irritating and corrosive; a 5-minute exposure to 1% KOH was irritating; a 24-hour exposure to 0.1% KOH was marginally irritating; and a 24-hour exposure to 0.1% KOH was not irritating (Johnson et al., 1975; ECHA). [Kl. score = 2]

Sensitization

Potassium hydroxide was not considered to be a skin sensitizer in a guinea pig sensitization test. The induction and challenge dose were 0.1% (Johnson et al., 1975; ECHA). [Kl. score = 2]

Repeated Dose Toxicity

No studies are available.

Genotoxicity

KOH was not mutagenic to S. typhimurium strains TA97 and TA102 with or without metabolic activation (ECHA) [Kl. score = 2].

Carcinogenicity

No adequate studies are available.

Reproductive/Developmental Toxicity

No studies are available.

Derivation of Toxicological Reference and Drinking Water Guidance Values

No repeated dose, reproductive, and developmental toxicity studies have been conducted on KOH. Thus, a toxicological reference value was not derived for KOH.

The Australian drinking water guideline values for pH of 6.5 to 8.5 may be applicable (ADWG, 2011).

References

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Toxicity Profile

Potassium persulfate
(CAS No. 7727-21-1)

Acute Toxicity

The oral LD_{50} is 1,130 mg/kg in rats (ECHA) [Kl. score = 2]. The inhalation 1-hour LC_{50} in rats is >242.9 mg/L (ECHA) [Kl. score = 2]. The dermal LD_{50} in rats is >10,000 mg/kg (ECHA) [Kl. score = 1].

Irritation

Application of potassium persulfate to the skin of rabbits (application time and conditions unspecified) was not irritating. The mean of the 24 and 72 hours scores were 0.00 for both erythema and edema (ECHA) [Kl. score = 2].

Studies in humans indicate that persulfates have the potential for skin irritation (NICNAS, 2001). Calnan and Schuster (1963) reported skin irritation in a human patch test with 5% ammonium persulfate. Jordan (1998) reported that a mixture with 17.5% persulfates (ammonium, potassium, and sodium) induced skin irritation in human subjects from patches applied under occlusive conditions.

Instillation of potassium persulfate into the eyes of rabbits was considered non-irritating. The mean of the 24, 48, and 72 hours scores were: 0.00 for corneal opacity; 0.00 for iridial lesions; and 0.00 for conjunctival redness (ECHA) [Kl. score = 2].

Sensitization

Potassium persulfate was considered a skin sensitizer in mouse local lymph node assay (ECHA) [Kl. score = 1].

Human exposure to persulfates have been linked to a variety of skin and respiratory complaints indicative of sensitization. The complaints consist of immediate and delayed contact hypersensitivity, contact urticarial, rhinitis, bronchitis, and asthma (NICNAS, 2001).

Repeated Dose Toxicity

Oral
Male and female CR-CD rats were fed in their diet 0, 100, 316, or 1,000 ppm potassium persulfate for 28 days. The estimated daily intakes are 0, 13, 41, and 132 mg/kg-day. There were no treatment-related effects. The NOAEL is 132 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 2].

Male and female CR strain rats were fed in their diet 0, 300, 1,000 or 3,000 ppm sodium persulfate for 90-days. On day 48 of the study, the dietary concentration of the group receiving 1,000 ppm was increased to 5,000 ppm for the remainder of the study. Body weights was decreased in the two highest dose groups during the last six weeks of treatment. There were no treatment-related effects on urinalysis, clinical chemistry or hematology parameters.

Histopathological findings were limited to the 3,000 ppm group only and consisted of necrosis and atrophy of the gastrointestinal tract epithelial lining. The absence of the gastrointestinal lesions in the group receiving 1,000 ppm for 8 weeks, followed by 5000 ppm for 5 weeks, indicates that the lesions are related both to concentration in diet (dose) and length of exposure. A clear NOAEL for this study is 300 ppm, which is estimated to be 22 mg/kg-day. Another NOAEL may be the 1,000 ppm dietary group for an 8-week exposure period. (ECHA; OECD, 2005a,b). [Kl. score = 2]

Inhalation

Male and female SD rats were exposed (whole-body) by inhalation to 0, 5, 10.3, or 25 mg/m^3 ammonium persulfate dust, 6 hours/day, 5 days/week for 13 weeks. Additional groups of animals were exposed for 13 weeks, followed by either a 4- or 13-week recovery period. The MMAD was 2.5, 2.7, and 2.5 µm for the 5, 10, and 25 mg/m^3 groups, respectively. No deaths occurred during the study that were considered to be exposure-related. The 25 mg/m^3 animals showed increased respiration rates, as well as a few of the 25 mg/m^3 animals. This clinical sign disappeared during the first few weeks of the recovery period. Body weights of the 25 mg/m^3 animals were significantly lower during most of the exposure period; by the end of the recovery period the body weights were comparable to the controls. Lung weights were increased in the 25 mg/m^3 animals at the end of the 13-week exposure period but were similar to controls after 6 weeks in the recovery period. Histopathologic changes indicative of irritation was seen in the trachea and bronchi/bronchioles in the 25 mg/m^3 animals; these lesions were not seen after 6 weeks in the recovery period. The NOAEL for this study is 10.3 mg/m^3 (ECHA). [Kl. score = 1]

Genotoxicity

There are no available genotoxicity studies on potassium persulfate. The *in vitro* genotoxicity studies on sodium persulfate are presented below in Table 1.

Table 1: *In vitro* Genotoxicity Studies on Sodium Persulfate

Test System	**Results***		**Klimisch Score**	**Reference**
	-S9	**+S9**		
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	1	ECHA
Unscheduled DNA synthesis (rat hepatocytes)	NA	-	1	ECHA

*+, positive; -, negative; NA, not applicable

In vivo Studies

Sodium persulfate did not induce micronuclei in the bone marrow cells of male and female mice given a single intraperitoneal injection of 0, 85, 169, or 338 mg/kg sodium persulfate (ECHA) [Kl. score = 2].

Carcinogenicity

No carcinogenicity studies are available for potassium persulfate.

A 51-week dermal study in female SENCAR mice exposed to 0.2 ml of a 200 mg/mL solution of ammonium persulfate showed that ammonium persulfate is neither a tumor promoter nor a complete carcinogen when applied to the skin (OECD, 2005a,b; ECHA). [Kl. score = 2]

Reproductive/Developmental Toxicity

No reproductive or developmental toxicity studies are available for potassium persulfate.

A reproductive and developmental toxicity screening study (OECD 421) has been conducted on ammonium persulfate. Male and female Crl:CD (SD)GS BR rats were fed in their diet 0, 40, 100, or 250 mg/kg ammonium persulfate. In the parental animals, there was no treatment-related mortality, clinical signs, body or organ weight changes, or effects seen in gross necropsy. There were no effects on reproductive performance, fertility, fetal anomalies, fetal viability, spermatogenesis, spermatogenic cycle. The NOAEL for reproductive and developmental toxicity and parental toxicity is 250 mg/kg-day, the highest dose tested (ECHA). [Kl. score = 1]

Derivation of Toxicological Reference and Drinking Water Guidance Values

Toxicological reference values were not derived. Potassium persulfate dissociates in water to potassium and persulfate ions. The persulfate ions will further hydrolyze to sulfate ions.

The Australian drinking water guideline value for sulfate is 500 mg/L based on health. Concentrations of >500 mg/L can have purgative effects. There is also an Australian drinking water guideline value for sulfate of 250 mg/L based on aesthetics; it is the taste threshold (ADWG, 2011).

References

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Pang, S., and Fiume, M.Z. (2001). Cosmetics Ingredient Review: Final Report on the Safety Assessment of Ammonium, Potassium, and Sodium Persulfate. Intl. J. Toxicol. 20(Suppl 3): 7-21.

Toxicity Profile

Potassium sorbate
(CAS No. 24634-61-5)

Acute Toxicity

The oral LD_{50} of sorbic acid to rats is 10,500 mg/kg (ECHA) [Kl. score = 2]. The dermal LD_{50} of sorbic acid to rats was >2,000 mg/kg (ECHA) [Kl. score = 1]. There are no reliable acute inhalation toxicity studies.

Irritation

Application of 0.15 mL potassium sorbate (in saline) to the skin of rabbits for 4 hours under semi-occlusive conditions was not irritating. The mean of the 24, 48, and 72 hour scores were 0.00 for both erythema and edema (ECHA) [Kl. score = 1].

Instillation of 100 mg potassium sorbate to the eyes of rabbits was irritating (ECHA) [Kl. score = 1].

Sensitization

Sorbic acid was not considered a skin sensitizer in a guinea pig maximization test (ECHA) [Kl. score = 2].

Repeated Dose Toxicity

Male and female SD rats were fed in their diet 0, 25,000, 50,000, or 100,000 ppm sorbic acid for 28 days. There were no overt clinical signs of toxicity, nor mortalities, no treatment-related effects on feed consumption. A reversible trend of slightly reduced mean body weight gains was seen in the high-dose group, which was attributed to the palatability of the dosed feed. There were no treatment-related effects on the hematology and blood serum parameters, urinalysis, gross pathology, or histopathology. The NOAEL is 100,000 ppm in the diet, the highest dose tested, which is estimated to be 9,200 and 8,600 mg/kg-day for males and females, respectively (ECHA) [Kl. score = 1].

Male and female SD rats were fed in their diet 0, 25,000, 50,000, or 100,000 ppm sorbic acid for 90 days. There were no overt signs of toxicity, no mortalities, no treatment-related effects on feed consumption. Body weights were initially lower in the high-dose males and returned to normal by week 5. In females, body weights were slightly to moderately increased in all dose groups. In both sexes, feed intake was constantly lower compared to the controls, indicating weight compensation or even over-compensation because of the relatively high caloric substitution from sorbic acid in the diet. The clinical pathology and organ weight data indicated sex-specific metabolic involvement of sorbic acid during the elimination process, which involved lipid metabolism, transport proteins and liver weights in females, but not in males. In males, the only clinical pathology finding was a slight increase in ALP isoenzyme activity, suggesting a different metabolic pathway in males. It is important to note that none of these metabolic changes identified in the clinical pathology and organ weight evaluation in either sex resulted in any histopathologic changes. It was concluded that the findings due to

the test compound-induced metabolic changes were not toxicologically important. The NOAEL for this study was considered to be 100,000 ppm in the diet, the highest dose tested, which is estimated to be 6,800 and 7,200 mg/kg-day for males and females, respectively (ECHA) [Kl. score = 1].

Male and female Wistar rats were fed in their diets 0, 1.5, or 10% sorbic acid for two years. A decrease in body weight gain was seen in the high-dose animals; but the difference was small and was considered associated with some reduction in feed intake. Feed consumption and compound intake was similar between treated and control animals. There were no changes in hematological and clinical chemistry parameters that were considered treatment-related. Relative liver weights were significantly increased in the high-dose animals. Relative kidney, small intestine, and gonad weights were significantly increased in the high-dose females. Histopathologic examination showed changes in the high-dose females; these changes were an increase in focal fatty change, a statistically significant decreased incidence of bile-duct hyperplasia, and a statistically significantly increased incidence of focal necrosis. The fatty change could have resulted from an increased intake of fatty acids. The focal necrosis may have been an indication of an incidental infection, probably of viral origin. In the high-dose males, a statistically significant decreased incidence of increased extramedullary hematopoiesis in the spleen and a decrease of hemosiderin in the spleen was observed. The NOAEL for this study is 1.5% in the diet, which is estimated to be 750 mg/kg-day (Gaunt et al., 1975; ECHA) [Kl. score = 2]

Male and female ASH/CSI mice were fed in their diets 0, 1, 5, or 10% sorbic acid for 80 weeks. There were slightly lower body weights in the high-dose animals, increased relative kidney weights in the mid- and high-dose groups, and increased relative liver weights in all treated groups. There were not treatment-related effects on survival; and the histopathologic examination showed no changes attributed to treatment. The NOAEL for this study is 1% in the diet, which is estimated to be 1,300 mg/kg-day (Hendy et al., 1976; ECHA).

Genotoxicity

The *in vitro* genotoxicity studies on potassium sorbate are presented below in Table 1.

Table 1: *In vitro* Genotoxicity Studies on Potassium Sorbate

Test System	**Results***		**Klimisch Score**	**Reference**
	-S9	**+S9**		
Bacterial reverse mutation (*S. typhimurium* strains	-	-	2	ECHA
Bacterial reverse mutation (*S. typhimurium* strains	-	-	2	ECHA
Mammalian cell gene mutation (HGPRT, CHO cells)	-	-	2	ECHA
Chromosomal aberrations (CHL cells)	-	-	2	ECHA

*+, positive; -, negative

Male and female NMRI mice were dosed by oral gavage with 0, 500, 1,500, or 5,000 mg/kg sorbic acid. There were no increases in the frequency of micronucleated polychromatic erythrocytes in the bone marrow of treated mice compared to the controls (ECHA) [Kl. score = 2].

Male and female NMRI mice were dosed by oral gavage with 0, 500, 1,500, or 5,000 mg/kg sorbic acid. There were no increases in sister chromatid exchanges in bone marrow cells of treated mice compared to the controls (ECHA) [Kl. score = 2].

Carcinogenicity

Male and female Wistar rats were fed in their diets 0, 1.5, or 10% sorbic acid for two years. There were no treatment-related increases in tumor incidences (Gaunt et al., 1975; ECHA) [Kl. score = 2].

Male and female ASH/CSI mice were fed in their diets 0, 1, 5, or 10% sorbic acid for 80 weeks. There were no treatment-related increases in tumor incidences (Hendy et al., 1976; ECHA) [Kl. score = 2].

Reproductive Toxicity

A two-generation reproductive toxicity study has been conducted on sorbic acid. Male and female Crj: CD(SD) rats were dosed by oral gavage with 0, 300, 1,000, or 3,000 mg/kg potassium sorbate. There was significantly reduced feed consumption in the 3,000 mg/kg males and females of the P and F_1 generation during the pre-mating period and in the 3,000 mg/kg females during the gestation and lactation period. The 1,000 mg/kg dams also showed a slight reduction in feed consumption during the pre-mating period (P and F_1 generation) and the gestation period (P generation). The reduced food intake was related to caloric substitution by the sorbic acid. The 3,000 mg/kg males of the P and F_1 generation had reduced body weight and body weight gain. A significant dose-related reduction in body weights of the F_1 pups was observed in the $\geq$1,000 mg/kg dose groups during the lactation period. The 3,000 mg/kg F_2 pups also showed significantly lower body weights, but this effect was not considered adverse, but related to the administration of an acid at a high dose (see findings from the 90-day dietary study). There were treatment-related deaths in the 3,000 mg/kg F_1 males and females. The animals in the 3,000 mg/kg group also had treatment-related clinical signs during the pre-mating period, which included lateral position, reduced motility, pilo-erection, and dyspnea. There were no treatment-related effects on male fertility parameters, estrus cycle length and normality, as well as reproductive performance. Cleavage of the balanopreputial gland and vaginal opening were marginally, but statistically significantly, delayed in the 3000 mg/kg F_1 pups selected for mating compared to the controls. The reduced anogenital distance found for the F_2 pups were related to the slightly reduced body weight of the F_2 pups during lactation and were thus not considered adverse. Gross pathologic and histopathologic examination did not show any treatment-related changes. Absolute brain weights were significantly reduced in the 3,000 mg/kg F_1 parental animals, and absolute adrenal weights were significantly reduced in the 3,000 mg/kg females. The 3,000 mg/kg F_1 weanlings of both sexes showed decreased absolute brain and spleen weights and reduced fasting body weights. The F_2 pups had decreased absolute spleen weights and reduced body weights at necropsy. The statistically significant reduction in food intake for the F_0 and F_1 dams at $\geq$1,000 mg/kg, in the presence of caloric substitution by sorbic acid was considered to be the cause of reduced body weight

development and slight developmental disturbances (morphological landmarks, learning and memory) of the ≥1,000 mg/kg F_1 and F_2 offspring during lactation. The reason for this effect is unknown, but nutritional deficiencies in the pups masked by caloric overcompensation in lactating females may be a possible reason. The NOAEL for reproductive toxicity is 3,000 mg/kg-day. The NOAEL for developmental toxicity is 1,000 mg/kg-day. The NOAEL for parental (P and F_1 generation) is 3,000 mg/kg-day (ECHA) [Kl. score = 1].

Developmental Toxicity

Pregnant female Wistar rats were dosed by oral gavage with up to 340 mg/kg potassium sorbate during gestational days 6 to 15. There was no indication of maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity is 340 mg/kg-day (ECHA) [Kl. score = 2].

Pregnant female CD-1 mice were dosed by oral gavage with up to 460 mg/kg potassium sorbate during 10 days of the gestational period (actual days were unspecified). There was no indication of maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity is 340 mg/kg-day (ECHA) [Kl. score = 2].

Derivation of Toxicological Reference and Drinking Water Guidance Values

The lowest NOAEL from the subchronic and chronic toxicity studies on sorbic acid is 750 mg/kg-day from the 2-year dietary study by Gaunt et al. (1975). The equivalent NOAEL for potassium sorbate is approximately 1,000 mg/kg-day, based on the molecular weights of sorbic acid (112.13 g/mol) and potassium sorbate (150.22 g/mol). The NOAEL of 1,000 mg/kg-day will be used to derive an oral reference dose and a drinking water guidance value for potassium sorbate.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 1,000/(10 x 10 x 1 x 1 x 1) = 1,000/100 = 10 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,

Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (10 x 70 x 0.1)/2 = 3.5 mg/L

References

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances

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Toxicity Profile

Quaternary Ammonium Compounds, bis(Hydrogenated Tallow Alkyl) Dimethyl, Salts with Bentonite
[Quaternium-18 Bentonite]
(CAS No. 68953-58-2)

Quaternary ammonium compounds, bis (hydrogenated tallow alkyl) dimethyl, salts with bentonite, also known as quaternium-18 bentonite, will be designated "2M(2Alk) bentonite".

2M(2Alk) bentonite is one of a group of organoclays composed of quaternary ammonium compounds (cations) that have the following general formula:

N+R1, R2, R3, R4

Where R1, R2, R3, and R4 are substitutions on the N (nitrogen atom) of the quaternary compound (salt) as follows:

Methyl – 1 or 2 substitutions
Benzyl – 0 or 1 substitutions
Alkyl (C14-22) – 1, 2 or 3 substitutions

The organoclays discussed in this dossier are hydrogenated tallowalkonium bentonites and are the product of the reaction of hydrogenated tallowalkonium chloride and bentonite. Bentonite is a widely distributed natural material consisting predominantly of the clay montmorillonite, a smectite clay. Bentonite is formed of highly colloidal and plastic clays and is produced by in-situ devitrification of volcanic ash (CIR, 2016).

Acute Toxicity

The oral LD_{50} for 2M(2Alk) bentonite is >8,000 mg/kg in rats (CIR, 1982) [Kl. score = 4]. The inhalation LC_{50} for 2M(2Alk) bentonite is >5.7 mg/L in rats for a 4-hr. 22-min. exposure. There were no mortalities, and the particle size was $\geq$ 10 μm, 30% $\leq$ μm (CIR, 2016) [Kl. score = 4]. No acute dermal toxicity studies are available.

Irritation

Application of 0.5 g. 2M(2Alk) bentonite to the skin of rabbits for 6 hours/day for five consecutive days, followed by 10 days of rest and then five more days of exposure, did not result in any signs of irritation (CIR, 1982) [Kl. score = 4].

Instillation of 0.1 mL of a 10% suspension of 2M(2Alk) bentonite in physiological saline produced no signs of irritation (CIR, 1982) [Kl. score = 4].

Sensitization

2M(2Alk) bentonite was not considered a skin sensitizer when tested in a guinea pig sensitization test (CIR, 1982) [Kl. score = 4].

Repeated Dose Toxicity

Oral

Rats were fed diets containing 0, 1%, 5%, or 25% 2M(2Alk) bentonite for 12 weeks. The 25% dietary group showed reduced food efficiency. There were no treatment-related effects seen in the hematology parameters, organ weights, gross pathology, or histopathology. The NOAEL is 5% in the diet, which corresponds to 2,500 mg/kg-day (CIR, 1982) [Kl. score = 4].

Dermal

Rabbits were administered to the skin under occlusive conditions 0.5 g 2M(2Alk) bentonite for 6 hours/day for 90 days. There was no evidence of local or systemic toxicity (CIR, 1982) [Kl. score = 4].

Genotoxicity

2M(2Alk) bentonite was not mutagenic to S. typhimurium strains TA98, TA100, TA1545, TA1537, and TA1538 in the absence or presence of metabolic activation (CIR, 2016) [Kl. score = 4].

Carcinogenicity

No studies are available.

Reproductive/Developmental Toxicity

No studies are available.

Derivation of Toxicological Reference and Drinking Water Guidance Values

2M(2Alk) bentonite has been tested in a rat 12-week dietary study. At the highest dietary dose of 25%, there was reduced food efficiency (CIR, 1982). There were no other treatment-related effects. The NOAEL for this study is 5% in the diet, which corresponds to 2,500 mg/kg-day. The NOAEL of 2,500 mg/kg-day will be used to derive an oral reference dose and drinking water guidance value for 2M(2Alk) bentonite.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 3
UF_D (database uncertainty) = 1

Oral RfD = 2,500/(10 x 10 x 1 x 3 x 1) = 2,500/300 = 8 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (8.3 x 70 x 0.1)/2 = 29 mg/L

References

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

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Toxicity Profile

Sodium benzoate
(CAS No. 532-32-1)

Acute Toxicity

The oral LD_{50} values in rats have been reported to be 3,140 mg/kg (OECD, 2001; ECHA) [Kl. score = 4]. The dermal LD_{50} in rabbits is >2,000 mg/kg (ECHA) [Kl. score = 2].

Irritation

Application of 0.5 g sodium benzoate to the skin of rabbits for 4 hours under semi-occlusive conditions was not irritating. The mean of the 24, 48, and 72 hours scores were 0.00 for both erythema and edema (ECHA) [Kl. score = 1].

Instillation of 60 mg sodium benzoate to the eyes of rabbits was irritating. The mean of the 24, 48, and 72 hour scores were: 0.00 for corneal opacity; 0.00 for iridial lesions; 2.45 for conjunctival redness; and 0.67 for chemosis. There were no signs of irritation by the end of the 14-day observation period (ECHA) [Kl. score = 1].

Sensitization

Benzoic acid was not considered to be a skin sensitizer in a guinea pig maximization test (OECD, 2001) [Kl. score = 2].

Repeated Dose Toxicity

Oral

Male and female Sherman rats were fed in their diet 0, 1, 2, 4, or 8% sodium benzoate for 90 days. In the 8% dietary group, there was increased mortality (4/8 died); reduced weight gain; increased liver and kidney weights; and pathological lesions (not specified). There were no adverse effects noted in the ≤4% dietary groups. The NOAEL for this study is 4% in the diet, which is estimated to be 3,145 mg/kg-day (OECD, 2001; ECHA) [Kl. score = 2]

Inhalation

Male and female CD rats were exposed by inhalation to 0, 25, 250, or 1,200 mg/m^3 benzoic acid dust aerosol for 6 hours/day, five days/week for over 4 weeks. The MMAD was 4.7 μm. At 25 mg/m^3, there was an increased incidence of interstitial cell infiltrate and interstitial fibrosis in the lungs of treated animals compared to the controls, with no dose-related response. At 250 mg/m^3, upper respiratory tract irritation and decreased absolute kidney weights were seen in the females. At 1,200 mg/m^3, one rat per six died and the body weight gain was decreased in both sexes. There was also a decrease in platelets (both sexes), absolute and relative liver weight (males), and trachea/lung (females). The NOAEL for systemic toxicity is 25 mg/m^3 (OECD, 2001; ECHA) [Kl. score = 2]

Dermal

Male and female New Zealand White rabbits were given dermal applications of 0, 100, 500, or 2,500 mg/kg benzoic acid 5 days/week for 21 days. There were no treatment-related effects on behavior, body weights, organ weights, clinical laboratory tests, or survival. A very slight dermal irritation was noted for 1/8 of the high-dose animals. The NOAEL for systemic toxicity is 2,500 mg/kg-day (OECD, 2001; ECHA) [Kl. score = 2].

Genotoxicity

The *in vitro* genotoxicity studies on sodium benzoate are presented below in Table 1.

Table 1: *In vitro* Genotoxicity Studies on Sodium Benzoate

Test System	**Results***		**Klimisch Score**	**Reference**
	-S9	**+S9**		
Bacterial reverse mutation (*S. typhimurium* and *E. coli* strains)	-	-	2	ECHA
Chromosomal aberrations (human embryonic lung cultures)	-	-	2	ECHA

*-negative, +positive

Male SD rats were dosed by oral gavage with 0, 50, 500, and 5,000 mg/kg sodium benzoate. There were no increases in chromosomal aberrations in bone marrow cells of treated mice compared to the controls (ECHA) [Kl. score = 2].

Carcinogenicity

Male and female F344 rats were fed in their diet 0, 1, or 2% sodium benzoate for 18 to 24 months. Survival was poor in all groups due to intercurrent sialodacryoadenitis and mycoplasma infections. There were no adverse clinical signs; body weights and body weight gain were similar between treated and control animals. The incidence of tumors was similar between the treated and control rats (OECD, 2001; ECHA) [Kl. score = 2].

Male and female Swiss mice were given in their drinking water 0 or 2% sodium benzoate from 5 weeks of age until death. The average daily intake was 6,200 and 5,960 mg/kg-day for males and females, respectively, based on daily water consumption. The incidence of tumors was similar between the treated and control mice (Toth et al., 1984; OECD, 2001) [Kl. score = 2].

Reproductive Toxicity

A multi-generation reproductive toxicity study has been conducted on benzoic acid. Male and female rats were fed in their diet 0, 0.5%, or 1% benzoic acid over four generations. The estimated average daily intake is 0, 375, or 750 mg/kg-day. The first generation was exposed for eight weeks and then allowed to mate. Mating was then repeated in week 48 for a second generation. The third generation was terminated after 16 weeks and examined histopathologically. The fourth generation was terminated after weaning of the pups. There was no indication of reproductive or developmental toxicity. The NOAEL for reproductive, developmental, and systemic toxicity is 1% in the diet, the highest dose tested, which is calculated to be 750 mg/kg-day (ECHA) [Kl. score = 2].

Developmental Toxicity

Pregnant female Wistar rats were dosed by oral gavage with up to 0, 1.75, 8, 38, or 175 mg/kg sodium benzoate on gestational days 6 to 15. There was no indication of maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity is 175 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 2].

Pregnant female CD-1 mice were dosed by oral gavage with 0, 1.75, 8, 38, or 175 mg/kg sodium benzoate on gestational days 6 to 15. There was no indication of maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity is 175 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 2].

Pregnant female Dutch-belted rabbits were dosed by oral gavage with 0, 2.5, 12, 54, or 250 mg/kg sodium benzoate on gestational days 6 to 18. There was no indication of maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity is 250 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 2].

Pregnant female golden hamsters were dosed by oral gavage with 0, 3, 14, 65, or 300 mg/kg sodium benzoate on gestational days 6 to 10. There was no indication of maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity is 300 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 2].

Derivation of Toxicological Reference and Drinking Water Guidance Values

The NOAEL from a 90-day rat dietary study on sodium benzoate is 3,145 mg/kg-day (ECHA). The NOAEL of 3,145 mg/kg-day will be used to derive an oral reference dose and drinking water guidance value for sodium benzoate.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 3
UF_D (database uncertainty) = 1

Oral RfD = 3,145/(10 x 10 x 1 x 3 x 1) = 3,145/300 = 10 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (10 x 70 x 0.1)/2 = 35 mg/L

References

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

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Toxicity Profile

Sodium bisulfite
(CAS No. 7631-90-5)

At environmental pHs, sodium bisulfite dissociates in water to form sodium ions (Na^+), bisulfite ions (HSO_3^-), sulfite ions (SO_2^{3-}), and sulfur dioxide (SO_2) which is a gas.

Acute Toxicity

No acute toxicity studies are available for sodium bisulfite.

The oral LD_{50} value in rats for sodium sulfite is 2,610 mg/kg (ECHA) [Kl. score = 2]. The oral LD_{50} values in rats for sodium metabisulfite are 1,420 mg/kg (males), 1,630 mg/kg (females), and 1,540 mg/kg (combined sexes) (ECHA) [Kl. score = 2].

The 4-hour inhalation LC_{50} in rats for sodium sulfite is >5.5 mg/L (ECHA) [Kl. score = 2].

The dermal LD_{50} in rats for sodium sulfite is >2,000 mg/kg (ECHA) [Kl. score = 2].

Irritation

No studies are available on sodium bisulfite.

Application of 0.5 mL of sodium sulfite to the skin of rabbits for 4 hours under occlusive conditions was minimally irritating. The mean of the 24, 48, and 72 scores were: 0.5 for erythema and 0.0 for edema (ECHA) [Kl. score = 2].

Instillation of 0.1 mL of sodium sulfite (with 0.5% cobalt sulfate) into the eyes of rabbits produced slight irritation. The mean of the 24, 48, and 72 hour scores are as follows: 0.5 for conjunctival redness; 0.5 for conjunctival chemosis; 0.0 for corneal lesions; and 0.0 for iridial lesions (ECHA) [Kl. score = 2].

Sensitization

No studies are available on sodium bisulfite.

Sodium bisulfite was not considered a skin sensitizer in a mouse local lymph node assay (ECHA) [K. score = 1].

Repeated Dose Toxicity

No studies are available on sodium bisulfite.

A study is available on sodium metabisulfite. Sodium metabisulfite dissociates in water to form sodium ions (Na^+), disulfite ions ($S_2O_5^{2-}$), and sulfur dioxide (SO_2). The disulfite ions can form bisulfite (HSO_3^-) and sulfite (SO_2^{3-}) ions; at neutral pH, a mixture of 50% sulfite (SO_3^{2-}) and 50% bisulfite (HSO_3^{2-}) ion is present.

Male and female Wistar rats were fed in their diet 0, 0.125, 0.25, 0.5, 1.0, or 2.0% sodium metabisulfite for up to two years and over three generations. The diet was enriched with thiamine to prevent thiamine deficiency as a result of sulfite-induced destruction of this vitamin. During storage up to the time of consumption, the losses of sulfite from the feed containing sodium metabisulfite at levels of 0.125, 0.25, 0.5, 1.0, and 2.0% averaged 22, 14,12, 8, and 4.5%, respectively, while the decrease in thiamine was 2.7, 1.7, 8.3, 14.5, and 15.4%, respectively. Addition of thiamine to the diet prevented thiamine deficiency in rats at all dose levels based on measurements of thiamine levels in the urine and liver. The general condition of the rats was good during the first 72 weeks in the F_0 generation, as well as the other two generations. After 72 weeks, there was a rapid increase in mortality in all groups. Survival in the treated groups were generally higher than the controls, except for the 2% F_1 males; no deaths occurred in the 2% F_2 females. A marginal reduction in body weight gain was observed in the 2% dose group (both sexes) in the F_1 and F_2 generations. Feed consumption was similar between treated and control groups. There were no changes in hematology and clinical chemistry parameters and urinalysis that were considered toxicologically significant. The $\geq$1% dietary groups had occult blood in their feces. Relative kidney weights were increased in the 2% F_2 females, but there were no pathological changes noted in the kidneys from this group. Hyperplastic changes in the fore- and glandular stomachs were noted in the $\geq$1% groups in all three generations. Some slight alterations were also noted in stomachs of the 0.5% F_2 rats. The NOAEL for systemic toxicity is 1.91% in the diet. This was estimated to be 955 mg/kg-day based on a rat body weight of 400 g and a daily feed intake of 20 g. The histopathologic effects on the stomach and the occult blood in feces are considered to be the result of localized irritation (a site-of-contact effect) from the ingestion of sodium metabisulfite (Til et al., 1972; ECHA). [Kl. score = 2]

Genotoxicity

No *in vitro* genotoxicity studies were located for sodium bisulfite. Table 1 presents the findings from *in vitro* genotoxicity studies conducted on structural analogues of sodium bisulfite.

Table 1: *In Vitro* Genotoxicity Studies on Structural Analogues to Sodium Bisulfite

Test System	**Test Substance**	**Results***		**Klimisch Score**	**Reference**
		-S9	**+S9**		
Bacterial reverse mutation (*S. typhimurium* strains)	Sodium metabisulfite	-	-	2	ECHA
Bacterial reverse mutation (*S. typhimurium* strains)	Potassium metabisulfite	-	-	2	ECHA
Bacterial reverse mutation (*S. typhimurium* strains)	Potassium metabisulfite	-	-	2	ECHA
Bacterial reverse mutation (*S. typhimurium* and *E. coli* strains)	Sodium metabisulfite	-	-	2	ECHA
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	Sodium metabisulfite	-	-	2	ECHA

Test System	Test Substance	Results*		Klimisch Score	Reference
		-S9	+S9		
Chromosomal aberration (human lymphocytes)	Sodium metabisulfite	-	-	1	ECHA

*+, positive; -, negative

Sodium bisulfite did not show a mutagenic response in a rat dominant lethal assay when given in feed at doses of 0, 4.5, 15, or 45 mg/kg-day (ECHA) [Kl. score = 2]. Sodium sulfite was not genotoxic in a bone marrow micronucleus test in rats. Male NMRI rats were given a single subcutaneous injection of 0, 250, 500, or 1,000 mg/kg sodium sulfite (ECHA) [Kl. score = 1].

Carcinogenicity

No studies are available on sodium bisulfite.

Male and female Wistar rats were fed in their diet 0, 0.125, 0.25, 0.5, 1.0, or 2.0% sodium metabisulfite for up to two years and over three generations. There was no increased incidence of tumors in the treated groups compared to the controls (Til et al., 1972) [Kl. score = 2].

Male and female ICR/JCL mice were given in their drinking water 0, 1, or 2% potassium metabisulfite for two years. There was no increased incidence of tumors in the treated groups compared to the controls (Tanaka et al., 1979) [Kl. score = 2].

Reproductive Toxicity

No studies are available on sodium bisulfite.

Male and female Wistar rats were fed in their diet 0, 0.125, 0.25, 0.5, 1.0, or 2.0% sodium metabisulfite for up to two years and over three generations. The diet was enriched with thiamine to prevent thiamine deficiency as a result of sulfite-induced destruction of this vitamin. During storage up to the time of consumption, the losses of sulfite from the feed containing sodium metabisulfite at levels of 0.125, 0.25, 0.5, 1.0, and 2.0% averaged 22, 14,12, 8, and 4.5%, respectively, while the decrease in thiamine was 2.7, 1.7, 8.3, 14.5, and 15.4%, respectively. Addition of thiamine to the diet prevented thiamine deficiency in rats at all dose levels based on measurements of thiamine levels in the urine and liver. The effects other than reproductive and developmental toxicity are discussed above in the Repeated Dose Toxicity section. There were no treatment-related effects on female fertility, the number of young per litter, or birth weight or mortality of the offspring. The number of F_{2a} pups was significantly reduced in the $\geq$0.5% groups during the first breeding cycle, but there was no dose-response and the reduction did not occur during the second breeding cycle. Slight growth retardation was observed in the F_1 and F_2 generation rats both before and after weaning. The NOAEL for reproductive toxicity is 1.91% in the diet. This was estimated to be 955 mg/kg-day based on a rat body weight of 400 g and a daily feed intake of 20 g (Til et al., 1972; ECHA). [Kl. score = 2]

Male and female rats were given sodium metabisulfite in their drinking water for up to 2.5 years and in three successive generations. The doses were 375 and 750 ppm as sulfur dioxide (SO_2). There was no evidence of systemic toxicity in either dose group. The number of

offspring of either the F_1 and F_2 generation and the proportion surviving to the end of lactation were similar between treated and control groups. The NOAEL for reproductive toxicity is 750 ppm (as SO_2) in drinking water. Assuming an average rat body weight of 400 g and a daily water intake of 28 mL, 750 ppm (as SO_2) corresponds to 53 mg/kg-day sodium metabisulfite (Lockett and Natoff, 1960; ECHA) [Kl. score = 2].

Developmental Toxicity

Pregnant female Wistar rats were dosed by oral gavage with up to 110 mg/kg-day sodium bisulfite during GD 6-15. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity for this study is 110 mg/kg-day (ECHA) [Kl. score = 2].

Pregnant female CD-1 mice were dosed by oral gavage with up to 150 mg/kg-day sodium bisulfite during GD 6-15. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity for this study is 150 mg/kg-day (ECHA) [Kl. score = 2].

Pregnant female Dutch-belted were dosed by oral gavage with up to 100 mg/kg-day sodium bisulfite during GD 6-18. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity for this study is 100 mg/kg-day (ECHA) [Kl. score = 2].

Derivation of Toxicological Reference and Drinking Water Guidance Values

No repeated dose toxicity studies have been conducted on sodium bisulfite. In a study conducted on sodium metabisulfite, there was no evidence of systemic toxicity in rats fed up to 2% for two years (Til et al., 1972). The NOAEL for this study is 2% or 955 mg/kg-day. Using the molecular weights of sodium metabisulfite (190.1 g/mol) and sodium bisulfite (104.1 g/mol), the NOAEL of 955 mg/kg-day for sodium metabisulfite is converted to 523 mg/kg-day for sodium bisulfite. The NOAEL of 523 mg/kg-day will be used for determining the oral reference dose (RfD) and the drinking water guidance value for sodium bisulfite.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 523/(10 x 10 x 1 x 1 x 1) = 523/100 = 5 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,

Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (5 x 70 x 0.1)/2 = 18 mg/L

The Australian drinking water guidance value for sodium is 180 mg/L based on aesthetics (ADWG, 2011).

References

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

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Toxicity Profile

Sodium erythrobate
(CAS No. 6381-77-7)

Acute Toxicity

The oral LD_{50} value in rats is >5,000 mg/kg (ECHA) [Kl. score = 2]. The dermal LD_{50} value in rabbits is >2,000 mg/kg (ECHA) [Kl. score = 2]. No acute inhalation studies are available.

Irritation

Application of 2,000 mg/kg sodium erythrobate to the skin of rabbits for 24 hours under occlusive conditions was not irritating (ECHA) [Kl. score = 2]. Instillation of 100 mg sodium erythrobate to the eyes of rabbits was not irritating (ECHA) [Kl. score = 2].

Sensitization

Sodium erythrobate was not considered a skin sensitizer in a mouse local lymph node assay (ECHA) [Kl. score = 1].

Repeated Dose Toxicity

Male and female B6C3F_1 mice were given in their drinking water 0, 0.625%, 1.25%, 2.5%, 5%, or 10% sodium erythrobate for 10 weeks. Mortality occurred in the 10% dose group: 6/10 males and 1/10 females by the end of week 1. There was hydropic degeneration of the renal tubular epithelium and marked atrophy of hepatocytes and splenic follicle cells in the $\geq$5% males and the 10% females. The NOAELs for this study is 2.5% and 5% in the drinking water for males and females, respectively (ECHA) [Kl. score = 2].

Male and female F344/DuCrj mice were given in their drinking water 0, 0.625%, 1.25%, 2.5%, 5%, or 10% sodium erythrobate for 10 weeks. All the rats in the 10% dose group did not drink the water and died in 2 to 5 weeks. In the 5% dose group, 3/10 males and 1/10 females died during the first 4 days of the study. Body weight gain was lower in the 2.5% group by 12% in males and 6% in females. There was no histopathologic examination, or clinical chemistry and hematology parameters measured. The NOAEL is 1.25% in drinking water (ECHA) [Kl. score = 3].

Genotoxicity

Sodium erythrobate was not mutagenic to *S. typhimurium* strains TA 1535, TA 1537, TA 98, and TA 100 with or without metabolic activation (ECHA) [Kl. score = 2]. There were no increases in chromosomal aberrations in Chinese hamster lung (CHL) cells when treated with sodium erythrobate in the presence or absence of metabolic activation (ECHA) [Kl. score = 2].

In a dominant lethal assay, male rats were given either a single oral gavage dose or 5 consecutive daily doses of sodium erythrobate (amount not specified). There was no evidence of mutagenicity (ECHA) [Kl. score = 2].

Carcinogenicity

B6C3F$_1$ mice were given sodium erythrobate in their drinking water for 96 weeks. The dose levels were 1.25% and 2.5% for males, and 2.5% and 5% for females. There were no differences in the incidence of tumors between the treated and control groups (ECHA) [Kl. score = 2].

F344/DuCrj mice were given sodium erythrobate in their drinking water for 96 weeks. The dose levels were 1.25% and 2.5% for both males and females. There were no differences in the incidence of tumors between the treated and control groups (ECHA) [Kl. score = 2].

Reproductive Toxicity

No studies are available.

Developmental Toxicity

Pregnant female Wistar rats were dosed by oral gavage with 0, 9, 41.8, 194, or 900 mg/kg sodium erythrobate on gestational days 6 to 15. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity is 900 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 2].

Pregnant female Wistar rats fed in their diet 0, 0.05, 0.5, or 5% sodium erythrobate on gestational days 7 to 14. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity is 5% in the diet, the highest dose tested (ECHA) [Kl. score = 2].

Pregnant female CD-1 mice were dosed by oral gavage with 0, 10.3, 47.8, 221.9, or 1,030 mg/kg sodium erythrobate on gestational days 6 to 15. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity is 1,030 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 2].

Derivation of Toxicological Reference and Drinking Water Guidance Values

The 10-week study in mice with the Kl. score of 2 will be used to derive the oral reference dose and drinking water guidance value. This study included a histopathologic study, whereas the other 10-week mouse study did not. The NOAEL for this study is 2.5% sodium erythrobate in drinking water (which is estimated to be 4,250 mg/kg-day) based on spleen, kidney, and liver effects in males in the 5% dose group.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 3
UF_D (database uncertainty) = 1

Oral RfD = 4,250/(10 x 10 x 1 x 3 x 1) = 4,250/300 = 14 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (14 x 70 x 0.1)/2 = 49 mg/L

References

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

Toxicity Profile

Sodium hydroxide
(CAS No. 1310-73-2)

Sodium hydroxide (NaOH) is a strong alkaline substance that dissociates completely in water to sodium (Na^+) and hydroxyl (OH^-) ions.

Acute Toxicity

There are no oral toxicity guideline studies on sodium hydroxide. An oral LD_{50} of a 1 to 10% solution of NaOH in rabbits was reported to be 325 mg/kg (expressed as 100% NaOH) (OECD, 2002a,b). Mortality was also observed when a 1% NaOH solution was dosed, but in this case, the applied volume was relatively high (24 mL per kg body weight) (OECD, 2002a,b).

Acute toxicity studies were not identified for the inhalation and dermal route.

Irritation

Animal studies have shown that an 8% NaOH solution is corrosive to the skin. In humans, 0.5 to 4% NaOH concentrations produced skin irritation; and, based on the results of two different human patch tests, a NaOH solution that is slightly less than 0.5% would be non-irritating to human skin (OECD, 2002a,b).

Results from animal eye irritation studies indicate that a 0.2-1.0% NaOH solution would be non-irritating, while 1.2 or >2% NaOH solutions would be corrosive (OECD, 2002a,b).

Sensitization

Male volunteers were exposed on the skin of their back to solutions of 0.063 to 1.0% NaOH in the induction phase of a human patch test. After 7 days the volunteers were challenged to a concentration of 0.125% NaOH. The irritant response correlated well with the concentration of NaOH, but an increased response was not observed when the previously patch tested sites were re-challenged. Based on this study, sodium hydroxide is not a skin sensitiser (OECD, 2002a,b; ECHA). [Kl. score = 2]

Repeated Dose Toxicity

There are no studies conducted by the oral and dermal route. An inhalation study was conducted in rats exposed to aerosols of solutions of NaOH ranging from 5% to 40%. Exposures were twice weekly (hours/day and total exposure days unspecified). All animals in the 40% solution group died within a month mostly from bronchopneumonia. At the lower concentrations, respiratory tract lesions were observed; an NOAEL was not identified (NIOSH, 1975).

Genotoxicity

Several *in vitro* studies have been conducted on NaOH (OECD, 2002a,b; ECHA). Although these studies reported negative results, they are considered unreliable (Kl. score = 3) due to methodological or reporting deficiencies.

Several *in vivo* studies have been conducted on NaOH (OECD, 2002a,b; ECHA). Although these studies reported negative results, they are considered unreliable (Kl. score = 3) due to methodological or reporting deficiencies.

Carcinogenicity

No studies were identified.

Reproductive/Developmental Toxicity

No valid studies were identified regarding toxicity to reproduction or developmental toxicity in animals after oral, dermal or inhalation exposure to NaOH.

Derivation of Toxicological Reference and Drinking Water Guidance Values

Oral and dermal repeated dose, reproductive, and developmental toxicity studies have not been conducted on NaOH. A repeated dose toxicity study was conducted by the inhalation route, but the methodology and documentation preclude its use for deriving a toxicological reference value. These toxicity studies would have questionable usefulness because of the corrosive/irritating nature of NaOH, which would limit the amount absorbed. NaOH dissociates to sodium and hydroxyl ions in bodily fluids, and a significant amount of these ions are already ingested in foods. Furthermore, both ions are present in the body and are highly regulated by homeostatic mechanisms. Thus, a toxicological reference value was not derived for NaOH.

The Australian drinking water guideline values for sodium (180 ppm, aesthetic) and pH may be applicable (ADWG, 2011).

References

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

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Toxicity Profile

Sodium Polyacrylate
(CAS No. 9003-04-7)

Sodium polyacrylates are polymers that range in molecular weight (MW) from 1,000 to 78,000 (HERA, 2014). The sodium polyacrylates mostly used in detergents have a typical molecular weight of approximately 4,500 (HERA, 2014).

Acute Toxicity

Acute oral toxicity studies have been conducted in rats on sodium polyacrylates with molecular weights (MW) of 1,000 to 78,000. The oral LD_{50} values are >5,000 or >10,000 mg/kg (the highest doses tested), with the exception of one study on a 3,500 MW sodium polyacrylate, which was reported to be >1,000 mg/kg (the attainable limit dose of a 10% aqueous solution) (HERA, 2014). [Kl. scores = 2]

The dermal LD_{50} values in rabbits for sodium polyacrylates with MW of 1,000 or 4,500 are >5,000 mg/kg (HERA, 2014). [Kl. scores = 2]

Irritation

The sodium polyacrylates with MW of 1,000 to 78,000 are not irritating to the skin or eyes (HERA, 2014). [Kl. scores = 2]

Sensitization

Sodium polyacrylates with MW of 4,500 or 78,000 were not dermal sensitizers in the guinea pig maximization test (HERA, 2014). [Kl. scores = 2 and 4, respectively]

Repeated Dose Toxicity

Oral

Male rats were fed diets containing 0 or 2.5% sodium polyacrylate (MW 2,500) for four weeks. Body weight, body weight gain, and appearance of the animals were similar between treated and control animals. In the fourth week of the study, a small, but significant, decrease in total weight of bone minerals was detected and confirmed by radiographic and histological examination. There was a significant reduction in the concentration of magnesium in the bones and plasma of the treated animals. Calcium loss was slight and not statistically significant. Urinary excretion of sodium and phosphorus was markedly increased; calcium only slightly increased. The authors of the study interpreted the finding as a metabolic imbalance rather than systemic toxicity. Sodium excretion could have been increased by the high intake of the sodium-neutralized test substance. The NOAEL for the study was considered to be 2.5% sodium polyacrylate in the diet, which was estimated to be 1,136 mg/kg-day (HERA, 2014). [Kl. score = 2]

Inhalation

Male and female rats were exposed by inhalation to 0, 0.2, 1.0, or 5.0 mg/m^3 sodium polyacrylate (MW 4,500) as an aerosol for 6 hours/day, 5 days/week for 13 weeks. Additional groups of animals were exposed for 13 weeks followed by a 91-day recovery period. There were no treatment-related effects on body weights, organ weights, feed and water consumption, clinical observations, and blood chemistry. In the histopathologic examination, the lungs of the mid- and high-dose animals showed signs of mild pulmonary irritation: increases in polymorphonuclear granulocytes or alveolar macrophages, pneumocyte hyperplasia, alveolar wall thickening and focal alveolitis. The lung effects were reversible and were not seen in the recovery group animals. The NOEC for systemic effects in this study was considered to be 5 mg/m^3, and the NOEC for localized irritation is 0.2 mg/m^3 (HERA, 2014). [Kl. score = 2]

Genotoxicity

The results of the *in vitro* studies on sodium polyacrylates are presented below in Table 1. All of the studies show that sodium polyacrylates are not mutagenic or genotoxic.

Table 1: In Vitro Genotoxicity Studies on Sodium Polyacrylates (HERA, 2014)

Mean MW	Test System	Results*	Klimisch Score	Reference
2,000	Bacterial reverse mutation	-	2	HERA (2014)
2,000	Mouse lymphoma	-	2	HERA (2014)
2,000	Unscheduled DNA synthesis	-	2	HERA (2014)
4,500	Bacterial reverse mutation	-	2	HERA (2014)
4,500	Mouse lymphoma	-	2	HERA (2014)
4,500	Unscheduled DNA synthesis	-	2	HERA (2014)
4,500	Cytogenetic (CHO cells)	-	2	HERA (2014)
4,500	Bacterial reverse mutation	-	2	HERA (2014)
4,500	Mammalian cell gene mutation	-	2	HERA (2014)
4,500	Unscheduled DNA synthesis	-	2	HERA (2014)

*+, positive; -, negative

There was no increase in micronuclei in polychromatic erythrocytes from the bone marrow of mice given a single oral gavage dose of 13,850 mg/kg sodium polyacrylate with a MW of 2,000 (HERA, 2014).

Carcinogenicity

No studies are available.

Reproductive Toxicity

No studies are available.

Developmental Toxicity

Pregnant female rats were dosed by oral gavage with 0, 500, 1,000, or 3,000 mg/kg sodium polyacrylate (MW 4,500) on GD 6 to 15. At 3,000 mg/kg, the dams had soft or liquid stools during the treatment period. There was no maternal or developmental toxicity observed in this study. The NOAEL for maternal and developmental toxicity is 3,000 mg/kg-day (HERA, 2014). [Kl. score = 2]

Pregnant female rats were dosed by oral gavage with 0, 125, 375, or 1,125 mg/kg sodium polyacrylate (MW 90,000 as a 77.5% aq. solution) during GD 6 to 13. Some of the dams were sacrificed on GD 13 and the remaining on GD 19. One mid-dose dam and 6 high-dose dams died during the study; of these, three of the high-dose deaths were treatment-related and the remaining were considered the result of gavage errors. There was a transient decrease in feed consumption in the high-dose dams during GD 7-9, but not other indications of maternal toxicity. There was no developmental toxicity. The NOAELs for maternal and developmental toxicity are 375 and 1,125 mg/kg-day (HERA, 2014). [Kl. score = 2]

Derivation of Toxicological Reference and Drinking Water Guidance Values

NICNAS has assessed sodium polyacrylates in an IMAP Tier 1 assessment and considers it "a chemical identified as low concern to human health by application of expert validated rules".[1]

A 4-week dietary study showed no systemic toxicity in rats given 2.5% sodium polyacrylate (MW 2,500) in their feed. The estimated dose is 1,136 mg/kg-day. Two pre-natal developmental toxicity studies showed no effects at the highest dose tested: 3,000 and 1,125 mg/kg-day for sodium polyacrylates with MW of 4,500 and 90,000, respectively. The NOAEL of 1,136 mg/kg-day from the 4-week dietary study will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subacute to chronic) = 10
UF_D (database uncertainty) = 1

[1] https://www.nicnas.gov.au/chemical-information/imap-assessments/imap-assessments/tier-i-human-health-assessments#cas-A_9003-04-7

Oral RfD = 1,136 (10 x 10 x 1 x 10 x 1) = 1,136/1,000 = 1.0 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD:

Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (1 x 70 x 0.1)/2 = 3.5 mg/L

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Toxicity Profile

Sodium tetraborate decahydrate
[Disodium tetraborate decahydrate; Borax]
(CAS No. 1303-96-4)

Sodium tetraborate decahydrate ($Na_2B_4O_7 \bullet 10H_2O$) is very soluble in water, with the main species in freshwater being the borate ion $[B(OH)_4]^-$ and boric acid $B(OH)_3$, depending on the pH. The relative proportion of boric acid and borate ions is controlled by pH: $B(OH)_3 + 2H_2O \Leftrightarrow [B(OH)_4]^- + H_3O^-$. In dilute aqueous solutions, boric acid does not dissociate at pH <7; at pH values between 7 and 11, both boric acid and borate ions are present. In dilute aqueous solutions and physiological conditions, the predominant species present is un-dissociated boric acid. So, the consideration of boric acid addresses the relevant environmental stability properties for borates.

Exposure to borates are often expressed in terms of boron (B) equivalents based on the fraction of boron in the source substance on a molecular weight basis. The B equivalents used are a generic designation rather than a designation of the element boron. The factor for converting sodium tetraborate decahydrate to B-equivalents is 0.1134.

Acute Toxicity

The oral LD_{50} for sodium tetraborate decahydrate in rats is 5,560 mg/kg (ECHA) [Kl. score = 1]. The oral LD_{50} of boric acid in rats is 3,450 mg/kg (ECHA) [Kl. score = 1]. The oral LD_{50} of anhydrous boric acid in rats is >2,500 mg/kg. [Kl. score = 1].

The 4-hour inhalation LC_{50} value for sodium tetraborate pentahydrate in rats is >2.04 mg/L (ECHA) [Kl. score = 1]. The 4-hour inhalation LC_{50} value for boric acid in rats is >2.01 mg/L. The mass median aerodynamic diameter (MMAD) was 2.8 μm (ECHA) [Kl. score = 1]. In another study, the 4-hour inhalation LC_{50} value for boric acid in rats was >2.03 mg/L (ECHA) [Kl. score = 1].

The dermal LD_{50} in rats for sodium tetraborate pentahydrate is >2,000 mg/kg (ECHA) [Kl. score = 2].

Irritation

Application of 0.5 g. of sodium tetraborate decahydrate to the skin of rabbits for 4 hours under occlusive conditions was not irritating. The mean erythema and edema scores were 0.00 (ECHA) [Kl. scores = 2]. Application of 0.5 g. of boric acid to the skin of rabbits for 24 hours under occlusive conditions was not irritating. The mean of the 24 and 72 hour scores were: 0.13 for erythema and 0.00 for edema (ECHA) [Kl. scores = 1].

Instillation of sodium tetraborate decahydrate into the eyes of rabbits was irritating. (ECHA) [Kl. score = 1]. The effects were thought to be due to the glassy nature of the crystals of the test substance. In another study on sodium tetraborate pentahydrate, the test substance was ground to a fine powder before instillation to reduce the glassy, sharp crystals in the sample; no irritancy was then observed (ECHA) [Kl. scores = 2]. Instillation of 0.08 mL boric acid into

the eyes of rabbits was slightly irritating. The mean of 24, 48, and 72 hours scores were: 0.22 for corneal opacity; 0.22 for iridial lesions; 2.8 for conjunctival redness; and 1.89 for chemosis (ECHA) [Kl. score = 1].

Sensitization

Sodium tetraborate decahydrate was not a skin sensitizer to guinea pigs in a Buehler test (ECHA) [Kl. score = 1]. Boric acid was not a skin sensitizer to guinea pigs in a Buehler test (ECHA) [Kl. score = 1]. Sodium tetraborate pentahydrate was not a skin sensitizer to guinea pigs in a Buehler test (ECHA) [Kl. score = 1].

Repeated Dose Toxicity

Oral

Male and female SD rats were given in their feed boric acid at doses of 0, 52.5, 175, 525, 1,750 or 5,250 ppm B equivalents for 90 days. The average intake has been estimated to be approximately 0, 2.6, 8.8, 26, 87.5 or 262.5 mg B/kg-day, respectively (U.S. EPA, 2004). By week 6, all of the animals in the highest dose died. Clinical signs in the top two dose levels were rapid respiration, inflamed eyes, swollen paws, and desquamated skin on the paws and tails. There was also reduced food consumption and body weight gain. The 1,750 ppm females showed reduced liver, spleen ovary, and adrenal weights; the 1,750 ppm males showed reduced liver, spleen, kidney, testes, and adrenal weights. The adrenals of 4 of the 1,750 ppm males showed minor increases in lipid content and size of the cells in the zona reticularis. Atrophied testis (complete atrophy of the spermatogenic epithelium and decreased in the size of the seminiferous tubules) was seen in all of the 1,750 ppm males. One 525 ppm male had partial testicular atrophy. The NOAEL for this study is 175 ppm boron or 8.8 mg B/kg-day (Weir and Fisher, 1972). [Kl. score = 2]

Male and female SD rats were given in their diet sodium tetraborate decahydrate at doses of 0, 52.5, 175, 525, 1,750 or 5,250 ppm B equivalents for 90 days. The average intake has been estimated to be approximately 0, 2.6, 8.8, 26, 87.5 or 262.5 mg B/kg-day, respectively (U.S. EPA, 2004). By week 6, all of the animals in the highest dose died. Clinical signs in the top two dose levels were rapid respiration, inflamed eyes, swollen paws, and desquamated skin on the paws and tails. There was also reduced food consumption and body weight gain. The 1,750 ppm females showed reduced liver, spleen and ovary weights; the 1,750 ppm males showed reduced liver, spleen, kidney, testes, and brain weights. The adrenals of the majority of the 1,750 ppm males and females showed slight to moderate increases in lipid content and size of the cells in the zona reticularis. Atrophied testis (complete atrophy of the spermatogenic epithelium and decreased in the size of the seminiferous tubules) was seen in all of the 1,750 ppm males. Four 525 ppm males had partial testicular atrophy. Spermatogenic arrest was found in one 525 ppm male. The NOAEL for this study is 175 ppm boron or 8.8 mg B/kg-day (Weir and Fisher, 1972). [Kl. score = 2]

Male and female B6CF1$_1$ mice were given in the diet 0, 1,200, 2,500, 5,000, 10,000 or 20,000 ppm boric acid for 13 weeks (control and highest dose group) or 16 weeks (remaining dose groups). These dietary levels correspond to approximately 0, 34, 70, 141, 281 and 563 mg B/kg-day for males, respectively; and 0, 47, 97, 194, 388 and 776 mg B/kg-day for females, respectively (U.S. EPA, 2004). There was mortality (8/10 males; 6/10, females) in the 20,000 ppm, as well as hyperkeratosis and acanthosis. One male also died in 10,000 ppm group.

Degeneration or atrophy of the seminiferous tubules occurred in the ≥5,000 ppm males. Minimal to mild extramedullary hematopoiesis of the spleen was observed in all dose groups. The LOAEL for this study is 1,200 ppm, corresponding to 34 and 47 mg B/kg-day for males and females, respectively (NTP, 1987). [Kl. score = 2]

Male and female SD rats were given in their diet 0, 117, 350 or 1,170 ppm boric acid for two years. The average intake has been estimated to be approximately 0, 5.9, 17.5 or 58.5 mg B/kg-day, respectively (U.S. EPA, 2004). The 1,170 ppm rats had decreased food consumption during the first 13 weeks of the study and suppressed growth throughout the study. Signs of toxicity in the 1,170 ppm animals included swelling and desquamation of the paws, scaly tails, inflammation of the eyelids, and bloody discharge from the eyes. All of the 1,170 ppm males had testicular atrophy at the 6, 12 and 24 month time points. The seminiferous epithelium was atrophied, and the tubular size in the testes was decreased. There were significant decreases in the absolute and relative testes weights. Brain and relative thyroid weights were increased. The NOAEL for this study is 350 ppm B equivalents or 17.5 mg B/kg-day (Weir and Fisher, 1972) [Kl. score = 2].

Male and female $B6C3F_1$ mice were given 0, 2,500 or 5,000 ppm boric acid in their feed for 103 weeks (NTP, 1987). These dose levels were equivalent to 0, 275 or 550 mg/kg-day boric acid or 0, 48 or 96 mg B/kg-day (U.S. EPA, 2004). There was reduced survival in the male mice, which was significantly different from the controls in the 2,500 ppm mice after week 63 and in the 5,000 ppm mice after week 84. The survival rates by the end of the study were 82, 60 and 44% in the 0, 2,500, and 5,000 ppm males, respectively; and 66, 66 and 74% in the 0, 2,500, and 5,000 ppm females, respectively. Mean body weights were 10-17% lower in the 5,000 ppm animals after 32 (males) or 52 (females) weeks compared to the controls. There was testicular atrophy and interstitial cell hyperplasia in the testes of the 5,000 ppm males. A dose-related increase in the incidences of splenic lymphoid depletion in male mice was also observed. NTP considered this lesion to be associated with stress and debilitation, and it is reflected in the increased mortality in these groups of male mice. The NOAEL for this study is (NTP, 1987) [Kl. score = 2].

Inhalation

Male and female rats were exposed by inhalation to 0, 77, 175, or 470 mg/m^3 boron oxide. The exposures were 6 hours/day, 5 days/week for 24, 12, and 10 weeks for the 77, 175, and 470 mg/m^3 concentrations groups, respectively. The MMAD were 2.5, 1.9, and 2.4 μm for the 77, 175, and 479 mg/m^3 concentrations groups, respectively. There was no evidence of systemic toxicity. Some of the 470 mg/m^3 had reddish exudate from the nose. As these animals were covered with dust, this effect may have been local irritation of the nose and from the animals scratching the nose. The NOAEL for systemic toxicity is 470 mg/m^3, the highest exposure concentration tested. The NOAEL for localized effects (irritation) is 175 mg/m^3 (ECHA) [Kl. score = 2].

Dermal

No studies are available.

Genotoxicity

There are no *in vitro* genotoxicity studies on sodium tetraborate decahydrate. Table 1 presents the results of the *in vitro* genotoxicity studies on boric acid.

Table 1: *In vitro* Genotoxicity Studies on Boric Acid

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	1	ECHA
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	ECHA
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	-	-	1	ECHA
Chromosomal aberrations (Chinese Hamster Ovary cells)	-	-	1	ECHA
Chromosomal aberrations (Chinese Hamster Ovary cells)	-	-	1	ECHA
Chromosomal aberrations (Human peripheral lymphocytes)	NS	+	2	ECHA
Unscheduled DNA synthesis (rat liver cells)	NA	-	1	ECHA

*+, positive; -, negative; NA, not applicable; NS, not specified.

Carcinogenicity

Male and female SD rats were given in their diet disodium tetraborate decahydrate (Borax) or boric acid at doses of 0, 117, 350, or 1,170 ppm as B equivalents (approximately 0, 5.9, 17.5, or 58.5 mg B/kg-day) for two years. There was no mention of tumors in the report. Nevertheless, NTP (1987) concluded that this study provided adequate data on the lack of carcinogenic effects of boric acid in rats (Weir and Fisher, 1972; U.S. EPA, 2004) [Kl. score = 4].

Male and female $B6C3F_1$ mice were given in their diet 0, 2,500, or 5,000 ppm boric acid for 103 weeks. The dietary levels are equivalent to 0, 446, or 1,150 mg/kg-day boric acid or 0, 78.1, or 201.3 mg B/kg-day. There was no evidence of carcinogenicity (NTP, 1987). [Kl. score = 2]

Reproductive Toxicity

A three-generation reproductive toxicity study was conducted in albino rats (strain not specified) with boric acid. Male and female rats were fed a diet containing 0, 117, 350 or 1,170 ppm boron (approximately 0, 5.9, 17.5 or 58.5 mg B/kg-day, respectively). In the lower two dose groups, there were no treatment-related effects on reproduction. Litter size, progeny

weights, fertility, live birth indices, lactation, appearance were similar to the controls. No gross abnormalities were noted in these two dose groups. The 1,170 ppm dose group were found to be sterile, and there were no litters from mating the treated females with control males. Lack of viable sperm was found in the atrophied testes of all 1,170 ppm males. Decreased ovulation was also seen in the majority of the ovaries of the 1,170 ppm females. The NOAEL for this study is 350 ppm boron or approximately 17.5 mg B/kg-day (Weir and Fisher, 1972). [Kl. score = 2]

A three-generation reproductive toxicity study was conducted in albino rats (strain not specified) with disodium tetraborate decahydrate. Male and female rats were fed a diet containing 0, 117, 350 or 1,170 ppm boron (approximately 0, 5.9, 17.5 or 58.5 mg B/kg-day, respectively). In the lower two dose groups, there were no treatment-related effects on reproduction. Litter size, progeny weights, fertility, live birth indices, lactation, appearance were similar to the controls. No gross abnormalities were noted in these two dose groups. The 1,170 ppm dose group were found to be sterile, and there were no litters from mating the treated females with control males. Lack of viable sperm was found in the atrophied testes of all 1,170 ppm males. Decreased ovulation was also seen in the majority of the ovaries of the 1,170 ppm females. The NOAEL for this study is 350 ppm boron or approximately 17.5 mg B/kg-day (Weir and Fisher, 1972). [Kl. score = 2]

In a continuous breeding protocol, male and female CD-1 mice were given in their diet 0, 1,000, 4,500 or 9,000 ppm boric acid in their feed. The authors estimated that the average daily intakes were: 0, 26.6, 111, and 220 mg B/kg-day to males; and 0, 31.8, 152, 257 mg B/kg-day to females. Boric acid consumption did not differ among the groups. There were no litters in the 9,000 ppm breeding pairs. At 4,500 ppm, there was a successful first litter, after which there was a progressive decrease in fertility; only one pair produced a fourth and fifth litter. All fertility indices were affected in the 4,500 ppm group. A complete crossover mating trial was conducted using control mice and the 4,500 ppm mice. The results showed that the probable cause of the reduced fertility was a decrement in male fertility. A dose-related decrease in body, testicular and epididymal weights was observed in the 4,500 and 9,000 ppm F_0 males. Sperm count was significantly decreased in these two dose groups, and percent motile sperm was decreased in all dose groups. Testicular histopathology showed seminiferous tubular atrophy in the 9,000 ppm males and partial atrophy of the seminiferous tubules in the 4,500 ppm males. There were no histopathologic changes in the 4,500 ppm females. No statistically significant decreases in mating index, fertility index, or live pups/litter in the 4,500 ppm females, but the number of days to litter in this dose group was increased. Estrous cyclicity was unaffected. Reproductive organ weights were unaffected, but relative maternal liver and kidney/adrenal weights were reduced. An F_1 fertility trial was performed using offspring from the 1,000 ppm groups. There was no decreases in mating, fertility or reproductive performance. The F_2 adjusted live pup weight was slightly, but significantly, reduced from controls. A clear NOAEL for reproductive toxicity in males was not seen in this study. The 1,000 ppm males had decreased sperm motility in the F_0 generation and decreased sperm concentration in the F_1 generation. Decreased F_2 pup relative body weight was statistically significant from controls. The NOAEL in this study for females is 1,000 ppm boric acid or 32 mg B/kg-day). The LOAEL in this study for males is 1,000 ppm or 27 mg B/kg-day; a NOAEL was not established (Fail *et al.,* 1991). [Kl. score = 2]

Developmental Toxicity

Pregnant female SD rats were given 0, 0.1, 0.2 or 0.4% boric acid in their feed on gestational days (GD) 0 to 20 or 0.8% boric acid on GD 6 to 15. The average amounts of boric acid ingested were estimated to be 0, 78, 163, 330 or 539 mg/kg-day (0, 13.6, 28.5 or 57.7 mg B/kg-day), respectively. Effects on the pregnant rats were altered food and/or water intake at ≥0.2% boric acid, increased liver and kidney weights relative to body weights at ≥0.2%, reduced weight gain at ≥0.4%, and increased corrected weight gain at 0.4% boric acid. There was a reduction in fetal body weights in all treated groups (94, 87, 63, and 47% of control weight, respectively). Increased malformations occurred at ≥0.2%, and prenatal mortality was increased at 0.8%. There was a dose-response for altered skeletal morphology in rats (≥0.1%), and specific findings were significantly elevated above controls at ≥0.2%. Specifically, there was an increased incidence of short rib XIII (a malformation) and a decreased incidence or rudimentary or full rib(s) at lumbar I (an anatomical variation) (Heindel *et al.,* 1992). [Kl. score = 2]

Pregnant female SD rats were given in their feed 0, 0.025, 0.005, 0.075, 0.1 or 0.2% boric acid on GD 0 to 20. Approximately half of the dams were terminated on GD 20, and the remaining dams delivered their litters. Pup growth and viability were monitored until postnatal day (PND) 21. The average amounts of boron ingested on GD 20 were: 0, 3.3, 6.3, 9.6, 13.3, and 25 mg B/kg-day, respectively. The average amounts of boron ingested on PND 21 were : 0, 3.2, 6.5, 9.7, 12.9, and 25.3 mg B/kg-day, respectively. There were no maternal deaths and no treatment-related clinical signs. Maternal body weights were similar across all groups during gestation. However, decreased maternal body weights (GD 19 and 20 at sacrifice) and decreased maternal body weight gain (GD 15-18 and GD 0-20) were statistically significant in trend tests. There was a 10% reduction in gravid uterine weight (statistically significant) in the 0.2% group. Corrected maternal weight (maternal gestational weight minus reduced gravid uterine weight) was unaffected by treatment. Feed intake in the 1,000 ppm dams was minimally affected and only during the first three days of dosing. Water consumption was higher in the treated groups after GD 15. The number of corpora lutea and uterine implantation sites, and the percentage of preimplantation loss were similar across all groups. Increased relative kidney weights were increased in the 0.2% group. There were no differences in the viability of the offspring between treated and controls. On GD 20, fetal body weight was 94% and 88% of controls in the 0.1% and 0.2% groups, respectively; recovery was complete at birth (~GD 22). The incidence of short rib XIII was increased on GD 20 in the ≥0.1% groups, but only in the 0.2% group at PND 21. The incidence of wavy rib was increased on GD 20 in the ≥0.1% group; the reversibility of this effect was confirmed on PND 21. There was a slight decrease in extra lumbar ribs in the 0.2% group on GD 20, and extra lumbar ribs were seen in the 0.2% group on PND 21. The developmental NOAEL was considered to be 0.075% boric acid or 9.6 mg B/kg-day on GD 20; and 0.1% boric acid or 12.9 mg B/kg-day on PND 21 (Price *et al.* 1996a). [Kl. score = 1]

Pregnant Swiss mice were given in their diet 0, 0.1, 0.2 or 0.4% boric acid on gestational days (GD) 0 to 17. The average amounts of boric acid ingested were estimated to be 248, 452 or 1,003 mg/kg-day (0, 43.4, 79.0 or 175.3 mg/B/kg-day), respectively. Maternal toxicity consisted of mild kidney lesions (≥0.1%), increased water intake and relative kidney weights (0.4%), and decreased water intake during treatment. Fetal body weights were reduced in the ≥0.2% groups, and there were increased incidences of resorptions and malformed fetuses per litter in the 0.4% group. The LOAEL for maternal toxicity is 248 mg/kg-day boric acid or 43.4 mg B/kg-day; a NOAEL was not established. The NOAEL for developmental toxicity is 248 mg/kg-day boric acid or 43.4 mg B/kg-day (Heindel *et al.,* 1992). [Kl. score = 2]

Pregnant female New Zealand rabbits were dosed by oral gavage with 0, 62.5, 125 or 250 mg/kg boric acid (0, 10.9, 21.9 or 43.7 mg B/kg) during GD 6-19. Feed intake was in the 250 mg/kg maternal animals during the exposure period, but it was increased in the ≥125 mg/kg dose groups. In the 250 mg/kg group, maternal body weights during GD 9-30, weight gain during GD 6-19, gravid uterine weight, and number of corpora lutea per dam were significantly reduced. In the ≥125 mg/kg groups, maternal corrected gestational weight gain was increased compared to controls. Maternal liver weights were unaffected by treatment. In the 250 mg/kg group, relative, but not absolute, kidney weights were increased, although no effects in the kidney were noted in the histopathological examination. Prenatal mortality was increased in the 250 mg/kg group (90% resorptions/litter versus 6% for controls); the proportion of pregnant females with no live fetuses was increased (73% versus 0%), and live litter size was reduced (2.3 fetuses versus 8.8). Thus, there were only 14 live fetuses (6 live litters) available for evaluation in the 250 mg/kg group. The percentage malformed fetuses/litter was increased in the 250 mg/kg group, primarily due to cardiovascular defects (72% versus 3% of controls). There was no definitive maternal or developmental toxicity in the 62.5 or 125 mg/kg dose groups. The NOAEL for maternal and developmental toxicity is 125 mg/kg-day boric acid or 21.9 mg B/kg-day (Price *et al.,* 1996b). [Kl. score = 1]

Derivation of Toxicological Reference and Drinking Water Guidance Values

The developing fetus and the testes are the two most sensitive targets of boron toxicity in multiple species (U.S. EPA, 2004; ECHA, 2010). The testicular effects include reduced organ weight and organ to body weight ratio, atrophy, degeneration of the spermatogenic epithelium, impaired spermatogenesis, reduced fertility, and sterility (U.S. EPA, 2004). The developmental effects from boron exposure include high prenatal mortality; reduced fetal body weight; and malformations and variations (U.S. EPA, 2004).

The U.S. Environmental Protection Agency (U.S. EPA) derived an Oral Reference Dose (RfD) for boron of 0.2 mg B/kg-day (U.S. EPA, 2004) based on developmental effects in rats from two studies (Price *et al.* 1996a; Heindel *et al.* 1992).

The RfD was derived using the benchmark dose (BMD) method ($BMDL_{05}$ from Allen *et al.,* 1996) using a data derived uncertainty factor of 66. Decreased fetal body weight ($BMDL_{50}$ = 59 mg boric acid/kg-day or 10.3 mg B/kg-day) was considered by Allen *et al.* (1996) as the most suitable endpoint for developing a point of departure, because the benchmark doses calculated for the other endpoints (incidence of total malformations, enlarged lateral ventricles in the brain, shortening of rib XIII, and variations of the first lumbar rib) were higher.

Derivation of an Oral Reference Dose

Oral RfD = $BMDL_{05}$ / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 7.9 [3.16, toxicodynamics; 3.3, toxicokinetics]
UF_H (intraspecies variability) = 6.2 [3.16, toxicodynamics; 2.0, toxicokinetics]
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 10.3/(7.9 x 6.3 x 1 x 1 x 1) = 10.3/66 = 0.2 mg B/kg-day

Derivation of a drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (0.2 x 70 x 0.1)/2 = 0.7 mg/L

Australian drinking water guideline

The Australian drinking water guideline for boron is 4 mg/L (ADWG, 2011).

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Santos

APPENDIX F.11 HALLIBURTON HYBOR-DELTA HYDRAULIC FRACTURING FLUID SYSTEMS

ACETIC ACID

This dossier on acetic acid does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of acetic acid in its use in drilling muds and hydraulic fracturing fluids. The majority of information presented in this dossier was obtained from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC): Acetic acid

CAS RN: 64-19-7

Molecular formula: $C_2H_4O_2$

Molecular weight: 60.1

Synonyms: Acetic acid, ethanoic acid, ethylic acid, methane carboxylic acid, vinegar acid

SMILES: CC(=O)O

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Acetic Acid

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Colorless liquid with a pungent odor.	2	ECHA
Melting Point	16.64°C	2	ECHA
Boiling Point	117.9°C	2	ECHA
Density	1.04 g/cm^3	2	ECHA
Vapor Pressure	20.79 hPa @ 25°C	2	ECHA
Partition Coefficient (log K_{ow})	-0.17	2	ECHA

Water Solubility	602.9 g/L	2	ECHA
Flash Point	39ºC @ 101.3 kPa	2	ECHA
Auto flammability	463ºC	2	ECHA
Viscosity	1.056 mPa s @ 25ºC	2	ECHA
Dissociation constant	4.756 @ 25ºC	2	ECHA

Acetic acid readily dissociates in aqueous media to the acetate ($H_3C2O_2^-$) and hydrogen (H^+) ions.

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

The acetate ion of acetic acid is readily biodegradable, is not expected to bioaccumulate, and has a low potential to adsorb to soil.

B. Biodegradation

Acetic acid was readily biodegradable a non-acclimated freshwater study. Degradation was 96% after 20 days (Price et al., 1974; ECHA) [Kl. score = 2]. Acetic acid is also readily biodegradable under anaerobic conditions (Kameya et al., 1995) [Kl. score = 2].

C. Environmental Distribution

Adsorption/desorption

No experimental data are available for acetic acid. Using KOCWIN in EPISUITE™ (EPA, 2017), the estimated K_{oc} values from log K_{ow} and the molecular connectivity index (MCI) are 1.153 and 1.0 L/kg ,respectively.

D. Bioaccumulation

There are no bioaccumulation studies on acetic acid. Bioaccumulation of acetic acid is not expected to occur because acetic acid dissociates completely in aqueous solution to acetate and its hydrogen ion. Both ions are ubiquitous in the environment. Acetate is naturally found in eukaryotic and prokaryotic cells and is involved in their biochemical pathways.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Acetic acid is a corrosive liquid. Depending on the concentration, aqueous solutions of acetic acid are either corrosive, irritating, or non-irritating to the skin, eyes, and gastrointestinal tract. Vapours from aqueous solutions of acetic acid can cause respiratory irritation. There are no adequate repeated dose toxicity studies on acetic acid. Acetic acid is not genotoxic. Positive findings have been reported in some *in vitro* genotoxicity studies, and are considered to be the result of the pH change in the test system. Animals studies have shown no developmental toxicity from ingestion of acetic acid.

B. Acute Toxicity

The oral LD_{50} of the sodium salt of acetic acid in rats is 3,310 mg/kg (Woodard et al., 1941; ECHA) [Kl. score =2]. The oral LD_{50} of the acetic acid in unfasted rats is 3,530 mg/kg (ECHA) [Kl. score =4]. The oral LD_{50} of the sodium salt of acetic acid in mice is 4,960 mg/kg (Smyth et al., 1951; ECHA) [Kl. score =2].

The 4-hour inhalation LC_{50} in rats for acetic acid vapor is 11.4 mg/L. There were clinical signs that were indicative of corrosion (ECHA) [Kl. score = 2].

C. Irritation

Application of a 3.3% or a 10% aqueous solution of acetic acid to the skin of rabbits for 4 hours was slightly irritating. The Primary Dermal Irritation Index scores were 0.5 and 1.1, respectively (Nixon et al., 1990; ECHA) [Kl. score = 2]. Application of a 10% solution of acetic acid to the skin of rabbits for 4 hours under semi-occlusive conditions was slightly irritating (ECHA) [Kl. score = 2].

Instillation of 0.1 mL of a 10% solution of acetic acid to the eyes of rabbits was considered irritating. The mean of the 24, 48, and 72 hours scores were: 2.67 for erythema; 1.67 for chemosis; 1.72 for corneal opacity; and a mean of 87% corneal swelling (Jacobs and Martens, 1989; ECHA) [Kl. score = 2]

D. Sensitization

No studies are available.

E. Repeated Dose Toxicity

<u>Oral</u>

No adequate studies for human health risk assessment are available.

Inhalation

No studies are available.

Dermal

No adequate studies for human health risk assessment are available.

F. Genotoxicity

In Vitro Studies

The *in vitro* genotoxicity studies on acetic acid are presented below in Table 2.

Table 2: *In vitro* Genotoxicity Studies on Acetic Acid

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* strains)	NC	-	2	Ishidate et al. (1984); ECHA
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	Zeiger et al. (1992); ECHA
Chromosomal aberrations (CHO cells)	-**	-**	2	Morita et al. (1990); ECHA
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	-***	-***	2	Seifried et al. (2006); ECHA

*+, positive; -, negative; NC, not conducted.
**A dose-dependent increase in chromosomal aberrations was observed with 10 mM acetic acid (-S9) and 8 mM acetic acid (+S9). These concentrations were close to the cytotoxic limit at which the cells could no longer be evaluated. These effects were abolished by neutralizing the test medium or increasing the buffer capacity. These results suggest that the positive findings are due to the acidic pH of the incubation medium rather than a consequence of an intrinsic clastogenic potential of acetic acid.
***Acetic anhydride (hydrolyzes to acetic acid in aqueous media).

In vivo Studies

No studies are available on acetic acid.

A bone marrow micronucleus study has been conducted on acetic anhydride (which hydrolyses to acetic acid). Male and female SD rats were exposed by inhalation to 0, 1, 5, or 20 ppm acetic anhydride, 6 hours/day, 5 days/week for 13 weeks. The incidence of micronucleated immature erythrocytes was not increased at any exposure concentration (ECHA) [Kl. score = 1]

G. Carcinogenicity

No oral or inhalation studies are available.

No deaths and no skin tumors were seen when acetic acid was applied dermally once a week to CD-1 mice for 32 weeks (Slaga et al., 1975; ECHA) [Kl. score = 4].

H. Reproductive Toxicity

No studies are available.

I. Developmental Toxicity

Pregnant female Wistar rats were dosed by oral gavage with 0 or various concentrations up to 1,600 mg/kg apple cider vinegar (5% acetic acid) on gestational days 6 to 15. There were no maternal or developmental toxicity at any dose level. The NOAEL for maternal and developmental toxicity is 1,600 mg/kg-day (ECHA). [Kl. score = 2]

Pregnant female CD-1 mice were dosed by oral gavage with 0, 16, 74.3, 345, or 1,600 mg/kg apple cider vinegar (5% acetic acid) on gestational days 6 to 15. There were no treatment-related effects on maternal or fetal survival, or on soft or skeletal tissues. There was no effect on the fetal development in the presence of slight maternal toxicity (reduced body weight gain) at 345 mg/kg. At 1,600 mg/kg, there was an increase in the number of litters containing a dead fetus and some reductions in ossification. The NOAELs for maternal and developmental toxicity are 74.3 and 345 mg/kg-day, respectively (ECHA). [Kl. score = 2]

Pregnant female Dutch-belted rabbits were dosed by oral gavage with 0, 16, 74.3, 345, or 1,600 mg/kg apple cider vinegar (5% acetic acid) on gestational days 6 to 18. There were no treatment-related effects on maternal or fetal survival, or on soft or skeletal tissues. There was a reduction in the pregnancy rate in the high-dose group; and a dose-dependent decrease in maternal body weights at $\geq$74.3 mg/kg. Some deaths or abortions occurred in all treated groups and some litter losses were reported at $\geq$345 mg/kg. Maternal effects were much more noticeable than the effects on fetal development. These findings have been considered a consequence of the bactericidal properties of orally administered acetic

acid within the gastrointestinal tract of female rabbits, and not a direct effect on embryonic implantation and development of acetic acid (EU, 2008). It is likely that this accounts for the apparent increased sensitivity of this species to oral administration of acetic acid. The NOAEL for developmental toxicity is 1,600 mg/kg-day; a NOAEL for maternal toxicity was not identified (ECHA). [Kl. score = 2]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for acetic acid follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

There are no repeated dose toxicity studies that were considered adequate for human health risk assessment.

The Joint FAO/WHO Expert Committee on Food Additives (JECFA) has maintained a group ADI of "not limited" for acetic acid and its potassium and sodium salts (JECFA).

The Australian drinking water guidance value for pH may apply to acetic acid.

B. Cancer

There are no carcinogenicity studies by the oral or inhalation route. A dermal carcinogenicity study in mice showed no carcinogenic activity when acetic acid was applied to the skin for 32 weeks. Thus, a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Acetic acid is a flammable liquid.

Acetic acid does not exhibit the following physico-chemical properties:

- Explosivity
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Acetic acid is of moderate acute toxicity concern to aquatic organisms, in part because of the effect of pH changes from the dissociated hydrogen ion. The acetate ion is of low acute toxicity concern to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

Table 3 presents the results of acute aquatic toxicity studies on acetic acid and potassium acetate.

Table 3: Acute Aquatic Toxicity Studies on Acetic acid and Potassium Acetate

Test Substance	Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Potassium acetate	*Oncorhynchus mykiss*	96-h LC_{50}	>300.82*	2	ECHA
Potassium acetate	*Danio rerio*	96-h LC_{50}	>300.82*	2	ECHA
Acetic acid	*Oncorhynchus mykiss*	96-h LC_{50}	64.8 (measured)	4	ECHA
Acetic acid	*Oncorhynchus mykiss*	96-h LC_{50}	31.3 – 67.6	4	ECHA
Potassium acetate	*Daphnia magna*	48-h EC_{50}	>300.82*	2	ECHA
Acetic acid	*Daphnia magna*	48-h EC_{50}	79.5 (measured)	4	ECHA
Acetic acid	*Daphnia magna*	48-h EC_{50}	18.9 (measured)	4	ECHA
Acetic acid	*Desmodesmus subspicatus*	72-h EC_{50}	486.5	4	ECHA

*As the acetate ion.

Chronic Studies

In a 21-day fish (*Oncorhynchus mykiss*) chronic study, the measured NOEC values for 60% and 100% acetic acid were 57.2 and 34.3 mg/L, respectively (ECHA). [Kl. score = 4]

In a 21-day *Daphnia* reproduction study, the measured NOEC for 60% and 100% acetic acid were 80 and 31.4 mg/L, respectively (ECHA). [Kl. score = 4]

In a 21-day *Daphnia* reproduction study, the measured NOEC for 100% acetic acid was 22.7 mg/L (ECHA). [Kl. score = 4]

C. Terrestrial Toxicity

No data are available.

D. Calculation of PNEC

The PNEC calculations for acetic acid follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. For the acute toxicity studies, data are available on both acetic acid and potassium acetate; both substances dissociate completely in aqueous media to the acetate anion and the corresponding cations (H^+ and K^+). The toxicity of these substances is expected to be driven by the acetate ion, with the cations having a minor role. The toxicity data on potassium acetate are preferred because of the absence of a potential pH change from the dissociated H^+ ion of acetic acid. For the chronic toxicity studies, only acetic acid has been tested for two trophic levels: fish and invertebrates. These studies will not be used to derive the PNEC value; however, an assessment factor of 100 will be applied to the lowest acute $E(L)C_{50}$ values.

From the potassium acetate studies, acute $E(L)C_{50}$ values (adjusted for acetic acid) are available for fish (300.82 mg/L) and *Daphnia* (300.82 mg/L). By applying an assessment factor of 100 to the $E(L)C_{50}$ value of 300.82 mg/L from either fish or *Daphnia*, the $PNEC_{aquatic}$ for acetic acid is 3.0 mg/L.

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 1.9 mg/kg sediment wet weight.

The calculations are as follows:

$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$
$= (0.82/1280) \times 1000 \times 3.0$
$= 1.9$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$K_{sed\text{-}water} = 0.8 + [(0.2 \times Kp_{sed})/1000 \times BD_{solid}]$
$= 0.8 + [(0.2 \times 0.04/1000 \times 2400]$
$= 0.82$

Where:
Kp_{sed} = solid-water partition coefficient (L/kg).
BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$Kp_{sed} = K_{oc} \times f_{oc}$
$= 1.0 \times 0.04$
$= 0.04$

Where:
K_{oc} = organic carbon normalized distribution coefficient (L/kg). The K_{oc} for acetic acid calculated from EPISUITE™ using the MCI is 1.0 L/kg .
F_{oc} = fraction of organic carbon in sediment = 0.04 [default].

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is 0.04 mg/kg soil dry weight.

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
$= (0.02/1500) \times 1000 \times 3.0$
$= 0.04$

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$

= 1.0 x 0.02
= 0.02

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for aceti acid calculated from EPISUITE™ using the MCI is 1.0 L/kg .
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Acetic acid is readily biodegradable; thus, it does not meet the screening criteria for persistence.

Bioaccumulation of acetic acid is not expected to occur because acetic acid dissociates completely in aqueous media to acetate and its hydrogen ion. Both ions are ubiquitous in the environment. Acetate is naturally found in eukaryotic and prokaryotic cells and is involved in their biochemical pathways. The log K_{ow} for acetic acid is -0.17. Thus, acetic acid does not meet the screening criteria for bioaccumulation.

The NOECs from the chronic aquatic toxicity studies on acetic acid are >0.1 mg/L. The $E(L)C_{50}$ values for potassium acetate are > 1 mg/L. Thus, acetic acid does not meet the criteria for toxicity.

The overall conclusion is that acetic acid is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Flammable Liquid Category 3
Skin Corrosion Category 1A

EU:
≥90%: Skin Corrosion 1A
≥25% to <90%: Skin Corrosion 1B
≥10% to <25%: Skin irritant Category 2; Eye irritant Category 2

In addition to the hazard statements corresponding the GHS classifications (if Skin Corrosion 1A or 1B is included), the following non-GHS hazard statement is to be added to the SDS: AUH071: Corrosive to the Respiratory Tract.

B. Labelling

Danger

C. Pictogram



X. SAFETY AND HANDLING

Eye Contact
Immediately flush open eyes with plenty of water for at least 15 minutes. Remove contacts, if present and easy to do. Get medical attention immediately, preferably a physician for an ophthalmologic examination.

Skin Contact
For minor skin contact, avoid spreading material on unaffected skin. Remove and isolate contaminated clothing. Wash the contaminated area of body with soap and fresh water. Get medical attention immediately.

Inhalation
Move person to fresh air. Administer oxygen if breathing is difficult. Do not use mouth-to-mouth method if victim inhaled the substance; give artificial respiration with the air of a pocket mask equipped with a one-way valve or other proper respiratory medical device. Give artificial respiration if victim is not breathing. Get medical attention immediately.

Ingestion
Rinse mouth and lips with plenty of water if person is conscious. Do not induce vomiting. Do not use mouth-to-mouth method if victim had ingested the substance. Obtain medical attention immediately if ingested.

Notes to Physician
Treat as a corrosive due to pH of the material. All treatments should be based on observed signs and symptoms of distress in the patient.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Use water spray or fog, foam, dry chemical or carbon dioxide. Do not use straight streams of water.

Specific Exposure Hazards
Flammable liquid and vapor. Vapors are flammable and heavier than air. Vapors may travel across the ground and reach remote ignition sources causing a flashback fire danger. Emits toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: carbon dioxide, carbon monoxide.

Special Protective Equipment for Firefighters
Structural firefighter's protective clothing provides limited protection in fire situations only; it is not effective in spill situations where direct contact with the substance is possible. Wear chemical protective clothing that is specifically recommended by the manufacturer. It may provide little or no thermal protection. Wear positive pressure self-contained breathing apparatus (SCBA). Move containers from fire area if you can do it without risk.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Isolate area. Keep unnecessary and unprotected personnel from entering the area. Use personal protective clothing. Ensure adequate ventilation. Wear respiratory protection if ventilation is inadequate. Do not breath mist, vapors, or spray Avoid contact with skin, eye, and clothing. Eliminate all sources of ignition.

Environmental Precautions
Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled
Eliminate all sources of ignition. All equipment used when handling the material must be grounded. A vapor suppressing foam may be used to reduce vapors. Use clean non-sparking tools to collect absorbed material. Pick up with suitable absorbent material and transfer to a container for chemical waste. For large amounts: dike spillage and pump off product into container for chemical waste. Dispose of contaminated material as prescribed.

D. STORAGE AND HANDLING

General Handling

Prevent exposure to ignition sources (i.e., use non-sparking tools and explosion-proof equipment). Avoid contact with eyes, skin, and clothing. Avoid breathing vapor. Wash thoroughly after handling. Keep container closed. Use with adequate ventilation. Use proper bonding and/or ground procedures. However, bonding and grounds may not eliminate the hazard from static accumulation. Peroxides may form upon prolonged storage. Exposure to light, heat or air significantly increases peroxide formation. If evaporated to a residue, the mixture of peroxides residue and material vapor may explode when exposed to heat or shock.

Storage

Keep container tightly closed. Store in a cool, well-ventilated area away from heat and light. Storage containers should be grounded and bonded. Fixed storage containers, transfer containers and associated equipment should be grounded and bonded to prevent accumulation of static charge.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards

The workplace exposure standard for acetic acid in Australia is 10 ppm (25 mg/m^3) as a 8-hr TWA and 15 ppm (37 mg/m^3) as a 15-min STEL.

Engineering Controls

Good general ventilation should be used. Ventilation rates should be matched to conditions. If applicable, use process enclosures, local exhaust ventilation, or other engineering controls to maintain airborne levels below recommended exposure limits. If exposure limits have not been established, maintain airborne levels to an acceptable level.

Personal Protection Equipment

Respiratory Protection:

If workers are exposed to concentrations above the exposure limit, they must use appropriate, certified respirators. If there are no applicable exposure limit requirements or guidelines, use an approved respirator. Selection of air-purifying or positive pressure supplied-air will depend on the specific operation and the potential airborne concentration of the product. For emergency conditions, use an approved positive-pressure self-contained breathing apparatus.

Hand Protection:

Use gloves chemically resistant to this material. Consult the SDS for appropriate glove barrier materials.

Skin Protection:

Use protective clothing chemically resistant to the this material. Selection of specific items such as face shield, boots, apron, or full body suit will depend on the task.

Eye protection*:*
Use chemical goggles.

Other Precautions:
Wash hands, forearms, and face thoroughly after handling chemical products, before eating, smoking, and using the lavatory and at the end of the working period. Appropriate techniques should be used to remove potentially contaminated clothing. Wash contaminated clothing before reusing. Ensure that eyewash stations and safety showers are close to the workstation location.

F. TRANSPORT INFORMATION

For glacial acetic acid or >80% acetic acid solutions:

UN 2789 (ACETIC ACID, GLACIAL or ACETIC ACID SOLUTION)
Class: 8
Packing Group: II

For ≥50% to 80% acetic acid solutions:

UN 2790 (ACETIC ACID SOLUTION)
Class: 8
Packing Group: II

For >10% to <50% acetic acid solutions:

UN 2790 (ACETIC ACID SOLUTION)
Class: 8
Packing Group: III

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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ALCOHOLS, C12-15, ETHOXYLATED

This dossier on alcohols, C12-15, ethoxylated does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of alcohols, C12-15, ethoxylated in its use in drilling muds and hydraulic fracturing fluids. The information presented in this dossier was obtained primarily from the Human & Environmental Risk Assessment on Ingredients of European Household Cleaning Products: Alcohol Ethoxylates (HERA, 2009), and from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA).. Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name: Alcohols, C12-15, ethoxylated

CAS RN: 68131-39-5

Molecular formula: Not available (UVCB substance)

Molecular weight: Not available (UVCB substance)

Synonyms: Alcohols, C12-15, ethoxylated

SMILES: Not available (UVCB substance)

Alcohol ethoxylates (AE) are a class of non-ionic surfactants that have the basic structure $C_{x-y}AE_n$. The subscript (x-y) following the 'C' indicates the range of carbon chain units. The hydrocarbon chain can be either linear or branched. AEs also contain an ethylene oxide (E) chain attached to the alcohol. The degree of ethylene oxide polymerization is indicated by the subscript (n) which indicates the average number of ethylene oxide units. Alcohols, C12-15, ethoxylated (CAS No. 68131-39-5) has an average number of 1 to 2.5 moles of ethylene oxide units.

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Alcohols, C12-15, Ethoxylated (1 to 2.5 moles ethoxylated)

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Clear liquid with a rancy odor*	2	ECHA
Melting Point	7.22°C	2	ECHA
Boiling Point	ca. 287°C	1	ECHA
Density	0.926 g/cm^3 @ 15.56°C	1	ECHA

Vapor Pressure	Negligible	-	ECHA
Partition coefficient (log K_{ow})	5.06* @ 25°C	2	ECHA
Water Solubility	7 – 63 mg/L @ 25°C	2	ECHA
Flash Point	165.56°C	2	ECHA
Auto flammability	235°C	2	ECHA
Viscosity	28.1 mPA s (dynamic) @ 20°C	2	ECHA

*Based on alcohols, C12-14, ethoxylated (1 to 2.5 EO) [CAS No. 68439-50-9]
**Weight-averaged log K_{oc} of whole substance based on normalized composition

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Alcohols, C12-15, ethoxylated is readily biodegradable. It has a low potential for bioaccumulation and a moderate potential for absorption to soil and sediment.

B. Biodegradation

Alcohols, C12-15, ethoxylated is readily biodegradable. In an OECD 301B test, degradation was 72% in 28 days, but failed the 10-day window (ECHA) [Kl. score = 1].

An alcohol, C12-15, ethoxylated (7 EO) degraded 80 to 88% in 28 days when tested using a shake-flask CO_2-evolution test method (ECHA) [Kl. score = 2].

C. Environmental Distribution

Adsorption/desorption

No experimental data are available for alcohols, C12-15, ethoxylated. Using KOCWIN in EPISUITE™ (EPA, 2019), the estimated K_{oc} values for surrogates of alcohols, C12-15, ethoxylated are:

C12 linear alcohol, ethoxylated (2 EO): 279.5 L/kg (MCI) and 464.2 L/kg (K_{ow})

C15 linear alcohol, ethoxylated (2 EO): 1,691 L/kg (MCI) and 3,018 L/kg (K_{ow})

E. Bioaccumulation

The BCF values for alcohol ethoxylates in fathead minnows have been reported to range from <5 to 387.5 (Toll et al., 2000). The uptake rates varied from 330 to 1660 (L x kg/d) and elimination rates varied from 3.3 to 59 per day (Toll et al., 2000). The high concentrations in fish is thought

to be prevented by an efficient biotransformation of the alcohol ethoxylates, leading to a high elimination rate.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

The acute toxicity of alcohols, C12-15, ethoxylated is low by the oral and dermal routes. The skin irritation rabbit studies on alcohols, C12-15, ethoxylated have shown mixed results, but human patch studies on these alcohol ethoxylates do not support a skin irritant classification. Alcohols, C12-15, ethoxylated is expected to be irritating to the eyes of rabbits. Alcohols, C12-15, ethoxylated is not a skin sensitizer. Repeated dose toxicity studies on alcohol ethoxylates similar to alcohols, C12-15, ethoxylated in rats do not indicate any target organ effects. These alcohol ethoxylates are not genotoxic, carcinogenic, and have a low potential for reproductive and developmental toxicity.

B. Acute Toxicity

No acute toxicity studies are available on alcohols, C12-15, ethoxylated.

The oral LD_{50} in rats for $C_{12\text{-}15}AE_3$ is >5,000 mg/kg (ECHA) [Kl. score = 2]. The oral LD_{50} in rats for $C_{12\text{-}15}AE_7$ is 1,700 mg/kg (HERA, 2009) [Kl. score = 2]. The oral LD_{50} value in rats for $C_{12\text{-}13}AE_{6.5}$ is 2,100 mg/kg (HERA, 2009) [Kl. score = 2]. The oral LD_{50} value in rats for $C_{12\text{-}15}AE_{11}$ is >2,000 mg/kg in males and between 1,000 and 2,000 mg/kg in females (HERA, 2009) [Kl. score = 2]. The oral LD_{50} values in rats for $C_{14\text{-}15}AE_{13}$ in two separate studies are 1,100 and 1,000 mg/kg (HERA, 2009) [Kl. score = 2]. The relative number of EO units, but not the carbon chain length, appears to influence acute oral toxicity (HERA, 2009).

An acute dermal LD_{50} values of >2,000 mg/kg were determined for $C_{12\text{-}14}AE_3$ and $C_{12\text{-}14}AE_6$ in two separate studies (HERA, 2009) [Kl. score = 2]. The acute dermal LD_{50} of $C_{12\text{-}15}AE_7$ is >2,000 mg/kg (HERA, 2009) [Kl. score = 2].

C. Irritation

Skin
Application of 0.5 mL isotridecanol, ethoxylated (3 EO) to the skin of rabbits for 4 hours under occlusive conditions was considered irritating (ECHA) [Kl. score = 2].

Application of 0.5 mL isotridecanol, ethoxylated (3 EO) to the skin of rabbits for 4 hours under semi-occlusive conditions was not considered irritating (ECHA) [Kl. score = 2].

In a 24-hour human patch test, there was some short-lived redness in some individuals from the application of $C_{12\text{-}14}AE_3$, but there was no scaling or edema in any subjects (HERA, 2009) [Kl. score = 2].

In a standard 4-hour human patch test, the irritation potential of $C_{12\text{-}15}AE_5$ and $C_{12\text{-}15}AE_5$ were compared to 20% sodium dodecyl sulfate (which is classified a skin irritant under GHS). The results showed that neither alcohol ethoxylate should be classified as a skin irritant (Basketter et al., 2004) [Kl. score = 2].

Eye

Most alcohol ethoxylates tested as the undiluted neat test material are moderately to severely irritating to the eyes of rabbits, with an eye irritation index (EII) ranging from >25 to 50 (HERA, 2009). The alcohol ethoxylates $C_{12\text{-}14}AE_3$, $C_{12\text{-}14}AE_6$, $C_{13}AE_6$, and $C_{12\text{-}14}AE_{10}$ were found to be moderately to severely irritating to the eyes of rabbits (HERA, 2009). In another study, $C_{12\text{-}15}AE_{11}$ was considered moderately to severely irritating to the eyes of rabbits (HERA, 2009).

Some alcohol ethoxylates were reported to be practically or minimally irritating to the eyes of rabbits with EII scores of 0.5 to 15. These alcohol ethoxylates include: $C_{12\text{-}15}AE_3$, $C_{14\text{-}15}AE_7$, $C_{12\text{-}14}AE_{15}$, $C_{14\text{-}15}AE_{18}$, and $C_{13}AE_{20}$ (HERA, 2009).

D. Sensitization

No sensitization studies are available on alcohols, C12-15, ethoxylated.

In a guinea pig maximization test, $C_{12\text{-}13}AE_{<2.5}$ (CAS No. 66455-14-9) was not considered a skin sensitizer (ECHA) [Kl. score = 2].

In a guinea pig maximization tests, $C_{12\text{-}15}AE_3$, $C_{12\text{-}15}AE_7$, and $C_{14\text{-}15}AE_7$ were not considered skin sensitizers (HERA, 2009) [Kl. scores = 2].

E. Repeated Dose Toxicity

Oral

Rats were given in their diet 0%, 0.0313%, 0.0625%, 0.125, 0.25, 0.5 or 1.0% $C_{12\text{-}15}AE_7$ for 90 days. The animals in the $\geq$0.25% groups showed significantly reduced body weight gain, which was associated with marked decreases in food and water consumption. Relative liver weights were significantly increased in the $\geq$0.5% male rats and $\geq$0.25% females. Histopathologic examination showed hepatocytic enlargement in the $\geq$0.125% groups, suggesting increased liver metabolism on the basis of increased alkaline phosphatase activity at the higher dose levels. The NOAEL was established at 0.0625% in the diet or 102 mg/kg-day (HERA, 2009) [Kl. score = 2].

Rats were fed $C_{12\text{-}14}AE_7$ in the diet at concentrations of 0%, 0.0313%, 0.0625%, 0.125%, 0.25%, 0.5% and 1.0% for 90 days. The animals in the $\geq$0.25% groups showed significantly reduced body weight gain, which was associated with marked decreases in food and water consumption. Relative liver weights were significantly increased in the $\geq$0.5% male rats and $\geq$0.25% females. Histopathologic examination showed hepatocytic enlargement in the $\geq$0.125% groups, suggesting increased liver metabolism on the basis of increased alkaline phosphatase activity at the higher dose levels. The NOAEL was established at 0.0625% in the diet or 110 mg/kg-day (HERA, 2009) [Kl. score = 2].

Male and female Wistar rats given in their diet 0, 300, 1,000, 3,000, and 10,000 ppm $C_{14\text{-}15}AE_7$ for 90 days. There were no deaths during the study. Mean body weights and feed were lower in 10,000 ppm males and the 3,000 ppm females. Feed consumption was lower in the 10,000 ppm animals and the 3,000 ppm females. Relative liver weights were increased in the $\geq$3,000 ppm

animals, and relative spleen weights were increased in the 10,000 ppm males. Clinical chemistry changes were noted in the 10,000 ppm group and consisted of significantly higher urea, chloride and potassium levels in males; significantly higher urea, chloride and cholesterol in females. Increased total leucocytes and lymphocytes were seen in the 10,000 ppm animals and in the 3,000 ppm males. The 10,000 ppm females showed lower numbers of neutrophils; mean cell volume and mean cell hemoglobin were identified in one or both sexes fed in the ≥3,000 ppm dose groups. In the 1,000 ppm females, there were minor, but statistically significant changes in the liver and kidney weights and plasma urea concentration; these effects were considered to be of no toxicological significance. Histopathologic examination showed no treatment-related effects at any dose level. The NOAEL for this study is 1,000 ppm in the diet, which corresponded to 50 mg/kg-day (HERA, 2009) [Kl. score = 2].

Rats were given in their diet 0, 0.1, 0.5, or 1% $C_{14\text{-}15}AE_7$ for 90 days. Body weights, food intake, organ weights, and hematology and clinical chemistry parameters were similar across groups. The NOAEL for this study is 1% in the diet, which corresponded to 700 and 785 mg/kg-day for males and females, respectively (HERA, 2009) [Kl. score = 2].

Rats were given in their diet 0, 0.1, 0.5 or 1% $C_{12\text{-}13}AE_{6.5}$ or $C_{14\text{-}15}AE_7$ for two years. Body weight gain was reduced in the 1% males and ≥0.5% females, which was likely due to the reduced food consumption in these animals. At study termination, organ to body weight ratios were increased in the ≥0.5% females (liver, kidney and brain), 1% females (heart), and 1% males (liver). A dose-related focal myocarditis was observed in males. While focal myocarditis is commonly observed in non-treated aging rats, the incidence in the treated animals were higher than in the controls. The NOAEL was established at 0.1% or 50 mg/kg-day (HERA, 2009) [Kl. score = 2].

Male and female CR rats were given in their diet $C_{14\text{-}15}AE_7$ at 0.1, 0.5 and 1% for two years. A treatment-related body weight depression was observed in females at the two highest treatment levels and in males at the 1% dose level, probably due to the poor palatability of the diet. Relative liver, kidney, heart, and thyroid/parathyroid gland weights were increased in the 1% dietary group at study termination. Histopathological examination showed a dose-related increase in the incidence of focal myocarditis at the 12-month time point, but not at the end of the study at two years. The NOAEL for this study was considered to be 0.5% in the diet, which corresponded to 162 and 190 mg/kg-day for males and females, respectively (HERA, 2009) [Kl. score = 2].

Inhalation

No studies are available.

Dermal

No adequate studies are available.

F. Genotoxicity

In Vitro Studies

The genotoxicity studies conducted on alcohol ethoxylates are reviewed in HERA (2009). The results of few of the *in vitro* studies on similar alcohol ethoxylates to alcohols, C12-15,

ethoxylated are presented below in Table 2.

Table 2: *In Vitro* Genotoxicity Studies on Selected Alcohol Ethoxylates

Test Substance	Test System	Results*		Klimisch Score	References
		-S9	+S9		
$C_{14-15}AE_7$	Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	HERA, 2009
$C_{14-15}AE_7$	Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	HERA, 2009
$C_{14}AE_{12}$	Chromosomal aberrations (CHO cells)	-	-	2	HERA, 2009

*+, positive; -, negative

In Vivo Studies

In two separate studies, CD-1 mice were given an intraperitoneal dose of 0, 50, or 100 mg/kg $C_{12-15}AE_3$ or $C_{12-14}AE_9$. There were no increases in the frequency of micronuclei in the bone marrow cells (Talmage, 1994) [Kl. score = 2].

Male and female Tunstall rats were given a single oral gavage dose of 0, 250, 500, or 1,000 mg/kg $C_{14-15}AE_7$. There were no increases in chromosomal aberrations in the bone marrow cells (HERA, 2009 [Kl. score = 2].

G. Carcinogenicity

No studies are available on alcohols, C12-15, ethoxylated.

Male and female Sprague-Dawley rats were given in their diet $C_{12-13}AE_{6.5}$ in the diet at doses up to 1% (500 mg/kg-day). Reduced food consumption was noted at the higher dose levels (*i.e.*, 0.5 and 1% for females and 1% for males), resulting in a lower body weight gain compared to the control group. No treatment-related histopathology was found and no increase in tumor incidence was observed (HERA, 2009) [Kl. score = 2].

Male and female Charles River rats were given in their diet 0, 0.1, 0.5 or 1% $C_{14-15}AE_7$ for two years. There were no treatment-related changes in general behavior and appearance. The survival rate of the test animals was comparable if not better than the controls. Body weights of the 0.5% females and the 1% males and females had significantly lower weight gains than the control. There were no treatment-related effects on organ weights and tumor incidence (HERA, 2009) [Kl. score = 2].

Male and female Sprague-Dawley rats were given in their diet $C_{14-15}AE_7$ at 0.1, 0.5 and 1% for two years. A treatment-related body weight depression was observed in females at the two highest treatment levels and in males at the 1% dose level, probably due to the poor palatability of the diet. There was no evidence for any carcinogenic activity (HERA, 2009) [Kl. score = 2].

H. Reproductive Toxicity

No studies are available on alcohols, C12-15, ethoxylated.

CD rats were given in their diet 0, 0.05, 0.1 or 0.5% (approximately 0, 25, 50 or 250 mg/kg-day) $C_{12}AE_6$ in a two-generation reproductive toxicity study. There were no treatment related effects in the parents or pups on general behavior, appearance or survival. At 0.5%, there was reduced weight gain in both the parental animals and the pups compared to the controls. Fertility was unaffected by treatment. The NOAEL for reproductive toxicity is 0.5% in the diet, which corresponds to 250 mg/kg-day (HERA, 2009) [Kl. score = 2].

In a two-generation developmental and teratogenicity study, CD rats were given in their diet 0, 0.05, 0.1 or 0.5% $C_{14\text{-}15}AE_7$ (approximately 0, 25, 50 or 250 mg/kg-day). Three of the treated groups were given the test substance continuously throughout the study; in the other three groups the females received the test substance on GD 6-15 and the males were untreated. None of the deaths of parental rats during the study was considered to be compound-related. There were no treatment-related changes in behavior or appearance in the parental rats or pups. Slightly lower body weight gain was noted in the 0.5% continuously treated females. Food consumption was similar for control and treated rats. Fertility, gestation and viability indices were similar across groups. The average 21-day body weights for the 0.5% continuous treated pups were significantly lower than that of the control. Relative liver weights of the 0.5% continuously treated F_1 parental animals were increased at the 91-day sacrifice; relative liver weights of the 0.5% continuously treated males were also increased at the 60-day and caesarean section sacrifices. There were no treatment-related histopathological lesions in any of the tissues from the F_0 and F_1 generations. The NOAEL for reproductive toxicity is 0.5% in the diet or 250 mg/kg-day (HERA, 2009) [Kl. score = 2].

I. Developmental Toxicity

No studies are available on alcohols, C12-15, ethoxylated.

In a two-generation reproductive toxicity study, Charles River rats were given in their diet 0, 0.05, 0.1 or 0.5% (about 0, 25, 50 or 250 mg/kg-day) $C_{12}AE_6$. General behavior, appearance and survival were unaffected by treatment. At the 0.5% dose level, adults and pups gained less weight than the control rats. In the 0.5% dose group, there was a statistical increase in embryo lethality and soft tissue anomalies and at the 0.1% there was a statistical decrease in mean fetal liver weight. Neither of these effects was considered to be treatment-related by the authors as they showed no dose response characteristics. The NOAEL for maternal toxicity is 50 mg/kg-day. The NOAEL for developmental and teratogenicity is 0.1% in the diet or 50 mg/kg-day (HERA, 2009) [Kl. score = 2].

Pregnant rabbits were given by oral gavage 0, 50, 100 or 200 mg/kg $C_{12}AE$ from gestational days 2 to 16. Nine control rabbits and 31 treated rabbits died during the study. Surviving rabbits at the 200 mg/kg dose group generally showed slight losses of body weight. At 100 and 200 mg/kg, ataxia and a slight decrease in body weight was observed in the pregnant animals. In seven treated and two control rabbits, early deliveries were recorded. There were no treatment-related effects on corpora lutea, implantations, number of live fetuses and spontaneous abortions. The NOAEL for maternal toxicity is 50 mg/kg-day; the NOAEL for developmental toxicity is 200 mg/kg-day (HERA, 2009) [Kl. score = 2].

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for alcohols, C12-15, ethoxylated follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

Two-year dietary studies in rats have been conducted on alcohol ethoxylates $C_{12\text{-}13}AE_{6.5}$ and $C_{14\text{-}15}AE_{7}$ (HERA, 2009). The lowest NOAEL from these studies is 50 mg/kg-day based on increased organ weights. The NOAEL of 50 mg/kg-day will be used to derive an oral reference dose and drinking water guidance value for alcohols, C12-15, ethoxylated.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 50/(10 x 10 x 1 x 1 x 1) = 50/100 = 0.5 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (0.5 x 70 x 0.1)/2 = 1.8 mg/L

B. Cancer

Several alcohol ethoxylates similar to alcohols, C12-16, ethoxylated were not carcinogenic to rats in a two-year dietary study. Thus, a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Alcohols, C12-15, ethoxylated does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Alcohol, C12-15, ethoxylated has moderate chronic toxicity concern to aquatic life.

B. Aquatic Toxicity

In developing a water quality guideline for alcohol ethoxylates (ANZECC, 2000), the toxicity data was normalized for a specific alkyl chain length or a specific number of ethoxylate (EO) groups. The NOECs listed below were normalized to an alkyl chain length of C13.3 and EO of 8.2.

Freshwater fish: 2 species, 720 to 1,500 μg/L.

Freshwater crustaceans: 2 species, 590 to 860 μg/L.

Freshwater rotifers: 1 species, *Brachionus calyciflorus*, 1,300 μg/L

Freshwater algae, diatoms and blue-green algae: 6 species, 200 to 8,700 μg/L.

Freshwater mesocosms: 4 NOEC data for multiple species tests were 80, 80, 320, and 330 μg/L, although replication was insufficient to meet OECD (1992) requirements. Normalized data were 380, 380, 320, and 1,520 μg/L.

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

$PNEC_{water}$: The ANZECC water quality guideline (2000) for freshwater is: **"A high reliability trigger value of 140 μg/L was derived for AE (normalized data) using the statistical distribution method with 95% protection."**

For the purposes of calculating the PNEC values for sediment and soil, the $PNEC_{water}$ will be 0.14 mg/L.

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ values are 0.9 to 5.6 mg/kg soil dry weight.

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
$= (9.28/1500) \times 1000 \times 0.14$
$= 0.87$

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
$= (60.36/1500) \times 1000 \times 0.14$
$= 5.63$

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
$= 464 \times 0.02$
$= 9.28$

$Kp_{soil} = K_{oc} \times f_{oc}$
$= 3{,}018 \times 0.02$
$= 60.36$

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} values for alcohols, C12-15, ethoxylated based on K_{ow} values range from 464 to 3,018 L/kg (see section III.C)
.
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Alcohols, C12-15, ethoxylated is readily biodegradable and thus does not meet the screening criteria for persistence.

The bioconcentration factors (BCF) in fish for ethoxylated alcohols (which includes alcohols, C12-15, ethoxylated) have been reported to range from <5 to 387.5. Thus, alcohols, C12-15, ethoxylated does not meet the screening criteria for bioaccumulation.

The chronic NOEC values for alcohols ethoxylates are >0.1 mg/L. Thus, alcohols, C12-15, ethoxylated do not meet the criteria for toxicity.

The overall conclusion is that alcohols, C12-15, ethoxylated is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Acute Toxicity Category 4 [Oral]
Eye Irritant Category 2
Aquatic Chronic Toxicity Category 3

B. Labelling

Warning

C. Pictogram



X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
Rinse immediately with plenty of running water. If easy to do, remove contact lenses. Get medical attention.

Skin Contact
Wash with soap and water. Get medical attention if symptoms occur.

Inhalation
Treat symptomatically. Move to fresh air. Get medical attention.

Ingestion
Rinse mouth with water and then drink plenty of water. Never give anything by mouth to an unconscious person. Seek medical attention.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, dry chemical, foam. Do not use water jet.

Specific Exposure Hazards
May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: carbon monoxide, carbon oxides.

Special Protective Equipment for Firefighters
Self-contained breathing apparatus and full protective clothing must be worn in case of fire.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Wear appropriate personal protective equipment. Do not breath mist or aerosol.

Environmental Precautions
Prevent from entering sewers, waterways, or low area

Steps to be Taken if Material is Released or Spilled
Absorb spill with inert absorbent material, then place in a container for chemical waste.

D. STORAGE AND HANDLING

General Handling
Protect against moisture. Shut containers immediately after taking product because product takes up the humidity of air. No special precautions are necessary beyond normal good hygiene practices.

Other Handling Precautions
Wash hands thoroughly after handling. Avoid breathing mists or aerosols.

Storage
Keep container closed.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards

Workplace Australia has not established an occupational exposure standard for isotridecanol, ethoxylated.

Engineering Controls
Good general ventilation should be used.

Personal Protection Equipment

Respiratory Protection:
Wear respiratory protection if ventilation is inadequate.

Hand Protection:
Chemical resistant protective gloves.

Skin Protection:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Chemical safety goggles.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible.

F. TRANSPORT INFORMATION

Isotridecanol, ethoxylated is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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AMIDES, TALL OILS FATTY, N,N-BIS(HYDROXYETHYL)

This dossier on amides, tall oils fatty, N,N-bis(hydroxyethyl) does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of amides, tall oils fatty, N,N-bis(hydroxyethyl) in its use in drilling muds and hydraulic fracturing fluids. The information presented in this dossier was obtained from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997; Kl).

I. SUBTANCE IDENTIFICATION

Chemical Name: Amides, tall oils fatty, N,N-bis(hydroxyethyl)

CAS RN: 68155-20-4

Synonyms:

Synonyms for oleamide DEA listed below.

While no specific composition data are available on amides, tall oils fatty, N,N-bis(hydroxyethyl), it is expected to be a mixture of diethanolamides of the fatty acids that constitute tall oil, which is composed of predominantly C18 unsaturated fatty acids: 48% oleic acid, 35% linoleic acid, 7% conjugated linoleic acid (REF).

This dossier is based on information on Amides, C18-unsatd, N,N-bis(hydroxyethyl) [CAS No. 93-83-4]. This is justified because amides, tall oils fatty, N,N-bis(hydroxyethyl) is predominantly diethanolamides of unsaturated C18 fatty acids and there are no available studies on this substance.

AMIDES, C18-UNSATD., N,N-BIS(HYDROXYETHYL)

Chemical Name: Oleamide DEA

CAS RN: 93-83-4

Molecular formula: UVCB substance

Molecular weight: UVCB substance

Synonyms for oleamide DEA:
Oleyl diethanolamide;(9Z)-N,N-Bis(2-hydroxyethyl)-9-octadecenamide; (z)-n,n-bis(2-hydroxyethyl)-9-octadecenamide; 9-Octadecenamide, N,N-bis(2-hydroxyethyl)-, (Z)-; Alkamide DO-280;

N,N-Bis(2-hydroxyethyl)-9-octadecenamide; Alrosol O; Amisol ode; Clindrol 2000; Clindrol 2020, Comperlan OD; Diethanololeamide; EMID 6545; Emulsifier WHC; Lauridit OD; Mackamide O, Marlamid D 1885, N,N-Diethanololeamide, Nitrene NO, Oleamide, N,N-bis(2-hydroxyethyl)-, Oleic acid diethanolamide, Oleic acid diethanolamine condensate, Oleic diethanolamide, Schercomid ODA, Stafoam DO, Steinamid DO 280SE, Witcamide 511C

SMILES: Not applicable.

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Amides, C18-unsatd, N,N-bis(hydroxyethyl) [CAS No. 93-83-4]

Property	Value	Klimisch score	Reference
Physical state at 20ºC and 101.3 kPa	Liquid	2	ECHA
Melting point	ca. -80ºC	1	ECHA
Boiling point	>300ºC	1	ECHA
Density	0.967 g/cm^3@ 20ºC	1	ECHA
Vapor pressure	0 Pa @ 25ºC	1	ECHA
Partition coefficient (log K_{ow})	>6 (experimental)	1	ECHA
Water solubility	<1 mg/L @ 20ºC	1	ECHA
Flash point	218ºC	1	ECHA
Auto flammability	350ºC	1	ECHA
Viscosity	805.87 mPa s @ 20ºC	1	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

According to ECHA, hydrolysis studies were not conducted; “the study does not need to be conducted because the substance is readily biodegradable.” (ECHA)

B. Biodegradation

Amides, C18-unsatd, N,N-bis(hydroxyethyl) is readily biodegradable. In an OECD 301 D test, degradation was 70% after 28 days (ECHA) [Kl. score = 1]. In an OECD 301 B test, degradation was 79% after 14 days and 86% after 28 days (ECHA) [Kl. score = 1].

C. Environmental Distribution

Adsorption/desorption

No experimental data are available for amides, C18-unsatd, N,N-bis(hydroxyethyl). Using KOCWIN v2.00, the estimated K_{oc} values for the individual components were calculated using the molecular connectivity index (MCI) approach. The final K_{oc} value was calculated on a weighted-average basis using the mole fractions of the individual components. The final K_{oc} value is 1,717 L/kg.

D. Bioaccumulation

There are no bioaccumulation studies on amides, C18-unsatd, N,N-bis(hydroxyethyl). The bioaccumulation potential of amides, C18-unsatd, N,N-bis(hydroxyethyl) was estimated using BCFBAF v3.01. The final BCF was calculated on a weighted-average basis using the mole fractions of all individual components. The calculated BCF was 112.53 L/kg, indicating a low potential for bioaccumulation (ECHA).

IV. HUMAN HEALTH HAZARD ASSESSMENT

Human health toxicity data were obtained from ECHA, unless another source is explicitly cited.

A. Summary

Amides, C18-unsatd, N,N-bis(hydroxyethyl) are considered acutely toxic and an skin and eye irritant. It is not considered a skin sensitizer or toxic via repeated doses, and has no reported reproductive or developmental effects. It is not considered genotoxic or carcinogenic.

B. Acute Toxicity

Amides, C18-unsatd, N,N-bis(hydroxyethyl) is considered acutely toxic via oral route of exposure, with an LD50 of 10,000 mg/kg in male Sprague-Dawley rats (Kl = 2).

C. Irritation

Based on the available data, the test substance is considered irritating to both the skin and eyes. The available in vivo studies demonstrate:

- Clear irritation response following semi-occlusive exposure to the test substance for 24 h. The data support a classification as Skin Irrit. 2 - H315 (causes skin irritation) according to CLP (EC 1272/2008) criteria (Kl =1).

- Undiluted test substance showed irritation to rabbit eyes and supports classification as Eye Irrit. 2 – H319 (causes serious eye irritation) according to CLP (EC 1272/2008) criteria (Kl = 1).

D. Sensitization

The test substance is not expected to be a skin sensitiser based on a negative in vivo skin sensitisation study conducted on a structurally similar substance (Kl=1). Therefore no classification is required for sensitisation according to CLP (EC 1272/2008) criteria. There are no data on the respiratory sensitization potential of the substance.

E. Repeated Dose Toxicity

Based on the NOAEL derived from an oral subacute study in rat (>750 mg/kg bw/day) in which no treatment-related effects were observed, and observed effects in a chronic dermal study in rat (NOAEL of 50 mg/kg bw/day for systemic effects and LOAEL of 50 mg/kg bw/day for local effects), the test substance is not considered to meet the requirements for repeated dose toxicity classification according to CLP (EC 1272/2008) criteria. There are no data to evaluate the repeated dose toxicity classification for the inhalation exposure route.

F. Genotoxicity

The test substance and read across substance (amides, C8-18 (even numbered) and C18-unsatd. N,N bis(hydroxyethyl) were negative in short-term in vitro and in vivo genotoxicity tests. Therefore no classification is required for this endpoint according to CLP (EC 1272/2008) criteria.

In Vitro Studies

The *in vitro* studies conducted for this substance are described in Table 2. The referenced studies indicate that the substance is not mutagenic or genotoxic *in vitro.*

Table 2: *In vitro* Genotoxicity Studies

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
In vitro gene mutation study in bacteria (*S. typhimurium* TA97, TA98, TA100 and TA1535)	-	-	2	Irwin, 1999**
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	-	-	1	Irwin, 1999**
Bacterial reverse mutation (S. typhimurium and E. coli strains)	-	-	1	Verspeek-Rip, 2014**

*+, positive; -, negative. ** As cited in ECHA.

In Vivo Studies

A study was conducted to evaluate the potential of the test material to induce micronuclei in B6C3F1 mice. Under the conditions of the study, the test substance did not increase the frequencies of micronucleated normochromatic erythrocytes (NCEs) in peripheral blood of both male and female mice at the end of 13 weeks (Kl =1).

G. Carcinogenicity

No studies are available for assessing the carcinogenicity of this substance via the oral or inhalation routes of exposure.

Rodent tests indicate that the substance is not carcinogenic by the dermal route. A study was conducted to evaluate the effects of chronic exposure to the test substance in B6C3F1 mice. Under the test conditions, no evidence of carcinogenic activity was observed with the test substance at any tested dose levels in mice (Kl =1). A study was conducted to evaluate the effects of chronic exposure to the test substance in F344/N rats. Under the test conditions, no evidence of carcinogenic activity was observed with the test substance at any tested dose levels in rats (Kl =1).

H. Reproductive and Developmental Toxicity

No studies were available to assess the effects of the substance on reproduction. No adverse developmental effects were observed following administration of 1,000 mg/kg bw day to pregnant Sprague-Dawley rats (Kl = 2).

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

The lowest NOAEL from these studies is a 750 mg/kg bw/day based on bodyweight, hematology, clinical chemistry, urinalysis, gross and microscopic pathology in male and female rats from a 28-day oral gavage study (Potokar, 1983). The NOAEL of 750 mg/kg-day will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10

UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 10
UF_D (database uncertainty) = 1

Oral RfD = 750/(10 x 10 x 1 x 10 x 1) = 750/1000 = 7.5 mg/kg-day

Drinking water guidance value

The drinking water guidance value is calculated as:

(animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD, the drinking water guidance value is calculated as:

(oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:

Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (7.5 x 70 x 0.1)/2 = 26.3 mg/L

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies conducted on amides, C18-unsatd, N,N-bis(hydroxyethyl).

Table 3: Acute Aquatic Toxicity Studies on Amides, C18-unsatd, N,N-bis(hydroxyethyl)

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Danio rerio	96-hr LC_{50}	5.1	1	ECHA
Daphnia magna	48-hr EC_{50}	3.2	2	ECHA
Desmodesmus subspicatus	72-hr EC_{50}	18.6	2	ECHA

Chronic Studies

The 28-day NOEC to *Oncorhynchus mykiss* in a fish chronic toxicity study is 0.32 mg/L [nominal] and 0.26 mg/L [measured] (ECHA) [Kl. score = 2].

The 21-d NOEC in a *Daphnia* reproduction test is 0.1 mg/L [nominal] and 0.07 mg/L [measured] (ECHA) [Kl. score = 2].

The 72-hr EC_{10} to *Desmodesmus subspicatus* is 1.4 mg/L (ECHA) [Kl. score = 2].

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for amides, C18-unsatd, N,N-bis(hydroxyethyl) follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (5.1 mg/L), invertebrates (3.2 mg/L), and algae (18.6 mg/L). Results from chronic studies are available for fish (0.26 mg/L), invertebrates (0.07 mg/L), and algae (1.4 mg/L). On the basis that the data consists of short-term and long-term results for three trophic levels, an assessment factor of 10 has been applied to the lowest reported NOEC or EC_{10} value of 0.07 mg/L for invertebrates. The $PNEC_{water}$ is 0.007 mg/L.

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is 0.16 mg/kg soil dry weight.

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
$= (34.34/1500) \times 1000 \times 0.007$
$= 0.16$

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
$= 1717 \times 0.02$
$= 34.34$

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for Amides, C18-unsatd, N,N-bis(hydroxyethyl) based on the molecular connectivity index (MCI) is 1,717 L/kg (ECHA).
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Amides, C18-unsatd, N,N-bis(hydroxyethyl) is readily biodegradable; thus, it does not meet the screening criteria for persistence.

Based on an estimated BCF value of 113 L/kg, amides, C18-unsatd, N,N-bis(hydroxyethyl) does not meet the criteria for bioaccumulation.

The lowest chronic NOEC or EC_{10} value for amides, C18-unsatd, N,N-bis(hydroxyethyl) is <0.1 mg/L. Thus, amides, C18-unsatd, N,N-bis(hydroxyethyl) meets the criteria for toxicity.

The overall conclusion is that amides, C18-unsatd, N,N-bis(hydroxyethyl) is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Skin Irritant Category 2
Eye Irritant Category 2
Aquatic Chronic Toxicity Category 2

May cause respiratory tract irritation.

B. Labelling

Warning

C. Pictogram



X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
Rinse thoroughly for at least 15 minutes and consult a physician.

Skin Contact
Remove contaminated clothing. Wash with soap and plenty of water. Consult a physician immediately.

Inhalation
Move the person to fresh air.

Ingestion
Rinse mouth with water; consult a physician immediately. Do not induce vomiting.

Notes to Physician
No data available

Medical Conditions Aggravated by Exposure

No data available

Emergency Personnel Protection
No additional notes

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, alcohol-resistant foam, dry chemical, or carbon dioxide.

Specific Exposure Hazards
May be combustible at high temperatures; container explosion may occur under fire conditions or if heated. Hazardous combustion products include carbon oxides and nitrogen oxides.

Special Protective Equipment for Firefighters
As in any fire, wear self-contained breathing apparatus and full protective gear.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Remove all sources of ignition. Ensure adequate ventilation. Use personal protective equipment. Avoid dust formation. Avoid breathing vapours, mist, or gas. Evacuate unprotected persons.

Environmental Precautions
Stop the spill if possible and safe. Prevent from reaching drains, sewers, or waterways.

Steps to be Taken if Material is Released or Spilled
Contain spill material by diking or using inert absorbent such as vermiculite, dry sand, or earth. Transfer to a disposal or recovery container.

D. STORAGE AND HANDLING

General Handling
Avoid contact with skin and eyes. Avoid formation of dust and aerosols.

Other Handling Precautions
Provide appropriate exhaust ventilation at places where dust is formed. Do not eat or drink while working with chemical substances.

Storage

Store in a cool, dry, well-ventilated place. Keep container tightly closed.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
No data available.

Engineering Controls
Provide ventilation.

Personal Protection Equipment

Respiratory Protection:
Wear dust mask when handling large quantities

Hand Protection:
Wear impervious gloves, inspect gloves before use.

Skin Protection:
Wear impervious clothing; PPE is to be selected according to the concentration and amount of the substance to be handled.

Eye protection*:*
Safety glasses with side-shields conforming to EN166. Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

Other Precautions:
No data available

F. TRANSPORT INFORMATION

UN Number: Not regulated

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

XIII. REFERENCES

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

Department of the Environment, Water, Heritage and the Arts [DEWHA] (2009). Environmental risk assessment guidance manual for industrial chemicals, Department of the Environment, Water, Heritage and the Arts, Commonwealth of Australia.

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U.S. Environmental Protection Agency [EPA] (2019). EPISuite™ v. 4.11, United States Environmental Protection Agency, Office of Pollution Prevention and Toxics and Syracuse Research Corporation. Available at: https://www.epa.gov/tsca-screening-tools/epi-suitetm-estimation-program-interface.

BUTYL ALCOHOL (1-BUTANOL)

This dossier on butyl alcohol (1-butanol) does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of 1-butanol in its use in drilling muds and hydraulic fracturing fluids. The information presented in this dossier was obtained from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997; Kl).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC): Butan-1-ol

CAS RN: 71-36-3

Molecular formula: C4H10O

Molecular weight: 74.123

Synonyms: 1-Butanol, 1-Butyl alcohol, 1-hydroxybutane, Butan-1-ol, butyl alcohol, Butyl hydroxide, Butylalcohol, CCS 203, ET5740PTB, Hemostyp, Methylolpropane, n-Butanol, n-Butyl alcohol, N300PTB, Nacol 4, PP100, Propylcarbinol

SMILES: CCCCO

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of 1-Butanol

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Clear, colorless liquid with an alcoholic odor	2	ECHA
Melting point	<-90°C	2	ECHA
Boiling point	119°C	2	ECHA
Density	0.81 g/cm^3 @ 20°C	2	ECHA
Vapor pressure	< 10 hPa @20°C	2	ECHA
Partition coefficient (log K_{ow})	1 @ 25°C	1	ECHA

Property	Value	Klimisch score	Reference
Water solubility	66 g/L @ 20°C	1	ECHA
Flash point	35°C	2	ECHA
Auto flammability	355°C	1	ECHA
Viscosity	2.947 mPa s @ 20°C	2	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

1-Butanol is readily biodegradable and not expected to bioaccumulate. No experimental data are available for adsorption/desorption; the estimated Koc value is 3.471 L/kg.

A calculated logKoc of 0.54 is available, suggesting a high mobility of 1-butanol in soil.

B. Biodegradation

1-Butanol is readily biodegradable. In a BOD test, degradation was 87% after 10 days and 92% after 20 day, meeting the 10-day window (ECHA) [Kl. score = 2].

C. Environmental Distribution

Adsorption/desorption

No experimental data are available for 1-butanol. Using KOCWIN in EPISUITE™ (EPA, 2019), the estimated K_{oc} value from log K_{ow} is 10.01 L/kg. The estimated K_{oc} value from the molecular connectivity index (MCI) is 3.471 L/kg.

D. Bioaccumulation

There are no bioaccumulation studies on 1-butanol. 1-Butanol is not expected to bioaccumulate based on a log K_{ow} of 1.0 (ECHA).

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Butyl alcohol is slightly acutely toxic to experimental animals via the oral and dermal routes of exposure; a low acute toxicity was observed after inhalative exposure. The chemical is classified in Australia as respiratory system and skin irritant but is not

considered a skin sensitiser. Butyl alcohol is not expected to be genotoxic; although there are no data on the carcinogenicity of butyl alcohol, based on the lack of genotoxicity, it is not expected to be. Few studies have evaluated reproductive or developmental toxicity but the available studies do not indicate reproductive or developmental effects. Any developmental toxicity is expected to be secondary to maternal toxicity.

B. Acute Toxicity

Butyl alcohol is slightly acutely toxic to experimental animals via the oral and dermal routes of exposure; a low acute toxicity was observed after inhalative exposure.

Oral

The most sensitive LD50 value was provided by a study comparable to OECD TG 401 (Union Carbide Corporation 1967). Here, 60 -day-old female Harlan Wistar rats were dosed with butan-1 -ol at various dose levels per gavage. The acute LD50 value was 2.83 mL/kg bw in female rats, corresponding to 2290 mg/kg bw (calculated with a density of 0.81 g/mL). No further data were available.

A comparable LD50 level was observed in a study following the standard acute method with acceptable restrictions (Jenner et al.1967). In this study, 5 young adult Osborne-Mendel rats per sex were dosed with butan-1-ol at different, but unspecified doses. The rats were observed for 14 days and the LD50 values were calculated. After 14 d observation period, the LD50 was 2510 mg/kg bw in rats. Mortality occurred within 4 -18 h after dosing, and depression and coma were reported as clinical signs. Weighing and performance of necropsy was not reported.

In another oral acute study, groups of 10 female rats were orally gavaged with 3160, 3980, 5000 or 6300 mg/kg and observed for 14 days after dosing. Here, 0, 3, 8 and 10 rats died at dose levels of 3160, 3980, 5000 or 6300 mg/kg, respectively. Deaths following oral doses occurred in many cases within 4 hours and in all but one instance within 24 hours. The LD50 was 4360 mg/kg/bw for female rats (Union Carbide Corporation 1951).

For other common test species oral LD50 values were reported with limited details: 2680 mg/kg bw for mice (Rumyanstev et al., 1979, Val. 4), 3500 mg/kg bw for rabbits (Munch, 1972; Munch and Schwarze, 1925, Val. 4), 1200 mg/kg bw for Golden hamsters (Dubina and Maksimov, 1976, Val. 4), and a minimum lethal dose of 1782 mg/kg bw for dogs (Von Oettingen, 1943, Val. 4). In the ECETOC JACC (2003) document also one publication with an oral LD50 in rats below 2000 mg/kg (790 mg/kg) is reported.

Dermal

The most reliable data were provided by a study comparable to OECD TG 402 (Union Carbide Corporation 1951). Here, butan-1 -ol was applied to the shaved skin of rabbits for 24 hours under occlusive conditions. Four doses of 1.26 to 10 ml/kg were applied to groups of four male rabbits and a LD50 value of 4.24 ml/kg bw (corresponding to ca. 3434 mg/kg bw; calculated with a density of 0.81 g/mL) was determined after an observation period of 14 days. Three rabbits of the 5 mL/kg bw group and all rabbits of

the 10 ml/kg bw group died; all deaths occurred on the day of application. Body weight gain during the observation period was highly variable in the sublethal dose groups and negative in the survivor of the 5 mL/kg bw group. No information regarding clinical signs or local effects was available. In the ECETOC JACC (2003) document further dermal LD50 values in rabbits of 7600, 5300 and 4200 mg/kg are reported.

Inhalation

In a study similar to OECD TG 403, 10 Sprague-Dawley rats per sex per dose were whole-body exposed to vapour atmospheres of butan-1-ol for 4 h and observed for 14 d. The LC0 is >17.76 mg/L; no mortality or clinical signs were observed at 17.76 mg/L; only slightly reduced body weight gain was observed. Therefore, the LD50 level is considered to be > 20 mg/L (BASF 1979).

In another study, which was similar to the inhalation hazard test of OECD TG 403, 12 Sprague-Dawley rats of both sexes were exposed to a vapour saturated butan-1-ol atmosphere for 7 h. None of the animals died (BASF 1980).

Additionally, in a further study comparable to OECD TG 403 no mortalities were observed after exposure to a substantially saturated vapour for 8 hours in male rats and after exposure to 8000 ppm (ca. 24 mg/L) for 4 h in female rats, respectively. Poor coordination or prostration was observed in both trials (Union Carbide Corporation 1951).

C. Irritation

Respiratory Irritation

The chemical is classified in Australia as hazardous with the risk phrase ‘Irritating to respiratory system’ (Xi; R37) in HSIS (Safe Work Australia). The available data from observations in animals and humans support this classification.

Based on an inhalation study in mice, it was reported that 1268 ppm (3909 mg/ m^3) of the chemical was predicted to be intolerable in humans, 127 ppm (390.9 mg/ m^3) would be uncomfortable in humans and 13 ppm (40 mg/ m^3) was expected to have no effect on humans (OECD 2001).

Skin Irritation

The chemical is classified in Australia as hazardous with the risk phrase ‘Irritating to skin’ (Xi; R38) in HSIS (Safe Work Australia). The available data from observations in animals and humans support this classification.

Moderate irritation was reported in a 24 hour patch test (non-guideline study) where 405 or 500 mg of the chemical was applied to the skin of the rabbits. It was reported that these effects may be due to the chemical's defatting (chemical dissolving of dermal lipids from the skin) and drying characteristics (OECD 2001).

Another non-guideline study reported the chemical was a skin irritant in several Vienna white rabbits exposed to 0.5 mL of the chemical for five minutes, one hour or two hours under occlusive conditions. The animals were observed for eight days. The authors concluded that exposure for two hours under occlusive conditions resulted in higher Draize scores and observed superficial necrosis (death of tissue). However, there was no full thickness destruction of the skin (REACH).

Eye Irritation

The chemical is classified in Australia as hazardous with the risk phrase 'Risk of serious damage to the eyes' (Xi; R41) in HSIS (Safe Work Australia). The available data from observations in animals and humans support this classification.

The chemical was reported to be a severe eye irritant when tested according to OECD Test Guideline (TG) 405 using 0.1 mL of the chemical applied to three New Zealand white rabbits. Severe ocular lesions were present at the end of the seven-day observation period, indicating severe eye damage and irreversible effects on the eye (REACH).

The chemical was reported to be a severe eye irritant in rabbits in non-guideline studies where 1.62 or 20 mg of the chemical was applied into rabbit eyes over a 24 or 72 hour period (OECD 2001). An additional non-guideline study reported severe corneal irritation when 0.005 mL of the chemical was applied into rabbit eyes.

D. Sensitization

Based on available repeat dose dermal studies, the chemical is not expected to be a skin sensitiser. OECD (2001) reported that human studies and experience show that the chemical is not likely to be a skin sensitiser.

E. Repeated Dose Toxicity

Oral

A no observed adverse effect level (NOAEL) of 125 mg/kg bw/day and a lowest observed adverse effect level (LOAEL) of 500 mg/kg bw/day in male and female CD rats was reported based on results from a repeat dose oral study (Kl = 1) using the chemical (OECD 2001). Groups of male and female rats (30/sex/group) were administered the chemical via gavage at 0, 30, 125 or 500 mg/kg/day for 13 weeks. It was reported that ataxia (impaired muscle coordination) and hypoactivity were observed at the highest dose during the final six weeks of the study. No treatment related effects were reported in the 30 and 125 mg/kg/ bw/day dose groups (OECD 2001).

Inhalation

In a non-guideline study, the chemical was applied to the skin of rabbits under occlusive conditions over a period of 21 days. Local effects were reported such as drying of the skin, cracking, wrinkling and exfoliation of the epidermis. However, no systemic toxicity was reported (REACH). In another non-guideline repeat dose dermal study on rabbits, 42 to 55 mL/kg of the chemical applied to the skin of rabbits over four consecutive days

resulted in 100 % mortality. However, the same study reported that 30 applications of 20 mL/kg of the chemical over six weeks did not produce any deaths (OECD 2001).

Dermal
No data are available.

F. Genotoxicity
The chemical is not expected to be genotoxic.

The chemical tested negative in a number of tests for genotoxicity. These included several in vitro tests (OECD Guideline 473: mammalian chromosome aberration test on Chinese hamster lung fibroblasts V79; OECD Guideline 471: bacterial reverse mutation assay on *S. typhimurium* TA 98, TA 100, TA 98, TA 1535 and TA 1537; OECD Guideline 476: mammalian cell gene mutation test on Chinese hamster lung fibroblasts V79) and in vivo tests (OECD Guideline 474: mouse micronucleus) (OECD 2001, REACH).

In Vitro Studies

Table 2: *In vitro* Genotoxicity Studies on

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (S. typhimurium strain TA 98, TA 100, TA 98, TA 1535 and TA 1537)	-	-	2	Jung et al., 1992
Mammalian cell gene mutation (Chinese hamster lung fibroblasts (V79))	-	-	1	REACH

*+, positive; -, negative

In Vivo Studies
Fewer studies are available for in vivo testing but are also negative for genotoxicity. According to the results of a reliable mouse study conducted according to OECD Guideline 474 (Mammalian Erythrocyte Micronucleus Test) (Kl =1), the single oral administration of butan-1-ol did not lead to any increase in the number of polychromatic erythrocytes containing either small or large micronuclei. The rate of micronuclei was always in the same range as that of the negative control in all dose groups and at all sacrifice intervals. No inhibition of erythropoiesis determined from the ratio of polychromatic to normochromatic erythrocytes was detected.

G. Carcinogenicity
OECD (2001) reported that based on the number of negative mutagenicity and clastogenicity findings, the chemical is not expected to be a carcinogen. A weight of

evidence study reported that the chemical is not expected to have carcinogenic potential as it does not contain structural components to support carcinogenicity (REACH, HSDB).

H. Reproductive and Developmental Toxicity

The chemical is not expected to be toxic to reproduction (OECD 2001). In a non-guideline study, male and female Sprague Dawley (SD) rats were exposed to the chemical via inhalation at 0, 3000 or 6000 ppm for seven hours/day. Female rats were exposed to the chemical throughout gestation, while males were exposed to the chemical for six weeks prior to mating. No harmful effects on fertility or pregnancy rate were reported at any of the dose levels. In another non-guideline study, no testicular toxicity (effect on testes weight or histopathology) was reported in SD male rats that were administered the chemical via oral intubation at 533 mg/kg bw/day over six days (OECD 2001).

Any developmental effects were only reported to be observed secondary to maternal toxicity, so the chemical is not expected to be a developmental toxin. OECD (2001) reported that the chemical showed mild foetotoxicity and developmental variations in offspring only at or near the maternally toxic and, in some cases, lethal dose of 8000 ppm. Offspring of female SD rats exposed via inhalation to 0, 3500, 6000 or 8000 ppm of the chemical on gestations days 1 to 19, reported a reduction of foetal weights at 6000 and 8000 ppm and a slight increase in skeletal malformations at 8000 ppm but not at the lower dosage levels. At a maternally toxic dose of 8000 ppm, decreased weight gain, food consumption and dam deaths were reported. The NOAEL for offspring and dams was 3500 ppm as there was a slight decrease in foetal weight at the 6000 ppm dose level.

In another 20 day study in male and female SD rats exposed to 0, 3000 or 6000 ppm of the chemical via inhalation, a small number of behavioural and neurochemical variations in offspring at 6000 ppm were reported. No maternal toxicity was reported throughout gestation for females or for six weeks prior to mating for males as a result of maternal or paternal exposure. However, the effects observed in offspring were not regarded as biologically significant by the authors due to inconsistences between dose-response patterns.

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for butyl alcohol follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

<u>Oral</u>

The lowest NOAEL from these studies is 125 mg/kg-day based on CNS effects in rats from a 90-day oral gavage study (Kl = 1; REACH). The NOAEL of 125 mg/kg-day will

be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 3
UF_D (database uncertainty) = 1

Oral RfD = 125/(10 x 10 x 1 x 3 x 1) = 125/300 = 0.4 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:

Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (0.4 x 70 x 0.1)/2 = 1.4 mg/L

B. Cancer

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

1-Butanol is a flammable liquid.

1-Butanol does not exhibit the following physico-chemical properties:

- Explosivity
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies conducted on 1-butanol.

Table 3: Acute Aquatic Toxicity Studies on 1-Butanol.

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Pimephelas promelas	96-hr LC_{50}	1,376	1	ECHA
Daphnia magna	48-hr EC_{50}	1,328	1	ECHA
Pseudokirchneriella subcapitata	72-hr EC_{50}	225	1	ECHA

Chronic Studies

The 21-d NOEC from a *Daphnia* reproduction test is 4.1 mg/L (ECHA) [Kl. score = 2].

96-hr EC_{10} to *Pseudokirchneriella subcapitata* is 134 mg/L (ECHA) [Kl. score = 1].

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for 1-butanol follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (1,376 mg/L), invertebrates (1,328 mg/L), and algae (225 mg/L). Results from chronic studies are available for invertebrates (4.1 mg/L) and algae (124 mg/L). On the basis that the data consists of short-term studies for three trophic levels and long-term studies for two trophic levels, an assessment factor of 50 has been applied to the lowest reported EC_{10} value of 4.1 mg/L for fish. The $PNEC_{water}$ is 0.08 mg/L.

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is 0.004 mg/kg soil dry weight.

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
$= (0.07/1500) \times 1000 \times 0.08$
$= 0.004$

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
$= 3.471 \times 0.02$
$= 0.07$

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for 1-butanol based on the molecular connectivity index (MCI) is 3.471 L/kg (EPA, 2019).
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

1-Butanol is readily biodegradable; thus, it does not meet the screening criteria for persistence.

Based on a measured log K_{ow} of 1.0, 1-butanol does not meet the screening criteria for bioaccumulation.

The lowest chronic EC_{10} or NOEC value for 1-butanol is >0.1 mg/L. The acute $E(L)C_{50}$ values are >1 mg/L. Thus, 1-butanol does not meet the criteria for toxicity.

The overall conclusion is that 1-butanol is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification
Flammable liquid Category 3

Acute toxicity Category 4
Specific target organ toxicity Category 3
Skin irritation Category 2
Eye damage Category 1

B. Labelling

Danger

C. Pictogram



X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
Rinse continuously with water for several minutes. Remove contact lenses if present and easy to do so. Continue rinsing. Call physician or poison center.

Skin Contact
Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower.

Inhalation
Remove victim to fresh air and keep at rest in a position comfortable for breathing.

Ingestion
Call physician or poison center.

Notes to Physician
May cause drowsiness or dizziness

Irritating to eyes, respiratory system and skin. Central nervous system effects. Hearing impairment Treat symptomatically.

Medical Conditions Aggravated by Exposure
No data available

Emergency Personnel Protection

First-Aid Providers: Avoid exposure to blood or body fluids. Wear gloves and other necessary protective clothing. Dispose of contaminated clothing and equipment as bio-hazardous waste.

B. FIRE FIGHTING INFORMATION

Extinguishing Media

Use foam, dry chemical, CO2 or water spray for extinction. Alcohol-resistant Foam; butanol is an alcohol. Do not use a solid (straight) water stream as it may scatter and spread fire.

Specific Exposure Hazards

Combustion products include carbon monoxide and carbon dioxide. Flammable. May be ignited by heat, sparks or flames. Material can burn with invisible flame. Vapor may travel considerable distance to source of ignition and flash back.
Vapors may form explosive mixtures with air. Most vapors are heavier than air. They will spread along the ground and collect in low or confined areas (sewers, basements, tanks). Container explosion may occur under fire conditions or when heated. Fire may produce irritating, corrosive and/or toxic gases.

Special Protective Equipment for Firefighters

Wear SCBA and fully encapsulating, gas-tight suit when handling these substances. Structural firefighter's uniform is NOT effective for these materials.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions

Ensure adequate ventilation. Keep people away from and upwind of spill/leak. Avoid contact with skin, eyes and clothing. Use personal protective equipment. Remove all sources of ignition. Pay attention to flashback. Take precautionary measures against static discharges. All equipment used when handling the product must be grounded. Use spark-proof tools and explosion-proof equipment. In case of large spill, water spray or vapor-suppressing foam may be used to reduce vapors, but may not prevent ignition in closed spaces.

Environmental Precautions

Prevent further leakage or spillage if safe to do so. Prevent product from entering drains. Prevent entry into waterways, sewers, basements or confined areas. In case of large spill, dike if needed. Dike far ahead of liquid spill for later disposal.

Steps to be Taken if Material is Released or Spilled

Stop leak if you can do it without risk. Absorb spill with inert material (e.g. vermiculite, dry sand or earth).
Use appropriate tools to put the spilled material in a suitable chemical waste disposal container. Use clean non-sparking tools to collect absorbed material.
Clean contaminated surface thoroughly.

D. STORAGE AND HANDLING

General Handling
Wear personal protective equipment. Use only in well-ventilated areas. Avoid contact with skin, eyes and clothing.
Keep away from heat and sources of ignition. Do not breathe vapors or spray mist. Do not ingest. When using do not smoke. Handle in accordance with good industrial hygiene and safety practice.

Other Handling Precautions
Remove all sources of ignition. To avoid ignition of vapors by static electricity discharge, all metal parts of the equipment must be grounded. Keep away from incompatible materials.

Storage
Keep container tightly closed in a dry and well-ventilated place. Store at room temperature in the original container. Keep away from heat and sources of ignition. Store in a segregated and approved area. Store away from incompatible materials.
Incompatible Materials: Oxidizing agents, Acids, Alkali Metals, Halogens, Aluminum, Caustics, isocyanates

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
The workplace exposure standard for butanol in Australia is 152 mg/m3 as an 8-hr TWA. No STEL is listed.

Engineering Controls
Ensure adequate ventilation. Provide exhaust ventilation or other engineering controls to keep the airborne concentrations of vapors and mist below their respective threshold limit value.

Personal Protection Equipment

Respiratory Protection:
Where ventilation is not adequate, respiratory protection may be required. Avoid breathing vapours or mists. Select and use respirators appropriately. When mists or vapours exceed the exposure standards then the use of the following is recommended: Approved respirator with organic vapour and dust/mist filters. Filter capacity and respirator type depends on exposure levels.

Hand Protection: Use appropriate, impervious gloves. Inspect gloves before use.

Skin Protection:
Chemical resistant apron, long sleeved clothing

Eye protection*:*
Use face shield, chemical goggles or safety glasses with side shield protection as appropriate.

Other Precautions:
No additional notes available.

F. TRANSPORT INFORMATION

UN Number 1120
Hazard class 3

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

AICS: Listed

XIII. REFERENCES

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CHLOROUS ACID, SODIUM SALT

This dossier on chlorous acid, sodium salt does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of chlorous acid, sodium salt in its use in drilling muds and hydraulic fracturing fluids. The majority of information presented in this dossier was obtained from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC): Sodium chlorite

CAS RN: 7758-19-2

Molecular formula: $ClHO_2.Na$

Molecular weight: 90.44

Synonyms: Chlorous acid, sodium salt; sodium chlorite

SMILES: [O-]Cl=O.[Na+]

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Chlorous Acid, Sodium Salt

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	White solid, slightly hydroscopic crystals or flakes. Aqueous solutions are colorless to greenish yellow with a slight chlorine-like odor	2	ECHA
Melting Point	180 – 200°C; decomposes at 200°C	2	ECHA
Density	2.432 g/mL	1	ECHA
Vapor Pressure	1.1×10^{-7} Pa @ 25°C	1	ECHA

Partition Coefficient (log K_{ow})	<-2.7	1	ECHA
Water Solubility	Very soluble (572 g/L @ 20°C)	1	ECHA
Oxidizing Properties	25.6% aq. solution – not an oxidizing liquid	1	ECHA

Chlorous acid, sodium salt in its dry form is a strong oxidizer.

Chlorous acid, sodium salt readily dissociates in aqueous solutions to the sodium (Na^+) and chlorite (ClO_2^-) ion. The chlorite (ClO_2^-) ion is in equilibrium with chlorous acid ($HClO_2$) in water. The chemical reaction is as follows:

$ClO_2^- + H^+ \rightleftharpoons HClO_2$

At pH values found in environmental media or physiological fluids, the chlorite ion will be the predominant form (pK_a of chlorous acid is 1.94).

Under acidic conditions, chlorous acid ($HClO_2$) will predominate and will disintegrate to chlorine dioxide (ClO_2). Chlorine dioxide (ClO_2) will degrade further to chlorite (ClO_2^-), and, ultimately, the chloride ion (Cl^-) is formed. The proportion of each oxy-chlorine species depends in part on the pH of the solution.

III. ENVIRONMENTAL FATE PROPERTIES

Chlorous acid, sodium salt readily dissociates in aqueous solutions to the sodium (Na^+) and chlorite (ClO_2^-) ion. The chlorite ion will ultimately degrade to chloride ions. Both sodium and chloride ions are ubiquitous in the environment. Biodegradation is not applicable to sodium chlorite. Neither sodium chlorite nor its dissociated ions are expected to adsorb to soil or sediment, or bioaccumulate.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Chlorous acid, sodium salt (sodium chlorite) in solution is moderately-to-highly toxic by the oral route, but has low acute toxicity by the dermal route. It is corrosive the skin and eyes. It is not a skin sensitizer. The critical effect seen in rodents given repeated oral administration of sodium chlorite is hemolytic anemia. Sodium chlorite was not mutagenic in a bacterial reverse mutation (Ames) test; however, chlorine dioxide (which breaks down to chlorite) was mutagenic in the mouse lymphoma assay in the absence and presence of metabolic activation. *In vivo* genotoxicity studies on sodium chlorite were generally negative. No reproductive toxicity was seen in male or female rats given sodium chlorite

in drinking water. There was, however, an effect on post-natal development in pups from the first generation; the effect was not seen in the pups from the second generation. There was no developmental toxicity in pregnant female rabbits given sodium chlorite in drinking water.

B. Acute Toxicity

The oral LD_{50} in rats is 284 mg/kg (ECHA) [Kl. score = 1]. The oral LD_{50} in rats of a 31% aqueous solution of chlorous acid, sodium salt is 390 mg/kg (ECHA) [Kl. score = 2).

There are no acute inhalation toxicity studies.

The dermal LD_{50} in rabbits is 134 mg/kg (ECHA) [Kl. score = 1]. The dermal LD_{50} in rabbits of a 31% aqueous solution of chlorous acid, sodium salt is >2,000 mg/kg (ECHA) [Kl. score = 2).

C. Irritation

Application of 0.5 mL of undiluted chlorous acid, sodium salt to the skin of rabbits for 4 hours under occlusive conditions was corrosive (ECHA) [Kl. score = 2]. Application of 0.5 mL of a 34.5% solution of chlorous acid, sodium salt to the skin of rabbits for four hours under semi-occlusive conditions was essentially non-irritating (ECHA) [Kl. score = 1].

Instillation of 0.1 mL of a 31% aqueous solution of chlorous acid, sodium salt to the eyes of rabbits was severely irritating (ECHA) [Kl. score = 2].

D. Sensitization

Chlorous acid, sodium salt was not considered to be a skin sensitizer when tested in a mouse local lymph node assay (ECHA). [Kl. score = 1]

E. Repeated Dose Toxicity

<u>Oral</u>

Male and female Crj:CD(SD) rats were dosed by oral gavage with 0, 10, 25, or 80 mg/kg chlorous acid, sodium salt for 13 weeks. Five animals died during the study: one in the 25 mg/kg group and five in the 80 mg/kg group subsequent to blood sampling. The deaths in the 80 mg/kg group were likely treatment-related; the animals were anemic and blood sampling may have exacerbated this problem, contributing to their death. Clinical signs were noted in the 25 and 80 mg/kg animals, the most notable being salivation. Body weights and feed consumption were similar across all groups. Hematological effects were

noted in the 80 mg/kg animals. The group mean erythrocyte count was significantly lower (both sexes). In males, hematocrit and hemoglobin levels were significantly lower, and methemoglobin levels and neutrophils counts were significantly higher than controls. The reticulocyte count was increased, but was not statistically significant. Two of the 80 mg/kg rats that prematurely died had marked changes in these hematological parameters. Morphological changes were also seen in the blood smears of three 80 mg/kg females: these were polychromasia, poikilocytosis, macrocytosis, and neutrophilia. Lymphocyte counts were significantly lower than controls in the 80 mg/kg males, and was likely due to the increased neutrophil count. Where the primary red blood cell parameters (mean erythrocyte count, hemoglobin, and hematocrit) were affected, there were also associated changes in mean cell volume, mean cell hemoglobin, and mean cell hemoglobin concentration. In the 25 mg/kg animals (both sexes) and the 10 mg/kg males, statistical trends highlighted a dose-dependent downward trend for erythrocyte counts. Statistical significance was not confirmed by direct comparison with the control group, and group mean values were within background range. Urine volume was unusually high in four 80 mg/kg females, and urinary specific gravity was reduced. There were no histopathologic changes seen in the kidneys of these animals. Absolute and relative spleen weights were increased in the 80 mg/kg males. Absolute spleen weights were increased in the 10 and 80 mg/kg females; relative spleen weights were increased in the 25 and 80 mg/kg females. Relative adrenal weights were increased in the 80 mg/kg males. Absolute adrenal weights were increased in the 80 mg/kg females; relative adrenal weights were increased in the 25 and 80 mg/kg females. Histopathologic changes indicative of chronic irritation were seen in the stomachs of many of the 80 mg/kg animals and a few of the 25 mg/kg males. Extramedullary hematopoiesis was seen in the spleen of a few 80 mg/kg animals and one animal each in the lower two dose groups. The NOAEL for this study is 10 mg/kg-day (ECHA). [Kl. score = 1]

Male C/J and C57L/L mice were given in their drinking water 0, 0.75, 7.5, or 75 mg/L chlorous acid, sodium salt (0, 0.19, 1.9, or 19 mg/kg-day chlorite ion) for 30 days. There were slight signs of oxidative stress of red blood cells at the high-dose. Glucose-6-phosphate dehydrogenase (G6PD) activity and osmotic fragility were slightly increased. Erythrocytes with irregular shapes were also observed. It was suggested that the primary effect of chlorous acid, sodium salt was a disruption of the erythrocyte cell membrane. However, the glutathione level in the erythrocyte was not affected and there were no associated signs of hemolytic anemia, suggesting that the slight increase in G6PD activity acted as a sufficient compensatory mechanism to limit the oxidative stress. The NOAEL for this study is considered to be 7.5 mg/L chlorous acid, sodium salt or 1.9 mg/kg-day chlorite (Moore and Calabrese, 1980). [Kl. score = 2]

Male C57L/J mice were given chlorous acid, sodium salt in their drinking water for 30, 90, or 180 days. The doses were 0, 3, 15, or 75 mg/L expressed as chlorite ion. The average daily doses were estimated to be: 0, 0.74, 3.57, and 17.23 mg/kg-day for the 30-day period; 0, 0.64, 3.15, and 16.2 mg/kg-day for the 90-day period; and 0, 0.69, 3.71, and 17.11 mg/kg-day for the 180-day period. There were no significant changes in body weight gain, absolute or relative kidney weights, water consumption, or histopathologic changes in the

kidney. The NOAELs for this study are: 17.23, 16.20, and 17.11 mg/kg-day for the 30-, 90-, and 180-day exposure periods, respectively (Connor et al., 1985). [Kl. score = 2]

Inhalation

No studies are available.

Dermal

No adequate studies are available.

F. Genotoxicity

In Vitro Studies

Table 2 lists the results of the *in vitro* genotoxicity studies on chlorous acid, sodium salt.

Table 2: *In vitro* Genotoxicity Studies on Chlorous Acid, Sodium Salt

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* TA97, TA102 strains)	-	-	4	ECHA
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	+**	+**	2	ECHA

*+, positive; -, negative
**Test material: chlorine dioxide (chlorite is a breakdown product)

In Vivo Studies

Male and female CD-1 mice were given by oral gavage a single dose of 0, 0.2, 0.5, or 1 mg/day (0, 10, 25, or 59 mg/kg-day) chlorous acid, sodium salt. Chromosomal aberrations were not increased in bone marrow cells of treated mice compared to those in the controls (Meier et al., 1985; ECHA).

Male and female CD-1 mice were given by oral gavage 0, 0.2, 0.5, or 1 mg/day (0, 10, 25, or 59 mg/kg-day) chlorous acid, sodium salt for five consecutive days. There were no significant differences between treated and control mice in the frequency of micronuclei or chromosomal aberrations in bone marrow cells (Meier et al., 1985; ECHA).

Male ddY mice were given a single intraperitoneal injection of 0, 7.5, 15, 30, or 60 mg/kg chlorous acid, sodium salt. Micronucleated polychromatic erythrocytes were statistically significantly increased at all dose levels. The increase was dose-dependent, but the frequency of micronucleated polychromatic erythrocytes decreased at the highest dose level (Hiyashi et al., 1988; ECHA). [Kl. score = 2]

Male ddY mice were given a single intraperitoneal injection of 0 or 15 mg/kg chlorous acid, sodium salt for four consecutive days. The frequency of micronucleated polychromatic erythrocytes were similar between treated and control mice (Hiyashi et al., 1988; ECHA). [Kl. score = 2]

Male ddY mice were given a single oral dose of 0, 37.5, 75, 150, or 300 mg/kg chlorous acid, sodium salt. There was no significant increases in the frequency of micronucleated polychromatic erythrocytes in the bone marrow of the treated mice compared to the controls (Hiyashi et al., 1988; ECHA). [Kl. score = 2]

G. Carcinogenicity

No studies are available.

H. Reproductive Toxicity

A two-generation reproductive toxicity study has been conducted on chlorous acid, sodium salt. Male and female SD rats were given in their drinking water 0, 35, 70, or 300 ppm chlorous acid, sodium salt. The average daily intakes are: 0, 4, 8, and 30 mg/kg-day for males ; and 0, 5, 10, and 39 mg/kg-day for females. The average daily intakes for chlorite are: 0, 2.9, 6, and 22 mg/kg-day for males; and 0, 4, 7.5, and 29 mg/kg-day for females. During lactation, the drinking water levels were reduced 50% to 17.5, 35, and 150 ppm chlorous acid, sodium salt. Water consumption was reduced in all treated groups. Body weights and feed consumption were reduced in the 70 and 300 ppm groups. There was no evidence of reproductive toxicity at any dose level. In the 300 ppm group, pup weights were reduced at birth and on PND 11 (-14%) compared to the controls. There was a decrease in the percent of the 300 ppm F_{2a} pups with eyes open on PND15 compared to the control group; this effects was not observed for the F_1 or F_{2b} pups. There was a small, but statistically significant, increase in the average time to preputial separation for the 70 and 300 ppm F_1 pups and in the vaginal opening for the 300 ppm F_1 pups. Similar changes were not observed for the F_2-generation pups. All of the high-dose animals exhibited mild methemoglobinemia. Thyroid levels were unaffected by treatment. There was a small decrease in the amplitude of auditory startle responses in the 70 and 300 ppm pups on PND 25; the toxicological significance of this effect is questionable. The NOAEL for reproductive toxicity is 300 ppm chlorous acid, sodium salt, the highest dose tested. The NOAEL for developmental toxicity is 35 ppm (4 and 5 mg/kg-day chlorous acid, sodium salt for males and females, respectively) based on the increase in the average time to preputial separation in the $\geq$70 ppm F_1 pups. The NOAELs for hematological effects is 70

ppm (8 and 10 mg/kg-day chlorous acid, sodium salt for males and female, respectively). The NOAEL for neurotoxicity is 300 ppm (30 and 39 mg/kg-day chlorous acid, sodium salt for males and females, respectively) (ECHA) [Kl. = 2].

I. Developmental Toxicity

Pregnant New Zealand White rabbits were given 0, 200, 600, or 1,200 mg/L (0, 12.2, 36.6, or 58.8 mg/kg-day) chlorous acid, sodium salt in their drinking water during GD 7 to PND 19. The animals in the mid- and high-dose groups showed reduced water consumption, along with reduced feed consumption, production of fecal pellets, and body weight gain. There was no evidence of embryotoxicity or teratogenicity at any dose level. The NOAELs for maternal and developmental toxicity are 12.2 and 58.8 mg/kg-day, respectively (ECHA). [Kl. score = 1]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for chlorous acid, sodium salt follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

The lowest NOAEL values from key toxicity studies on chlorous acid, sodium salt are listed below in Table 3.

Table 3: Lowest NOAEL Values from Key Toxicity Studies on Chlorous Acid, Sodium Salt by the Oral Route

Species/sex	Study Duration	mg/kg-day	Endpoint	Reference
Male/female rats	13 weeks	10	Clinical signs, stomach irritation	ECHA
Male pups	2-generation reproductive	4	↑ average time to preputial separation	ECHA
Male parental rats	2-generation reproductive	8	Hematological effects	ECHA

Female pregnant rabbits	Developmental (GD 6 to PND 17)	12.2	↓ Body weight gain, feed consumption	ECHA

The lowest NOAEL is 4 mg/kg-day based on increased average time to preputial separation in F_2 male pups from a two-generation reproductive toxicity study (ECHA). The NOAEL of 4 mg/kg-day will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Derivation of an Oral Reference Dose

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 10
UF_D (database uncertainty) = 1

Oral RfD = 4/(10 x 10 x 1 x 10 x 1) = 4/1000 = <u>0.004 mg/kg-day</u>

Derivation of a drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (0.004 x 70 x 0.1)/2 = <u>0.014 mg/L</u>

Australian Drinking Water Guidelines

The Australian drinking water guideline value for chlorite is 0.3 mg/L (ADWG, 2011).

The Australian drinking water guideline value for sodium is 180 mg/L based on aesthetics (ADWG, 2011).

B. Cancer

No carcinogenicity studies were found on chlorous acid, sodium salt. Thus, a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Chlorous acid, sodium salt in solution does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing Potential

[It should be noted that chlorous acid, sodium salt as a solid is a strong oxidizer.]

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Chlorous acid, sodium salt has a high acute toxicity concern to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies conducted on chlorous acid, sodium salt.

Table 3: Acute Aquatic Toxicity Studies on Chlorous Acid, Sodium Salt

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Oncorhynchus mykiss	96-h LC_{50}	149	2	ECHA
Daphnia magna	48-h EC_{50}	<1	2	ECHA

Peudokirchneriella subcapitata	96-h EC_{50}	1	1	ECHA

Chronic Studies

No studies are available.

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for chlorous acid, sodium salt follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (149 mg/L), invertebrates (<1 mg/L), and plants (1 mg/L). On the basis that the data consists of short-term studies from three trophic levels, an assessment factor of 1,000 has been applied to the EC_{50} value of 1 mg/L for algae. The $PNEC_{aquatic}$ is 0.001 mg/L.

PNEC sediment

No reliable experimental toxicity data on sediment organisms are available. Chlorous acid, sodium salt dissociates completely in water with its environmental distribution is dominated by its high water solubility. K_{ow} and K_{oc} parameters do not readily apply to inorganics, such as chlorous acid, sodium salt. Therefore, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sed}$. Based on its properties, no adsorption of chlorous acid, sodium salt to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

PNEC soil

No reliable experimental toxicity data on terrestrial organisms are available. The environmental distribution of chlorous acid, sodium salt is dominated by its water solubility. Sorption of chlorous acid, sodium salt should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. K_{oc} and K_{ow}

parameters do not readily apply to inorganics, such as chlorous acid, sodium salt. Therefore, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on its properties, chlorous acid, sodium salt is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Chlorous acid, sodium salt is an inorganic salt that dissociates completely in water to sodium (Na^+) and chlorite (ClO_2^-) ions. Chlorite will ultimately degrade to chloride (Cl^-) ions. Biodegradation is not applicable to these inorganic ions. For the purposes of this PBT assessment, the persistent criteria is not considered applicable to this inorganic salt.

As an inorganic compound, neither chlorous acid, sodium salt nor its dissociated ions are expected to accumulate. Thus, chlorous acid, sodium salt does not meet the criteria for bioaccumulation.

There are no chronic toxicity studies on chlorous acid, sodium salt. The acute $E(L)C_{50}$ values for chlorous acid, sodium salt are $\leq$1 mg/L in invertebrates and algae. Thus, chlorous acid, sodium salt meets the criteria for toxicity.

The overall conclusion is that chlorous acid, sodium salt is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification (Chlorous acid, sodium salt solutions)

Acute Toxicity Category 3 [Oral]
Skin Corrosive Category 1B
STOT RE Category 2 [Target organ: blood]
Aquatic Acute Category 1
Aquatic Chronic Category 3

B. Labelling

Danger

C. Pictogram



In addition to the hazard statements corresponding to the GHS classifications, the following non-GHS hazard statement is to be added to the SDS: AUH031: Contact with acids liberates toxic gas.

X. SAFETY AND HANDLING

Eye Contact
Immediately flush open eyes with plenty of water for at least 15 minutes. Remove contacts, if present and easy to do. Get medical attention immediately, preferably a physician for an ophthalmologic examination.

Skin Contact
Remove and isolate contaminated clothing. Rinse skin immediately with water for at least 15 min. Get medical attention immediately.

Inhalation
Move person to fresh air. Administer oxygen if breathing is difficult. Do not use mouth-to-mouth method if victim inhaled the substance; give artificial respiration with the air of a pocket mask equipped with a one-way valve or other proper respiratory medical device. Give artificial respiration if victim is not breathing. Get medical attention immediately.

Ingestion
Rinse mouth with water and then drink plenty of water. Get medical attention. Do not induce vomiting. Never give anything by mouth to an unconscious person.

Notes to Physician
Chlorine dioxide vapors are emitted when this product contacts acids or chlorine. If these vapors are inhaled, monitor patient closely for delayed development of pulmonary edema which may occur up to 48-72 hours post-inhalation Following ingestion, neutralization and use of activated charcoal is not indicated (OxyChem, 2015).

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Use dry chemical, carbon dioxide, water spray or fog, or foam.

Specific Exposure Hazards

Dried material can ignite upon contact wit combustibles. This product may represent an explosion hazard if it contacts acids, chlorine, or organic materials. Emits toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: chlorine and sodium oxides.

Special Protective Equipment for Firefighters

Structural firefighter's protective clothing provides limited protection in fire situations only; it is not effective in spill situations where direct contact with the substance is possible. Wear chemical protective clothing that is specifically recommended by the manufacturer. It may provide little or no thermal protection. Wear positive pressure self-contained breathing apparatus (SCBA). Move containers from fire area if it can be done without risk.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions

Ventilate enclosed areas. Do not walk through spilled material. Do not touch damaged containers or spilled material unless wearing appropriate protective clothing. Wear appropriate personal protective equipment, avoid direct contact. Do not breath mist, vapors, or spray. Do not get in eyes, on skin, or on clothing.

Environmental Precautions

Prevent entry into waterways, sewers, basements or confined areas.

Steps to be Taken if Material is Released or Spilled

As an immediate precautionary measure, isolate spill or leak area for at least 50 meters in all directions. Keep unauthorized personnel away. Remove all sources of ignition. Absorb or cover with dry earth, sand, or other non-combustible material and transfer to containers. Dike to collect large liquid spills. Every attempt should be made to avoid mixing spilled material with other chemicals or debris when cleaning up. Dried material can ignite upon contact with combustibles. Dispose immediately.

D. STORAGE AND HANDLING

General Handling

Do not get in eyes, on skin, or on clothing. Do not ingest or taste. Wear appropriate personal protective equipment, avoid direct contact. Do not breath mist, vapours, or spray. Use caution when combining with water. DO NOT add water to corrosive liquid, ALWAYS add corrosive liquid to water while stirring to prevent release of heat, steam, and fumes. This product becomes a fire hazard if allowed to dry. Remove and wash contaminated clothing to avoid fire.

Storage

Keep contain tightly closed. Store in a cool, dry, well-ventilated place. Keep from direct

sunlight. Avoid exposure to sunlight or ultraviolet light. Keep separated from acids, reducing agents, combustible material, oxidizing agents, hypochlorite, organic solvents and compounds, garbage, dirt, organic materials, household products, chemicals, soap products, paint products, vinegar, oils, pine oil, dirty rags, sulfur-containing rubber, or any other foreign matter.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards

Workplace Australia has not established an occupational exposure standard for chlorous acid, sodium salt.

Engineering Controls

Good general ventilation should be used. Localized ventilation should be used where vapours, mist, or aerosols may be generated.

Personal Protection Equipment

Respiratory Protection:

Wear an approved acid gas respirator with dust/mist pre-filters if any exposure to dust of mist is possible.

Hand Protection:

Wear appropriate chemical-resistant gloves.

Skin Protection:

Wear protective clothing to minimize skin contact.

Eye protection*:*

Wear chemical splash goggles and face shield.

Other Precautions:

Wash hands, forearms, and face thoroughly after handling chemical products, before eating, smoking, and using the lavatory and at the end of the working period. Appropriate techniques should be used to remove potentially contaminated clothing. Wash contaminated clothing before reusing. Ensure that eyewash stations and safety showers are close to the workstation location.

F. TRANSPORT INFORMATION

Sodium chlorite (dry)

UN1496 (SODIUM CHLORITE)
Class: 5.1
Packing Group: II

Environmentally Hazardous Substance

Sodium chlorite (liquid)
UN1908 (CHLORITE SOLUTION)
Class: 8
Packing Group: II
Contains Sodium chlorite

Environmentally Hazardous Substance

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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CHOLINE CHLORIDE

This dossier on choline chloride does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of choline chloride in its use in hydraulic fracturing fluids. The majority of information presented in this dossier was obtained from the OECD-SIDS documents on choline chloride (OECD, 2004), and the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC): 2-Hydroxy-N,N,N-trimethylethanaminium chloride

CAS RN: 67-48-1

Molecular formula: $C_5H_{14}NO.Cl$
$C_5H_{14}NO^+$ (choline)

Molecular weight: 139.6
104.2 (choline)

Synonyms: Choline chloride; 2-hydroxy-N,N,N-trimethylethanaminium chloride; trimethyl(2-hydroxyethyl)ammonium chloride; cholinium chloride; 2-hydroxyethyl(trimethyl)azanium chloride

SMILES: C[N+](C)(C)CCO.[Cl-]
C[N+](C)(C)CCO (choline)
OCCN(C)(C)C (choline)

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Choline Chloride

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa*	White crystalline solid*	2	OECD (2004)
Melting Point	ca. 200°C	1	ECHA
Boiling Point	Decomposition at 305°C prior to boiling.	2	ECHA
Density	70% aq. solution: 1.10 g/cm^3	4	OECD (2004)

Partition Coefficient (log K_{ow})	75% aq. solution: -3.77	1	ECHA
Water Solubility	Powder containing 50% choline chloride: 650 g/L	4	OECD (2004)
Auto flammability	330°C	2	ECHA
Viscosity	75% aq. solution: 26.2 mPa.s @ 20°C; 14.1 mPa.s @ 40°C	1	ECHA
Henry's Law Constant	2.06 x 10^{-11} Pa.m^3/mole @ 25°C (estimated using HENRYWIN v3.10)	-	OECD (2004)

*Choline chloride is a white crystalline solid; it is marketed as an aqueous solution (70-75% w/w in water), which is colorless with an amine-like odor.

Choline chloride is a quaternary amine salt that will dissociate in water into choline ($C_5H_{14}NO^+$) and chloride (Cl^-) ions.

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Choline chloride is readily biodegradable. Distribution modeling using Mackay Level 1 shows choline to be distributed completely into water. Choline chloride will not adsorb on soil and sediments. It is not expected to bioaccumulate.

B. Biodegradation

Choline chloride is readily biodegradable (93% within 14 days) in a MITI-I test (MITI, 1992; OECD, 2004). In another MITI-I test, biodegradation was $\geq$60%, indicating ready biodegradation (Tunkel *et al.*, 2000; OECD, 2004). A $BOD_5/ThOD_5$ ratio of 75% was obtained in a BOD_5 test performed according to DIN 38409 part 43 (BASF AG, 1984; OECD, 2004).

C. Environmental Distribution

Adsorption/desorption

No experimental data are available for choline. Choline is a quaternary ammonium compound (QAC); these compounds are not included in the training set for the K_{oc} estimation of the QSAR model KOCWIN v. 2.00 in EPISUITE™ (EPA, 2016), and therefore outside the program's prediction domain. A K_{oc} value of 2.3 had been estimated using the older QSAR model PCKOCWIN v. 1.66 (OECD, 2004).

Distribution Modeling

Results from Mackay Level I modeling indicate that choline chloride will be distributed completely into water (OECD, 2004).

D. Bioaccumulation

No measured data on bioaccumulation of choline chloride are available. An experimental log K_{ow} is -3.77 (OECD, 2004). Bioaccumulation is not expected in aquatic organisms.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Choline is a vitamin-like essential nutrient. It has low acute toxicity by the oral route, and is slightly irritating to the skin and eyes. Repeated high intake of choline in humans has been reported to cause a slight hypotensive effect. No adverse effects (including tumors) were seen in rats given choline in the diet for 72 weeks. Choline is not genotoxic. High dietary doses of choline to pregnant mice resulted in developmental toxicity (but no teratogenic effects) at levels that were maternally toxic.

B. Metabolism

Choline is a vitamin-like essential nutrient. Although the body can synthesize choline in small amounts, it is insufficient to maintain health and must be consumed in the diet. Choline is required for the synthesis of phospholipids in cell membranes, methyl group metabolism and acetylcholine synthesis (neurotransmitter) (Zeisel and Blusztajn, 1994).

Dietary choline is taken up into the body by transporter proteins present in the cells lining the small intestine (IOM, 2000). In the small intestine, prior to uptake into the small intestinal cells, some choline is metabolized by bacteria to betaine and methylamines (Zeisel et al., 1983). Dietary choline can be present as free choline or in esterified forms (i.e., phosphocholine, glycerophosphocholine, sphingomyelin, and phosphatidylcholine) (Zeisel and Blusztain, 1994). Free choline is formed from these esterified choline compounds by pancreatic enzymes.

Choline is involved in a number of biochemical pathways in eukaryotic and prokaryotic cells. It is a precursor for acetylcholine (a neurotransmitter); phospholipids (structural integrity and signaling roles for cell membranes); and a major source for methyl groups (IOM, 2000).

C. Acute Toxicity

The oral LD_{50} values of choline in rats are approximately 3,500 and 5,500 mg/kg (ECHA). [Kl. scores = 2]

No acute inhalation or dermal toxicity studies are available.

D. Irritation

Application of a 70% aqueous solution to the skin of rabbits for 20 hours under occlusive conditions resulted in ambiguous skin irritation (BASF AG, 1963a; OECD, 2004). [Kl. score = 2].

Slight eye irritation was seen in the eyes of rabbits after instillation of a 70% aqueous solution of choline chloride; no effects were seen 24 hours after exposure (BASF AG, 1963b; OECD, 2004). [Kl. score = 2].

E. Sensitization

No data are available in animals. In a Human Repeated Insult Patch Test (HRIPT), there was no evidence of dermal sensitization in two hundred subjects given 0.5% (w/v) aqueous solution of choline chloride during the induction phase and 0.2% (w/v) aqueous solution during the challenge phase (Colgate-Palmolive, 2003; OECD, 2004).

F. Repeated Dose Toxicity

Oral

A 72-week feeding study was conducted to investigate the impact of choline chloride on the liver tumor promoting activity of phenobarbital and DDT in diethylnitroamine-initiated Fischer 344 rats. Animals received approximately 500 mg/kg-day choline chloride. Following the end of the exposure period, the animals were kept on the same untreated diet as the control group until study termination at week 103. Histopathology was limited to the liver and organs that developed gross abnormalities. There were no significant differences between treated and control animals on survival rates, body weights, and relative liver weights. There were no increased number of neoplastic liver nodules, hepatocellular carcinomas, lung tumors, leukemia or other tumors between treated and control animals. The NOAEL for choline chloride in this study is 500 mg/kg-day (Shivapurkar *et al.*, 1986). [Kl. score = 3]

In humans, oral administration of 10,000 mg/day choline chloride in a pilot study treating a small number of patients with Alzheimer's disease resulted in a slight hypotensive effect (Boyd *et al.*, 1977). This dose was regarded as a LOAEL by the U.S. Institute of Medicine (IOM) Standing Committee on the Scientific Evaluation of Dietary Reference Intake (2000).

Inhalation

No studies are available.

Dermal

No studies are available.

G. Genotoxicity

In Vitro Studies

Choline chloride was not mutagenic to bacteria in reverse mutation assays (Haworth *et al.*, 1984; JETOC, 1997; Litton Bionetics, 1977).

A small, but statistically significant, and dose-related increase in chromosomal aberrations was reported in Chinese Hamster Ovary (CHO) cells at doses of 50 and 500 μg/ml choline chloride in the absence of S9 only (Bloom *et al.*, 1982). No higher concentrations were examined. These results could not be confirmed in two studies using CHO cells at concentrations of choline chloride up to 5,000 μg/ml (Galloway *et al.*,1985).

In sister chromatid exchange (SCE) assays, ambiguous results were obtained in two parallel studies (at two different laboratories) in CHO cells at concentrations up to 50 and 500 μg/ml choline chloride, respectively. Cytotoxicity was observed at 5,000 μg/ml. In laboratory 2, the increase in SCEs, which was sporadic and not dose-related, that was observed with metabolic activation was not reproduced in laboratory 1. Laboratory 1 showed a weak positive at the top dose without metabolic activation, but a comparison with laboratory 2 was not possible due to insufficient number of cells analyzed (Bloom *et al.*, 1982; Galloway *et al.*, 1985).

Choline chloride was negative in a gene conversion assay with *Saccharomyces cerevisiae* strain D4 in the presence or absence of metabolic activation (Litton Bionetics, 1977; OECD, 2004).

In Vivo Studies

No studies are available.

G. Carcinogenicity

No studies are available.

H. Reproductive Toxicity

No reliable studies have been conducted that address female fertility or reproductive toxicity by a relevant route of exposure.

I. Developmental Toxicity

Pregnant female mice were given in their feed 0, 1, 2.5, 5, or 10% choline chloride (0 or approximately 1,250, 4,160, 10,800, or 20,000 mg/kg choline chloride) on gestational days 1 to 18. Maternal body weight gain was reduced in all treated groups except for the 1,250 mg/kg group. Maternal weight gain of dams with embryonic/fetal absorptions showed no net weight gain at ≥4,160 mg/kg, but there was net weight loss in the 20,000 mg/kg group. All fetuses were resorbed in the 20,000 mg/kg group. Embryonic/fetal lethality of 35% and 69% were seen in the 4,160 and 10,800 mg/kg groups, respectively. No resorptions occurred in the 1,250 mg/kg group. Developmental toxicity was seen at ≥4,160 mg/kg group. There were no statistically significant increases in malformations in any dose group. The NOAEL for maternal and developmental toxicity is 1,250 mg/kg-day (BASF AG 1966; OECD 2004). [Kl. score = 2]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

The Standing Committee on the Scientific Evaluation of Dietary Reference Intakes selected hypotension as the critical effect from the study by Boyd *et al.* (1977) when deriving a Tolerable Upper Intake Level. Boyd *et al.* (1977) reported a LOAEL of 10,000 mg/day choline chloride (7,500 mg/day choline). An uncertainty factor of 2 was chosen because of the limited data regarding hypotension and the inter-individual variation in response to cholinergic effects. Thus, the value for the Tolerable Upper Intake Value for repeated exposure of adults to choline is 3,500 mg/day choline.

Note that the Australian National Health and Medical Research Council (2014) concluded that there are no data to suggest that there is increased susceptibility to choline during pregnancy or lactation; thus the upper level of intake choline is the same for women during pregnancy or lactation as it is for adults (3,500 mg/day choline).

Oral Reference Dose (oral RfD)

An oral RfD for choline is derived as follows: the LOAEL of 7,500 mg/day from the Boyd *et al.* (1977) study is divided by an uncertainty factor of 2 to obtain a value of 3,500 mg choline/day or 50 mg choline/kg-day for a 70 kg person.

Oral RfD = 50 mg/kg-day [choline]

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (50 x 70 x 0.1)/2 = 175 mg/L [choline]

The Australian drinking water guideline value for chloride ions is 250 mg/L based on aesthetics (ADWG, 2011).

B. Cancer

There are no carcinogenicity studies on choline chloride. Thus a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Choline chloride does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Choline chloride is of low toxicity concern to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

Table 2 lists the results of acute aquatic toxicity studies conducted on choline chloride.

Table 2: Acute Aquatic Toxicity Studies on Choline Chloride

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Oryzias latipes	96-hr LC_{50}	>100 (nominal and measured)	1	MOE Japan (1999a); OECD (2004)
Leuciscus idus	96-hr LC_{50}	>10,000*	2	OECD (2004); ECHA
Daphnia magna	48-hr EC_{50}	349 (nominal and measured)	2	MOE Japan (1999a); OECD (2004)
Daphnia magna	48-hr EC_{50}	>500*	2	OECD (2004)
Pseudokirchneriella subcapitata	72-hr EC_{50}	>1,000 (nominal and measured)	1	MOE Japan (1999a); OECD (2004)

*78% aqueous solution of choline chloride.

Chronic Studies

In a 21-day *Daphnia magna* reproduction test, the nominal and measured NOEC was reported to be 30.2 mg/L (MOE Japan, 1999d) [Kl. score = 1].

The NOEC from a 72-hr algae *Pseudokirchneriella subcapitata* study is 30.2 mg/L (MOE Japan, 1999c; OECD, 2004) [Kl. score = 1].

C. Terrestrial Toxicity

No data are available.

Choline is present in all plant and animal cells, mostly in the form of phospholipids (phosphotidylcholine or lecithin, lysophosphatidylcholine, choline plasmalogens and sphingomyelin), which are essential components of membranes (IOM, 2000).

D. Calculation of PNEC

The PNEC calculations for choline chloride follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (>100 mg/L), invertebrates (349 mg/L), and algae (>1,000 mg/L). Results from chronic studies are available for invertebrates (21-day NOEC = 30.2 mg/L) and algae (72-hour NOEC = 32 mg/L). On the basis that the data consists of chronic studies on two trophic level (albeit not on the species with the lowest $E(L)C_{50}$), an assessment factor of 100 has been applied to the lowest reported NOEC of 30 mg/L for *Daphnia*. The $PNEC_{aquatic}$ is 0.3 mg/L (0.22 mg/L for choline).

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 0.15 mg/kg sediment wet weight.

The calculations are as follows:

$$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$$
$$= (0.844/1280) \times 1000 \times 0.22$$
$$= 0.15$$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$$K_{sed\text{-}water} = 0.8 + [0.2 \times Kp_{sed}/1000 \times BD_{solid}]$$
$$= 0.8 + [0.2 \times 0.092/1000 \times 2400]$$
$$= 0.844$$

Where:
Kp_{sed} = solid-water partition coefficient (L/kg).
BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$$Kp_{sed} = K_{oc} \times f_{oc}$$

= 2.3 x 0.04
= 0.092

Where:

K_{oc} = organic carbon normalized distribution coefficient (L/kg). The K_{oc} for choline is estimated to be 2.3 L/kg (OECD, 2004).
F_{oc} = fraction of organic carbon in sediment = 0.04 [default].

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ for choline is 0.007 mg/kg soil dry weight (choline).

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
= (0.05/1500) x 1000 x 0.22
= 0.007

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
= 2.3 x 0.02
= 0.05

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for choline is estimated to be 2.3 L/kg (OECD, 2004).
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. LIVESTOCK HAZARD ASSESSMENT

Although choline is present in the diet of livestock (as a component of plant cell membranes), it is also given in significant volumes as an feed additive. Unlike humans, dietary choline in ruminants is rapidly and extensively degraded in the rumen of sheep (Neill et al., 1979) and cattle (Atkins *et al.*, 1988; Sharma and Erdman, 1988). Sharma and Erdman (1988) reported that increasing dietary choline intake in cows from 23.5 g/day in the controls to 326 g/day in the choline-supplemented diet group increased duodenal choline flow from 1.2 to 2.5 g/day, indicating intestinal uptake of only 0.8% to 5%.

No toxicity data are available on livestock.

A livestock oral reference dose (RfD) was derived for choline using the value determined for humans and taking into account the low oral uptake (≤5%) of choline in ruminants.

Oral RfD [livestock] = oral RfD [humans]/oral uptake fraction [livestock]
= 50/0.05
= 1,000 mg/kg-day [choline]

IX. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Choline chloride is readily biodegradable and thus it does not meet the screening criteria for persistence.

Based on a measured log Kow of -3.77, choline chloride does not meet the criteria for bioaccumulation.

The NOEC values from chronic toxicity studies on choline chloride are >0.1 mg/L. Thus, choline chloride does not meet the criteria for toxicity.

The overall conclusion is that choline chloride is not a PBT substance.

X. CLASSIFICATION AND LABELING

A. Classification

Not classified.

B. Labelling

No signal word.

C. Pictogram

None

XI. SAFETY AND HANDLING (Aqueous Solutions of Choline Chloride)

A. FIRST AID

Eye Contact
In case of contact, immediately flush eyes with plenty of water for at least 15 minutes.

Skin Contact
Wash thoroughly with soap and water.

Ingestion
Rinse mouth with water and then drink plenty of water. Never give anything by mouth to an unconscious person.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
Keep product and empty container away from heat and sources of ignition. May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: carbon monoxide, carbon dioxide, nitrogen oxides.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus and protective suit.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Use appropriate protective equipment.

Environmental Precautions
Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled
Soak up with inert absorbent material.

D. STORAGE AND HANDLING

General Handling
Keep product and empty container away from heat and sources of ignition. Ensure adequate ventilation, especially in confined areas.

Storage

Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
Workplace Australia has not established an occupational exposure standard for choline chloride.

Engineering Controls
Good general ventilation should be used.

Personal Protection Equipment

Respiratory Protection:
Respiratory protection is not required.

Hand Protection:
Chemical resistant protective gloves.

Skin *Protection*:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Safety glasses with side-shields.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Wearing of closed work clothing is recommended. Ensure that eyewash stations and safety showers are close to the workstation location.

F. TRANSPORT INFORMATION

Choline chloride is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XII. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XIII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

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CITRIC ACID

This dossier on citric acid does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of citric acid in its use in drilling muds and water treatment. The information presented in this dossier was obtained primarily from the OECD-SIDS documents on citric acid (OECD 2001a,b) and the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch et al., 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC): 2-Hydroxy-1,2,3-propanetricarboxylic acid

CAS RN: 77-92-9

Molecular formula: $C_6H_8O_7$

Molecular weight: 192.122

Synonyms: citric acid; 1,2,3-propanetricarboxylic acid, 2-hydroxy-; 2-hydroxy-1,2,3-propanetricarboxylic acid

SMILES: C(C(=O)O)C(CC(=O)O)(C(=O)O)O

Citric acid is an ubiquitous natural substance that is an intermediate in the basic physiological tricarboxylic acid (TCA) cycle in every eukaryote cell.

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Citric Acid

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	White crystalline solid; odourless.	2	ECHA
Melting Point	153°C	2	ECHA
Boiling Point	Not available; decomposition	-	ECHA
Density	1.67 @ 20°C	2	ECHA
Vapor Pressure	2.21 x 10^{-6} Pa @ 25°C	2	ECHA
Partition Coefficient (log K_{ow})	-1.61 to -1.80	2	ECHA
Water Solubility	Very soluble	4	ECHA
Flash Point	345°C	4	ECHA
Auto flammability	1010°C	4	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Citric acid is readily biodegradable. It is not expected to bioaccumulate. Due to its high water solubility, citric acid is unlikely to adsorb to soil or sediment.

B. Biodegradation

Citric acid can be considered readily biodegradable based on the results of the ready and inherent aerobic biodegradation studies listed in Table 2.

Table 2: Biodegradation Studies on Citric Acid (OECD 2001a,b)

Test System	Results*	Notes	Klimisch Score
Modified Sturm	97% (CO_2 evolution); 100% (DOC removal)	Readily biodegradable; exposure period not stated	2
Closed Bottle Test	BOD_{30}/COD Ratio = 90%	Readily biodegradable	2
BOD_5/COD Ratio	BOD_5 = 526 mg; COD = 728 mg; BOD_5/COD Ratio = 0.72	Readily biodegradable; concentration of test substance and activated sludge not stated	2
BOD_1/ThOD Ratio	BOD_1/ThOD Ratio = 13%	-	2
BOD_{20}/ThOD Ratio	BOD_{20}/COD Ratio = 98%	Readily biodegradable; initial test substance concentration 720 mg/L	2
Zahn-Wallen Test	85%, 1 day (DOC removal)	Inherently biodegradable	2
Zahn-Wallen Test	98%, 7 days (DOC removal)	Inherently biodegradable	
Coupled Units Test	93% (COD removal)	Ultimately biodegradable; exposure period not stated.	2

C. Environmental Distribution

Absorption/desorption

No experimental data are available for citric acid. Using KOCWIN program in EPISuite™ (EPA, 2016), the estimated K_{oc} value from the K_{ow} value of -1.08 is 0.3617 L/kg.

D. Bioaccumulation

The log K_{ow} for citric acid is -1.61 to -1.80. Thus, citric acid is not expected to bioaccumulate.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Citric acid exhibits low toxicity by the oral and dermal routes. It is an eye irritant, but slightly to non-irritating to the skin. No adequate studies were found to evaluate the sensitization potential of citric acid. Minimal toxicity and no carcinogenic effects were observed in rats given oral doses of citric acid for up to two years. Citric acid was not mutagenic to bacteria, but *in vitro* studies using human lymphocytes showed genotoxic effects. *In vivo* genotoxicity studies were negative. There were no reproductive or developmental effects in rats given oral doses of citric acid.

B. Acute Toxicity

The acute oral LD_{50} in male rats was reported to be 11,700 mg/kg (ECHA) [Kl. score = 2]. The acute oral LD_{50} values in mice are 5,400 and 5,790 mg/kg (ECHA) [Kl. score = 2]. The acute dermal LD_{50} value in rats is >2,000 mg/kg (ECHA) [Kl. score = 1].

C. Irritation

Application of 0.5 g citric acid powder to the skin of rabbits for 4 hours under semi-occlusive conditions was slightly irritating. The mean of the 24, 48, and 72-hour scores were: 0.3 for erythema and 0.0 for edema (ECHA) [Kl. score = 1]. Application of a 50% aqueous solution of citric acid to the skin of rabbits for 4 hours under occlusive conditions was non-irritating (ECHA) [Kl. score = 2].

Instillation of a 30% aqueous solution of citric acid into the eyes of rabbits produced well defined to moderate conjunctival irritation that did not fully resolve after the 14-day observation period. A 10% solution was associated with weak to moderate conjunctival effects, which resolved after 7 days (ECHA) [Kl. score = 2].

D. Sensitization

No adequate studies were found to evaluate the sensitization potential of citric acid.

E. Repeated Dose Toxicity

Oral

Male rats were given 0, 1.2, 2.4, or 4.8% citric acid in their feed for 6 weeks. The daily intakes were reported to be 1,150, 2,260, or 4,670 mg/kg-day. The high-dose animals had mild blood and urine parameter changes and slight degeneration of the thymus gland and spleen. The NOAEL is 2.4% in the diet or 2,260 mg/kg-day (OECD, 2001a,b). [Kl. score = 4]

Rats were given 3% or 5% citric acid in their diet for two years. The estimated daily intakes were 1,200 and 2,000 mg/kg-day, respectively. A slight decrease in growth was reported in the 2% group, but no tissue abnormalities in the major organs. The NOAEL is 1,200 mg/kg-day (OECD, 2001a,b). [Kl. score = 4]

Inhalation

No studies are available.

Dermal

No studies are available.

F. Genotoxicity

In Vitro Studies

Citric acid was not mutagenic in bacterial reverse mutation assays with strains of *S. typhimurium* or *E. coli* with and without metabolic activation (OECD, 2001a,b; ECHA). [Kl. score = 2]

Peripheral human lymphocytes were treated with 50 to 3,000 µg/ml citric acid. A statistically significant dose-dependent increase in the micronuclei was observed. In another set of studies by the same laboratory, there was a statistically significant and dose-related increase in the number of cells with aberrations, including sister chromatid unions. The study authors reported that the pH of the medium was unchanged (ECHA). [Kl. score = 2]

In Vivo Studies

Citric acid was not mutagenic in a dominant lethal assay when male rats were given either a single oral dose of citric acid (1.2 to 120 mg/kg) or a single oral dose on five consecutive days (300 to 3,500 mg/kg) (OECD 2001a,b) [Kl. score = 2]. There were no increases in chromosomal aberrations in the bone marrow of rats given either a single oral dose of citric acid (1.2 to 120 mg/kg) or a single oral dose on five consecutive days (300 to 3,500 mg/kg) (ECHA) [Kl. score = 2].

G. Carcinogenicity

Oral

There was no evidence of carcinogenicity in rats given 3% or 5% citric acid in feed (1,200 or 2,000 mg/kg/day, respectively) for two years (OECD, 2001a,b). [Kl. score = 4]

H. Reproductive Toxicity

In a non-standard repeat dose dietary study (duration and frequency not specified), 5% citric acid in feed did not affect either the number of young born to mice or rats or their subsequent survival up to the point of weaning (ECHA). [Kl. score = 4]

I. Developmental Toxicity

Pregnant female rats were dosed by oral gavage with 0, 2.95, 13.7, 63.6, or 295 mg/kg citric acid on GD 6-15. No maternal or developmental effects were noted. The NOAEL for maternal and developmental toxicity is 295 mg/kg-day, the highest dose tested (OECD, 2001a,b; ECHA). [Kl. score = 2]

Pregnant female rats were dosed by oral gavage with 0, 2.41, 11.2, 52, or 241 mg/kg citric acid on GD 6-15. No maternal or developmental effects were noted. The NOAEL for maternal and developmental toxicity is 241 mg/kg-day, the highest dose tested (OECD, 2001a,b; ECHA). [Kl. score = 2]

Pregnant female rabbits were dosed by oral gavage with 0, 4.25, 19.75, 91.70, or 425 mg/kg citric acid on GD 6-18. No maternal or developmental effects were noted. The NOAEL for maternal and developmental toxicity is 425 mg/kg-day, the highest dose tested (OECD, 2001a,b; ECHA). [Kl. score = 2]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for citric acid follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

In a two-year dietary study, the only effect seen in rats fed either 3 or 5% citric acid (approx. 1,200 or 2,000 mg/kg-day) was a slight decrease in growth in the 5% dose group. In the absence of statistical analysis of the body weight gain data, a conservative approach was taken, and the 5% dose group was considered an LOAEL. The NOAEL of 3% citric acid in the diet (1,200 mg/kg-day) will be used for determining the oral reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
- UF_A (interspecies variability) = 10
- UF_H (intraspecies variability) = 10
- UF_L (LOAEL to NOAEL) = 1
- UF_{Sub} (subchronic to chronic) = 1
- UF_D (database uncertainty) = 1

Oral RfD = 1,200/(10 x 10 x 1 x 1 x 1) = 1,200/100 = 12 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,

Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

Where:
- Human weight = 70 kg (ADWG, 2011)
- Proportion of water consumed = 10% (ADWG, 2011)
- Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (12 x 70 x 0.1)/2 = 42 mg/L

B. Cancer

Citric acid was not carcinogenic to rats in a chronic dietary study. Thus, no cancer reference value was derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Citric acid does not exhibit the following physico-chemical properties:
- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Citric acid is of low toxicity concern to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

The 48-hour LC_{50} values in *Leuciscus idus melanotus* (golden orfe) from two separate laboratories were 440 mg/L and 760 mg/L (ECHA) [Kl. scores = 2]. The 96-hour LC_{50} in *Lepomis macrochirus* (fathead minnow) is >100 mg/L (ECHA) [Kl. score = 2).

The 24-hour EC_{50} in *Daphnia* is 85 mg/L in un-neutralized test solution and 1,535 mg/L in a neutralized solution (OECD, 2001a,b; ECHA). [Kl. score = 2]

The 8-day toxicity threshold value (EC_0) in *Scenedesmus quadricauda* is 640 mg/L (ECHA; OECD, 2001a,b). [Kl. score = 2]

Chronic Studies

No studies are available.

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for citric acid follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for only fish (440 mg/L) and *Daphnia* (1,535 mg/L, neutralized). On the basis that the data consist of short-term results from two trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 440 mg/L for fish. The $PNEC_{water}$ is 0.44 mg/L.

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 0.277 mg/kg wet weight.

The calculations are as follows:

$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$
$= (0.807/1280) \times 1000 \times 0.44$
$= 0.277$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$K_{sed\text{-}water} = 0.8 + [0.2 \times Kp_{sed}/1000 \times BD_{soilid}]$
$= 0.8 + [0.2 \times 0.014/1000 \times 2400]$
$= 0.807$

Where:
Kp_{sed} = solid-water partition coefficient (L/kg).

BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$Kp_{sed} = K_{oc} \times f_{oc}$
= 0.3617 x 0.04
= 0.014

Where:

K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for citric acid is estimated to be 0.3617 L/kg.
F_{oc} = fraction of organic carbon suspended sediment = 0.04 [default].

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is 0.002 mg/kg soil dry weight.

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
= (0.007/1500) x 1000 x 0.44
= 0.002

Where:

Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
= 0.3617 x 0.02
= 0.007

Where:

K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for citric acid is estimated to be 0.3617 L/kg.
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT ASSESSMENT

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009, ECHA, 2008).

Citric acid is readily biodegradable; thus, it does not meet the screening criteria for persistence.

The log K_{ow} values for citric acid are -1.61 to -1.80. Thus, citric acid does not meet the screening criteria for bioaccumulation.

There are no adequate chronic aquatic toxicity studies on citric acid. The acute $E(L)C_{50}$ values for citric acid are >1 mg/L in fish and invertebrates. Thus, it does not meet the screening criteria for toxicity.

The overall conclusion is that citric acid is not a PBT substance.

IX. CLASSIFICATION AND LABELING

The information in this section is for a citric acid solution.

A. Classification

Eye Irritant Category 2

B. Labelling

Warning

C. Pictogram



X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact

In the case of contact, immediately flush eyes with plenty of water for at least 15 minutes. If symptoms persist, seek medical advice.

Skin Contact

Wash thoroughly with soap and water.

Inhalation

If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Ingestion

Rinse mouth with water and then drink plenty of water. Never give anything by mouth to an unconscious person. If symptoms develop, seek medical advice.

B. FIRE FIGHTING INFORMATION

Extinguishing Media

Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards

No data are available.

Special Protective Equipment for Firefighters

Wear self-contained breathing apparatus.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions

Use appropriate protective equipment.

Environmental Precautions

Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilt

Pick up with absorbent material. Dispose of contaminated material as prescribed.

D. STORAGE AND HANDLING

General Handling

No special measures necessarily provided product is used correctly.

Other Handling Precautions

Avoid eye and skin contact.

Storage

Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards

Workplace Australia has not established an occupational exposure standard for citric acid.

Engineering Controls

None

Personal Protection Equipment

Respiratory Protection: Respiratory protection is not required.

Hand Protection: Chemical resistant protective gloves.

Skin Protection: Body protection must be chosen depending on activity and possible exposure.

Eye protection: Safety glasses with side-shields.

Other Precautions: Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible.

F. TRANSPORT INFORMATION

Citric acid is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods Code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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XIV. ACRONYMS AND GLOSSARY

°C	degrees Celsius
ADWG	Australian Drinking Water Guidelines
DEWHA	Department of the Environment, Water, Heritage and the Arts
EC	effective concentration
ECHA	European Chemicals Agency
EU	European Union
GHS	Globally Harmonised System of Classification and Labelling of Chemicals
HHRA	enHealth Human Risk Assessment
HPV	High Production Volume
IUPAC	International Union of Pure and Applied Chemistry
Kl	Klimisch scoring system
LOAEL	lowest observed adverse effect level
mg/kg	milligrams per kilogram
NOAEL	no observed adverse effect level
NOEC	no observed effective concentration
OECD	Organisation for Economic Co-operation and Development
PBT	Persistent, Bioaccumulative and Toxic
PNEC	Predicted No Effect Concentration
ppm	parts per million
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RfD	Reference Dose
SDS	Material Safety Data Sheet
SMILES	simplified molecular-input line-entry system
USEPA	United States Environmental Protection Agency
µm	micrometre

COFFEE EXTRACT

This dossier on coffee extract does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of coffee extract in its use in hydraulic fracturing fluids. The information presented in this dossier was obtained from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name: Coffee, bean, roasted, extract

CAS RN: 68916-18-7

Molecular formula: UVCB substance

Molecular weight: UVCB substance

Synonyms: Coffee extract; coffee, bean, roasted, extract

Table 1 shows all of the constituents found in roasted arabica and robusta coffees.

Table 1: Composition of Medium-Roasted Coffee (Clarke, 1987; IARC, 1991)

Components	**Typical average content (dry basis, %)**		**% extractable with water, 100°C[a]**
	Arabica	**Robusta**	
Alkaloids (caffeine)	1.3	2.4	75 - 100
Trigonelline (including roasted by-products)	1.0	0.7	85 - 100
Minerals (as oxide ash)	4.5	4.7	90
Acids			
Residual chlorogenic	2.5	3.8	100
Aquinic	0.8	1.0	100
Aliphatic	1.6	1.6	100
Sugars			
Sucrose	0.0	0.0	-
Reducing	0.3	0.3	100

Polysaccharides (unchanged from green)	33	37	10
Lignin	2.0	2.0	0
Pectins	3.0	3.0	-
Proteinaceous compounds			
Protein	10	10	15 – 20
Free amino acids	0.0	0.0	-
Lipids (coffee oil)	17	11	1
Caramelized or condensation products (*e.g.*, melanoidins) by difference	23	22.5	20-25
Volatile substances other than acids	0.1	0.1	40-80

[a]Maier (1981), for normal household brewing

II. PHYSICO-CHEMICAL PROPERTIES

Table 2: Overview of the Physico-chemical Properties of Coffee Extract

Property	**Value**	**Klimisch score**	**Reference**
Physical state at 20°C and 101.3 kPa	Viscous liquid	2	ECHA
Melting point	ca. -16.82 to -15.95°C	1	ECHA
Boiling point	>102.21°C	1	ECHA
Density	1.234 g/cm^3 @ 20°C	1	ECHA
Vapor pressure	21.8 Pa @ 20°C	1	ECHA
Partition coefficient (log K_{ow})	<0.36 @ 25°C	1	ECHA
Water solubility	2.85 mg/L @ 25°C	1	ECHA
Flash point	No flash to boiling.	1	ECHA
Auto flammability	>600°C	1	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Coffee extract is inherently biodegradable and is expected to have a low potential for bioaccumulation. The potential for adsorption is unknown; however, the low octanol water partition coefficient for coffee extract suggests that it is low. The acute toxicity by the oral and dermal routes is low.

B. Biodegradation

Coffee extract is inherently biodegradable. In an OECD 301D test, degradation was 50.2% after 28 days (ECHA) [Kl. score = 1].

C. Environmental Distribution

Adsorption/desorption

No experimental data are available for coffee extract. Coffee extract is an UVCB substance containing a wide range of different constituents (see Table 1); thus, a K_{oc} value cannot be calculated.

D. Bioaccumulation

No bioconcentration studies have been conducted on coffee extract. Coffee extract is not expected to bioaccumulate based on the experimental log K_{ow} of <0.36 (ECHA).

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

The information on the human health hazard for coffee extract includes primarily data on caffeine, the pharmacologically active constituent of coffee extract, as well as the extract itself. Coffee extract is not irritating to the skin or eyes. Caffeine consumption up to 400 mg caffeine/day in healthy adults is not associated with overt, adverse cardiovascular effects, behavioral effects, reproductive and developmental effects, acute effects, or bone status. Also, consumption up to 300 mg caffeine/day in healthy pregnant women is generally not associated with adverse reproductive and developmental effects.

B. Pharmacokinetics

Caffeine is rapidly and completely adsorbed in humans, with approximately 99% absorbed within 45 minutes of consumption (Carillo and Benitez, 2000). Plasma caffeine levels may be influenced by the diet or route of exposure, but peak plasma levels occur approximately 15 to 120 minutes after consumption (Mandel, 2002; Beach *et al.*, 1984; Bonati *et al.*, 1984; Collomp *et al.*,

1991). Caffeine is water soluble and is rapidly distributed throughout the body, detected in all bodily fluids, including saliva, breast milk, urine and semen (Beach *et al.*, 1984). Caffeine elimination follows first-order kinetics (Newton *et al.*, 1981), with the plasma half-life of caffeine at approximately 3 to 6 hours in healthy adults and does not accumulate in body fat or other tissues (Kaplan *et al.*, 1997; Nawrot *et al.*, 2003). Caffeine is rapidly metabolized and excreted (1-3 mg/kg/minute) in the urine (Kaplan *et al.*, 1997), and varies between species, with a slightly different metabolic route noted in rats (Nawrot *et al.*, 2003).

C. Acute Toxicity

Animal Studies

The oral LD_{50} value of an aqueous extract of roasted and ground beans of *Coffea canephora robusta* containing 7.5% caffeine was between 2,000 and 5,000 mg/kg (ECHA) [Kl. score = 1].

No acute inhalation studies are available on coffee extract. The 4-hour LC_{50} value of a caffeine aerosol in rats is 4.94 mg/L (ECHA) [Kl. score = 2].

No acute dermal studies are available on coffee extract. The dermal LD_{50} value of an aqueous solution of caffeine in rats is >2,000 mg/kg (ECHA) [Kl. score = 2].

Human Studies

Studies in human have focused on caffeine, the pharmacologically active component in coffee. The fatal acute oral dose is estimated at 10 and 14 g (approximately 160 to 230 mg/kg for a 60 kg person) (Hodgman, 1998). The serum caffeine concentration is the most reliable indicator of potential caffeine toxicity, with a serum caffeine concentration >100 μg/ml considered lethal in humans (Mrvos *et al.*, 1989). Human caffeine consumption at up to 10 g has caused convulsions and vomiting, with recovery in six hours (Dreisbach, 1974). An acute dose of one gram caffeine can cause adverse effects, progressing from restlessness, nervousness, and irritability to delirium, emesis, neuromuscular tremors and convulsions (IOM, 2004). However, caffeine consumption through the day at up to 900 mg has been reported without adverse effects (Nawrot *et al.*, 2003).

D. Irritation

Coffee silverskin extracts was not considered a skin irritant when tested in an *in vitro* reconstructed human epidermis test (ECHA) [Kl. score = 1].

Coffee, bean, roasted, extract was not considered an eye irritant when tested in a bovine corneal opacity and permeability test (ECHA) [Kl. score = 1].

E. Sensitization

No studies are available.

F. Repeated Dose Toxicity

<u>Oral</u>

Male and female rats were given in their drinking water 0, 25, 50, or 100% with either instant or brewed coffee for 91 days. The average daily intakes of caffeine were 0, 20, 40, or 80 mg/kg-day for the brewed coffee and slightly lower intakes for the instant coffee. At study termination, the kidneys of the 100% male coffee groups had enlarged kidneys based on both absolute and relative weights. In the females, liver and kidneys were enlarged in all rats given brewed coffee, although the relative weights were significantly higher only in the 100% group. In the ≥50% instant coffee groups, both absolute and relative liver and kidney weights were increased, although there was no clear dose-response pattern. Histopathologic examination showed no treatment-related effects. In the absence of corresponding histopathologic changes, the liver and kidney weight changes were considered to be adaptive changes and not adverse. The NOAEL for this study is 100% coffee in drinking water, which corresponds to 80 mg/kg-day (Nolen, 1981; ECHA) [Kl. score = 2].

In an NTP study, male and female F344 rats were dosed by oral gavage with 0, 188, 375, 750, 1,500, or 3,000 ppm caffeine for 90 days. The average daily intakes were: 0, 19.7, 42, 85.4, 151, or 272 mg/kg-day for males; and 0, 23, 51, 104, 174, or 287 mg/kg-day for females). Body weight gain was reduced in all treated groups but was only significant in the 3,000 ppm animals (26% and 20% for males and females, respectively). Water consumption was decreased in the 3,000 ppm animals; it was increased in the 375 and 750 ppm groups. The only treatment-related effects observed was cellular enlargement in the salivary gland, which was dose-dependent. This effect in the salivary gland was considered an adaptive response as a result of the pharmacological effect of caffeine (sympathomimetic) and not an adverse effect. The NOAEL for this study is 1,500 ppm, which corresponds to 151 and 174 mg/kg-day for males and females, respectively (ECHA) [Kl. score = 2].

Inhalation

No studies are available.

Dermal

No studies are available.

G. Genotoxicity

In Vitro Studies

Instant and home brew coffees (caffeinated and decaffeinated) were evaluated for genotoxicity in an in vitro chromosomal aberration test using human lymphocytes with or without metabolic activation (S9 mix). Chromosomal aberrations were increased with all coffee samples with or without S9, although there was less of an increase with S9. Pure caffeine tested with or without S9 at doses equivalent to the levels in the caffeine-containing coffees did not induce a statistically significant increase in chromosomal aberrations (Aeschbacher et al., 1985; ECHA) [Kl. score 2].

Instant and home brew coffees (caffeinated and decaffeinated) were evaluated for mutagenicity in an in vitro bacterial reverse mutation assay with or without metabolic activation (S9 mix). The *S. typhimurium* strains were TA 98, TA 100, TA1535, TA 1537, and TA 1538. A mutagenic response was observed with TA 100 in the absence of S9, but not with S9. None of the other

strains showed a mutagenic response with or without S9 (Aeschbacher and Würzner, 1980; ECHA) [Kl. score = 2].

Five Americano coffees from selected coffee chains were evaluated for mutagenicity in an in vitro bacterial reverse mutation assay with or without metabolic activation (S9 mix). The *S. typhimurium* strains were TA 98, TA 100, and TA 1535. There were no mutagenic responses with or without metabolic activation (Liu et al., 2017; ECHA) [Kl. score = 2].

In Vivo Studies

Male Swiss OF-1 mice were dosed by oral gavage with 0, 500, 1,000, 2,000, or 3,000 mg/kg instant coffee for five consecutive days. There was no treatment-related increase in the frequency of micronuclei in bone marrow cells (Aeschbacher et. al., 1984 ECHA) [Kl. score = 2].

H. Carcinogenicity

No carcinogenicity studies are available.

I. Reproductive/Developmental Toxicity

Animal Studies

A one-generation reproductive toxicity study was conducted in rats. Male and female rats were given in their drinking water 0, 25, 50, or 100% with either instant or brewed coffee. The average daily intakes were 0, 20, 40, or 8 mg/kg-day for the brewed coffee and slightly lower intakes for the instant coffee. Exposure of parental animals were for 91 days and during mating. Exposure continued through the first gestation period and through weaning. Ten days later, the females were mated the second time and were sacrificed on GD 13 or 21. There were no indications of reproductive or developmental toxicity (Nolen, 1981; ECHA) [Kl. score = 2].

Human Studies

Studies in human have focused on caffeine, the pharmacologically active component in coffee. Studies that evaluated the potential teratogenicity of caffeine have been discussed in a review (Christian and Brent, 2001). In animal studies, caffeine administration to pregnant animals has been found to induce teratogenicity and toxic effects on the development of the fetuses only at doses that also caused toxic effects in the dams (Christian and Brent, 2001). Christian and Brent (2001) concluded that studies reporting positive teratogenic effects were administering large doses of caffeine that were far greater than human consumption and were providing the caffeine via gavage, which results in much higher peak serum caffeine levels and therefore overstates toxicity potential. Neither rodents nor humans could attain such peak exposures by consuming solutions of caffeine over several hours, the usual mode of human caffeine consumption.

There have been questions raised on whether high intake of coffee or caffeine may increase the risk of miscarriage. Caffeine crosses the placenta and increases maternal catecholamine levels (Goldstein and Warren, 1962). The American College of Obstetricians and Gynecologists (2010) have concluded the following: “Moderate caffeine consumption (less than 200 mg per day) does not appear to be a major contributing factor in miscarriage or preterm birth. The relationship of

caffeine to growth restriction remains undetermined. A final conclusion cannot be made at this time as to whether there is a correlation between high caffeine intake and miscarriage."

The American College of Obstetricians and Gynecologists (2010) have concluded that moderate caffeine consumption (<200 mg/day) does not appear to be a major contributing factor in miscarriage or preterm birth.

A recent systematic review of the potential adverse effects of caffeine consumptions in humans concluded that consumption up to 400 mg caffeine/day in healthy adults is not associated with reproductive and developmental effects. Also, consumption up to 300 mg caffeine/day in healthy pregnant women is generally not associated with adverse reproductive and developmental effects (Wikoff et al., 2017).

J. Human Studies

Caffeine is a stimulant and has been studied for its physiological and behavioral effects. Caffeine increases heart rate and blood pressure, increases diuresis, increases locomotion and alertness, and decreases sleepiness. Clinical studies indicate that doses <450 mg do not increase the risk or severity of cardiac arrhythmia, while acute doses of 150 mg caffeine may decrease heart rate (James, 1991; Green *et al.*, 1996; Myer, 1998). Studies evaluating effects of caffeine on cardiovascular health or serum cholesterol levels have not provided a consistent adverse effect with caffeine consumption (Nawrot *et al.*, 2003).

Nawrot *et al.* (2003) concluded in their review of the effects of caffeine on human health that "for the healthy adult population, moderate daily caffeine intake at a dose level up to 400 mg/day (equivalent to 6 mg/kg body weight/day in a 65-kg person) is not associated with adverse effects such as general toxicity, cardiovascular effects, effects on bone status and calcium balance (with consumption of adequate calcium), changes in adult behavior, increased incidence of cancer and effects on male fertility." It was indicated that habitual daily use of caffeine at greater than 500-600 mg/day (8.3 - 10 mg/kg) (4-7 cups of coffee or 7-9 cups of tea) could be considered a health risk. For women, caffeine intake greater than 400 mg/day (6.7 mg/kg) "may increase the risk of detrusor instability (unstable bladder) development in women" (Nawrot *et al.*, 2003).

A recent systematic review of the potential adverse effects of caffeine consumptions in humans also concluded that consumption up to 400 mg caffeine/day in healthy adults is not associated with overt, adverse cardiovascular effects, behavioral effects, acute effects or bone status (Wikoff et al., 2017).

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for coffee extract follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

<u>Oral</u>

A 90-day drinking water study on brewed and instant coffee reported no adverse effects up to 80 mg/kg-day (Nolen, 1982). A NTP 90-day oral gavage toxicity study in rats showed no adverse effects up to 174 mg/kg-day (NTP).

In two separate reviews (Nawrot et al., 2003; Wikoff et al., 2017) with the most recent one conducted using a systematic review approach (Wikoff et al., 2003), caffeine consumption in healthy adults up to 400 mg/day is not associated with any adverse health effects. Based on the acceptable daily intake of caffeine in coffee extract, the acceptable daily intake of caffeine of 400 mg/day will be used to derive the oral reference dose and drinking water guidance value for coffee extract.

Oral Reference Dose (oral RfD)

For a 70 kg person, the oral reference dose is 400/70 = 6 mg/kg-day.

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (5.7 x 70 x 0.1)/2 = <u>20 mg/L</u>

B. Cancer

No studies are available. Thus, a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Coffee extract does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Coffee extract has a low acute toxicity concern for aquatic life.

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies conducted on coffee extract.

Table 3: Acute Aquatic Toxicity Studies on Coffee Extract

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Oncorhynchus mykiss	96-hr LL_{50}	>100 WAF	1	ECHA
Daphnia magna	48-hr EL_{50}	>100 WAF	1	ECHA
Pseudokirchneriella subcapitata	72-hr EL_{50}	>100 WAF (growth)	1	ECHA

Chronic Studies

No studies are available.

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for coffee extract follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)L_{50}$ values are available for fish (>100 mg/L WAF), invertebrates (>100 mg/L WAF), and algae (>100 mg/L WAF). On the basis that the data consist of short-term results from three trophic levels, an assessment factor of 100 has been applied to the acute $E(L)L_{50}$ value of 100 mg/L WAF from fish, invertebrates, and algae. The $PNEC_{water}$ is 1 mg/L.

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. The $PNEC_{sed}$ was not calculated using the equilibrium partitioning method because the K_{oc} value cannot be determined.

PNEC soil

There are no toxicity data for terrestrial or soil organisms. The $PNEC_{soil}$ was not calculated using the equilibrium partitioning method because the K_{oc} value cannot be determined.

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008). Coffee extract is not readily biodegradable, but it does appear to be inherently biodegradable; thus, it is not expected to meet the screening criteria for persistence.

Based on a measured log K_{ow} of <0.36, coffee extract does not meet the screening criteria for bioaccumulation.

There are no chronic aquatic toxicity studies on coffee extract. The acute $E(L)L_{50}$ values for coffee extract are >1 mg/L for fish, invertebrates, and algae. Thus, coffee extract does not meet the screening criteria for toxicity.

The overall conclusion is that coffee extract is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Not classified.

B. Labelling

No signal word.

C. Pictogram

None.

X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
In case of contact, immediately flush eyes with plenty of water. If easy to do, remove contact lenses.

Skin Contact
Take off contaminated clothing immediately. Wash thoroughly with soap and water. Get medical attention if irritation develops and persists.

Inhalation
If inhaled, remove from area to fresh air. Get medical attention.

Ingestion
Rinse mouth with water and then drink a glass of water. Get medical attention. Do not induce vomiting. Never give anything by mouth to an unconscious person.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: carbon monoxide, carbon oxides, nitrogen oxides.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Use personal protective clothing.

Environmental Precautions
Do not empty into drains.

Steps to be Taken if Material is Released or Spilled
For small amounts: Pick up with absorbent material. Dispose of contaminated material. For large amounts: pump off product.

D. STORAGE AND HANDLING

General Handling
No special measures necessary provided product is used correctly.

Storage
Keep container tightly closed and dry. Store in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards

Workplace Australia has not established an occupational exposure limit for coffee extract.

Engineering Controls
None

Personal Protection Equipment

Respiratory Protection: Respiratory protection not required.

Hand Protection: Wear chemical resistant protective gloves.

Skin Protection: Body protection must be chosen depending on activity and possible exposure.

Eye protection*:* Wear safety goggles with side shields.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Wearing of closed work clothing is recommended. Ensure that eyewash stations and safety showers are close to the workstation location.

F. TRANSPORT INFORMATION

Coffee extract is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

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DIETHANOLAMINE

This dossier on diethanolamine (DEA) does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of diethanolamine in its use in drilling muds and hydraulic fracturing fluids. The majority of information presented in this dossier was obtained from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC): 2,2'-iminodiethanol

CAS RN: 111-42-2

Molecular formula: $C_4H_{11}NO_2$

Molecular weight: 105.14

Synonyms: Diethanolamine; 2,2'-iminodiethanol; 2,2'-dihydroxydiethylamine; 2-[(2-hydroxyethyl)amino]ethanol; bis(2-hydroxyethyl)amine; DEA; di(2-hydroxyethyl)amine; ethanol, 2,2'-iminobis-(9Cl); ethanol, 2,2'iminodi-(8Cl)

SMILES: C(CO)NCCO

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Diethanolamine

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Crystals (prisms) or syrupy liquid (>82°F)	2	ECHA
Melting Point	27°C	1	ECHA
Boiling Point	268.9°C (decomposition occurs ≥200°C)	1	ECHA
Density	1.095.3 kg/m^3	2	ECHA
Vapor Pressure	1 hPa @ 108°C (measured); 0 hPa at 25°C	2	ECHA

Partition Coefficient (log K_{ow})	-2.46 @ 25°C	2	ECHA
Water Solubility	Miscible	2	ECHA
Flash Point	176°C @ 1,013 hPa	2	ECHA
Auto flammability	375°C @ 1,013 hPa	1	ECHA
Flammable	Not flammable	1	ECHA
Viscosity	390.9 mPa s @ 30°C; 102.7 mPa s @ 50°C	2	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Diethanolamine is readily biodegradable. It is not expected to bioaccumulate, and it has low potential to adsorb to soil.

B. Biodegradation

Diethanolamine is readily biodegradable. In an OECD 301F test, there was 50% degradation after 7 days, 80% after 14 days, and 93% after 28 days (OECD 2007; ECHA) [Kl. score = 1]. In a "Ready" Biodegradability – Dissolved Organic Carbon (DOC) Die-Away test, there was 86% degradation after 7 days and 96% degradation after 10 days (ECHA) [Kl. score = 2]. In modified OECD 301E screening tests using river or pond water, there was 93% and 97% degradation (measured as DOC removal) after 28 days (OECD 2007; ECHA) [Kl. score = 2].

C. Environmental Distribution

Distribution Modeling

No experimental data are available for diethanolamine. The K_{oc} for diethanolamine (as the charged molecule) was calculated to be 10 at pH values between 5 and 8 (Franco and Trapp, 2008; Franco et al., 2009; ECHA). [Kl. score = 2]

E. Bioaccumulation

There are no bioaccumulation studies on diethanolamine. The BCF was estimated to be 2.3 based on calculations from OASIS Catalogic v.5.11.15 [BCF base-line model v.0208] (Dimitrov et al., 2005; ECHA).

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Diethanolamine exhibits moderate acute toxicity by the oral route, but low acute toxicity by the inhalation and dermal routes. It is a skin irritant and a severe eye irritant. Diethanolamine is not a skin sensitizer. Repeated oral exposure to rats (in drinking water) resulted in anemia, kidney toxicity, demyelinization of the brain/spinal cord, and damage to the testes in males, which included adverse effects on the sperm. Repeated oral exposure to mice (in drinking water) resulted in adverse effects to the kidney, liver, and heart. Repeated dermal exposure to rats and mice resulted in systemic toxicity, which included kidney toxicity, anemia (rats only), and liver toxicity (mice only). Rats exposed nose-only to an aerosol of diethanolamine developed anemia, adaptive liver and kidney effects, damage to the male reproductive organs, and upper respiratory tract irritation. There was no evidence of neurotoxicity. In short-term oral studies, rats and mice exposed to diethanolamine showed some immune-modulating effects at dose levels that resulted in overt signs of systemic toxicity. Diethanolamine was not genotoxic in a variety of *in vitro* and *in vivo* genotoxicity tests. Diethanolamine was not carcinogenic to rats in a two-year NTP dermal bioassay; but, in mice, there was an increased incidence of liver tumors in males and females and kidney tumors in males. Studies by the oral and dermal routes showed testicular damage in male rats, but no adverse effects in female reproductive organs. Developmental toxicity occurred in rats when exposures by the oral, dermal, or inhalation routes also caused maternal toxicity. There was no developmental toxicity in rabbits even at doses that caused maternal toxicity.

B. Pharmacokinetics/Metabolism

Following oral administration of [^{14}C]-diethanolamine, 57% of the dose was absorbed (Matthews et al., 1997). Absorption was lower through the skin than from oral administration. Diethanolamine may also facilitate its own absorption in rats, as 3% and 16% of the dermally applied doses (in 95% ethanol) of 2 and 27 mg/kg, respectively, were absorbed through the skin in a 48-hour period. Dermal absorption of diethanolamine is higher in the mouse than the rat: absorption was 25 to 60% from dermal doses of 8 to 80 mg/kg (Matthews et al., 1997).

The distribution of diethanolamine is similar across all routes of exposure (Matthews et al., 1997; Mendrala et al., 2001). The highest concentrations were found in the liver and kidney. The half-life of diethanolamine from tissues is about 6-7 days (Mendrala et al., 2001).

Following an oral dose of [^{14}C]diethanolamine to male F344 rats, the livers showed levels of un-metabolized diethanolamine, N-methyl-diethanolamine, N,N-dimethyl-diethanolamine, and phosphates of diethanolamine. In addition, the organic extract of the liver had radioactivity co-eluting with phosphatidyl ethanolamine and phosphatidyl choline. When the organic extract was digested with sphingomyelinase, 30% of the phospholipids were identified as ceramides and the remaining 70% as phosphoglycerides. Incubation of human liver slices with [^{14}C]-diethanolamine showed similar incorporation of diethanolamine into ceramides, followed by methylation (Matthews et al., 1995).

Diethanolamine is excreted primarily in urine as the parent compound (25-36%), with lesser amounts of O-phosphorylated and N-methylated metabolites (Matthews et al., 1997).

C. Acute Toxicity

The oral LD_{50} value for male and female rats combined was determined to be 1,600 mg/kg (ECHA) [Kl. score = 2]. The oral LD_{50} in female Wistar rats is 1,820 mg/kg (ECHA) [Kl. score = 2].

There were no deaths in rats following an 8-hour inhalation exposure to an atmosphere enriched with diethanolamine vapor. The technically highest attainable concentration is 1.9 mg/m^3 or 0.44 ppm (ECHA) [Kl. score = 2]. There were no deaths in rats following an 8-hour exposure to 0.2 mg/L diethanolamine vapor (ECHA) [Kl. score = 2].

There are no reliable acute dermal toxicity studies on diethanolamine.

D. Irritation

Application of 2 mL of diethanolamine to the skin of rabbits for 20 hours was irritating. The mean of the 24, 48, and 72 hours scores were 2.00 for erythema and 1.33 for edema (ECHA) [Kl. score = 2].

Instillation of diethanolamine into the eyes of rabbits was irritating. The mean of the 24, 48, and 72 hour scores were 1.67 for corneal opacity; 0.00 for iridial lesions; 1.50 for conjunctival redness; and 0.83 for chemosis. Corneal lesions still persisted in one of two animals at the end of the 8-day observation period (ECHA) [Kl. score = 2]. Instillation of 100 mg diethanolamine into the eyes of rabbits produced a mean irritation score based on Kay and Calandra of 50.75, indicating severe irritation (ECHA) [Kl. score = 2].

E. Sensitization

Diethanolamine was not considered a skin sensitizer in a mouse local lymph node assay (ECHA). [Kl. score = 1]

F. Repeated Dose Toxicity

Oral

Male and female F344 rats were given diethanolamine in their drinking water for 13 weeks at concentrations of 0, 320, 630, 1,250, 2,500, or 5,000 ppm for males; and 0, 160, 320, 630, 1,250, or 2,500 ppm for females. The average daily intakes were estimated to be: 0, 25, 48, 97, 2,202, or 436 mg/kg-day for males; and 0, 14, 32, 57, 124, or 242 mg/kg-day for females. In the top dose group, 2/10 males died during the study. Weight gain was reduced in the ≥630 ppm males and the ≥320 ppm females. Decreased water consumption among the higher dose groups may have contributed in part to the decreased body weight gain. Clinical signs of toxicity included tremors, emaciation, abnormal posture, and rough hair coat in the two highest dose groups. A dose-dependent microcytic, normochromic anemia was seen in all dose groups for both sexes. Hematologic effects included decreases in erythrocyte and reticulocyte counts, hemoglobin concentration, hematocrit, MCV, and MCH. MCV was reduced in rats at all dose levels. Hematologic effects were not associated with microscopic changes in the femoral bone marrow. Relative kidney weights were increased in a dose-dependent manner in the ≥320 ppm males and ≥160 ppm females, accompanied by increases in the incidence and/or severity of nephropathy, renal tubular cell necrosis, or tubular mineralization. Nephropathy consisted of tubules lined by epithelial cells with more basophilic staining of the cytoplasm and a higher nuclear/cytoplasmic ratio; occasionally, thickened basement membranes were seen around these tubules. This lesion was present to a minimal degree in controls, particularly in male rats, but was increased in incidence and severity in the 5,000 ppm males and in most of the groups of treated females. Increased nephropathy was considered a regenerative change and was supported by the observation of tubular necrosis at the higher dose groups. Relative liver weights were increased in the ≥630 ppm males and ≥320 ppm females, with no corresponding histopathological changes in the liver. There was, however, mild to moderate increases in serum levels of total bile acids in the ≥160 ppm females and in the ≥630 ppm males. Decreases in testis and epididymis weights (≥1,250 ppm) were associated microscopically with degeneration of seminiferous epithelium and with hypospermia (≥2,500 ppm). Testicular degeneration was diagnosed in all high-dose males and in 3/10 of the 2,500 ppm males. Intraluminal cellular debris and reduced numbers of sperm cells were present in the epididymis. These findings correlated with decreases in sperm motility and sperm count per gram caudal tissue. There was also atrophy of the seminal vesicle and prostate glands in the higher dose group males. In females, the estrous cycle length was similar across all groups. Minimal to mild demyelination of the brain and spinal cord was noted in the ≥2,500 ppm males and the ≥1,250 ppm females; there were no neurological clinical signs that could be attributed to these lesions. Cytoplasmic vacuolization of the zona glomerulosa of the adrenal cortex was seen in the 5,000 ppm males and in the ≥1,250 ppm females. This was a minimal change consisting of small clear vacuoles in the cytoplasm of these cells and may have been related to increased mineralocorticoid production secondary to kidney damage and/or dehydration. The most

sensitive endpoints were the microcytic anemia in both sexes and kidney effects in females (weight, nephrotoxicity) and males (weights). The LOAELs are 320 ppm (25 mg/kg-day) for males and 160 ppm (14 mg/kg-day) for females (NTP 1992; Melnick et al., 1994a). [Kl. score = 1]

Male and female B6C3F1 mice were given diethanolamine in their drinking water at concentrations of 0, 630, 1,250, 2,500, 5,000 or 10,000 ppm for 13 weeks. The average daily intakes were estimated to be: 0, 104, 178, 442, 807, or 1,674 mg/kg-day for males; and 0, 142, 347, 884, 1,154, or 1,128 mg/kg-day for females. All of the ≥5,000 ppm animals and 3/10 of the 2,500 ppm females died during the study. Body weight gains were lower in the 2,500 ppm males and in the 1,250 and 2,500 ppm females. Animals that survived to the end of the study had similar water consumption compared to the controls. Clinical signs in the animals that died early in the 2,500 ppm group were tremors, ruffled fur, emaciated appearance, abnormal posture, and hypoactivity. There was no significant gross findings at necropsy in the mice that died early or survived to study termination. Absolute and relative liver weights were increased in a dose-dependent manner in male and female mice and was associated with increases in serum alanine aminotransferase and sorbital hydrogenase activities and, in addition, microscopic changes diagnosed as hepatocellular cytologic alteration and necrosis. Cytologic alteration consisted of multiple hepatocyte changes including hypertrophy with increased eosinophilia and disruption of hepatic cords. These lesions were observed in mice that died early and those that survived to the end of the study. There was also increased nuclear pleomorphism and the frequent presence of large, multinucleated hepatocytes. These giant cells often contained 10 or more nuclei. Hepatocyte necrosis was randomly distributed and involved single cells or small foci. Absolute and relative kidney weights were increased in males and were associated with a dose-dependent increase in the incidence of nephropathy among those mice that survived to the end of the study. Nephropathy was minimal; there were renal tubules lined by basophilic cells with high nuclear/cytoplasmic ratio. This was considered to be a regenerative response, although active tubular necrosis was observed only in a few early-death mice at ≥5,000 ppm. Increased heart weight was seen in the 2,500 ppm females, and relative heart weight was seen in the 2,500 ppm males and the 1,250 and 2,500 ppm females. There was also minimal-to-marked degeneration and necrosis of cardiac myocytes in both sexes exposed to ≥2,500 ppm. Myocardial degeneration was generally more severe in mice that died early than in those that survived to study termination. The most sensitive endpoint was the increase in liver weights with corresponding histopathological changes. The LOAEL was 630 ppm (104 and 142 mg/kg-day in males and females, respectively) (NTP, 1992; Melnick *et al.*, 1992b). [Kl. score = 1]

Inhalation

Male and female Wistar rats were exposed nose-only to 0, 15, 150, or 450 mg/m^3 diethanolamine aerosol, 6 hours/day, 5 days/week for 90 days. The MMAD values were 1.1 – 1.9 μm, 1.0 μm, and 0.6 – 0.9 μm for the 15, 150, and 450 mg/m^3 exposure groups, respectively. The percent aerosol ranged among the exposure groups,, from 92 to 95%.

There were no deaths during the study. The 400 mg/m^3 males had slightly decreased body weights. The neurotoxicity endpoints (functional observation battery, sensorimotor test/reflexes, and motor activity) and ophthalmoscopy examination showed no treatment-related effects. At 400 mg/m^3, there was a significant decrease in red blood cells, hemoglobin, hematocrit, and mean corpuscular volume in both sexes. A marginal increase in anisocytosis was seen in the 400 mg/m^3 males; and no treatment-related effects were seen in white or differential blood counts. ALP serum activity was increase in the $\geq$150 mg/m^3 animals, and reduced ALT in the $\geq$150 mg/m^3 males. Blood chemistry changes included increased calcium, total protein, albumin, globulin in the $\geq$150 mg/m^3 females; and increased total protein and albumin in the $\geq$150 mg/m^3 males as a trend. Absolute and relative liver and kidney weights were increased in the $\geq$150 mg/m^3 animals. Histopathologic examination showed diffuse testicular atrophy accompanied by oligozoospermia in the epididymides, and slight prostate atrophy in the some of the 400 mg/m^3 males. There was also minimal or slight tubular hyperplasia of the kidney in some females as well as intratubular lithiasis in increased number (also in the 400 mg/m^3 males). There was also indications of local irritation of the respiratory tract. The larynx appeared to be the most sensitive area where some epithelia damage was observed at all concentrations. Focal inflammation at the tracheal bifurcation occurred in the $\geq$150 mg/m^3 animals. No treatment-related effects were seen in the neuropathologic examination. The NOAEC for systemic toxicity is 15 mg/m^3. The LOAEC for localized effects (irritation) is 15 mg/m^3; a NOAEC was not established (Garner et al., 2008). [Kl. score = 1]

Male and female Wistar rats were exposed nose-only to 0, 1.5, 3, or 8 mg/m^3 diethanolamine aerosol, 6 hours/day, 5 days/week for 90 days. Additional group of female rats were exposed for 90 days followed by a 3-month recovery period. The MMAD values were 0.6 μm, 0.6 μm, and 0.7 μm for the 1.5, 3, and 8 mg/m^3 exposure groups, respectively. At 8 mg/m^3, the animals showed upper respiratory tract irritation in the form of squamous metaplasia of the laryngeal epithelium at the base of the epiglottis; this was accompanied by some inflammatory cell infiltration. These effects were reversible following the 3-month recovery period. The NOAEC for localized effects (irritation) is 3 mg/m^3 (ECHA). [Kl. score = 1]

Dermal

Male and female F344 rats were given daily dermal applications of 0, 32, 63, 125, 250, or 500 mg/kg diethanolamine, 5 days/week for 13 weeks. The animals that died during the study are as follows: one 500 mg/kg male during week 9 and 2 500 mg/kg females that were killed in a moribund condition during week 10. Final mean body weights were lower in the $\geq$250 mg/kg male and the $\geq$125 mg/kg females. The primary clinical signs of toxicity in the $\geq$125 mg/kg animals were irritation and crusting of the skin at the application site. In all dosed groups, there was a moderate, poorly regenerative, microcytic, normochromic anemia in both sexes. Red blood cell variables were decreased in the $\geq$32 mg/kg dose groups. There were no histologic changes in the femoral bone marrow in any dose group. Serum biochemical changes in males were

increased UN and albumin in the 63 and 250 mg/kg groups, respectively, and mild increases in ALT in the ≥125 mg/kg animals. In females, UN, albumin, and total protein increased in the ≥32 mg/kg groups (≥63 mg/kg for total protein), and total bile acids increased in the ≥250 mg/kg groups. A mild increase was seen in ALT in the 500 mg/kg females. The kidney was a target organ. Absolute and relative kidney weights in male and female rats; these were associated with increased severity or increased incidences of nephropathy, renal tubular cell necrosis, or tubular mineralization. The incidence and severity of nephropathy was increased in a dose-dependent manner at the lower dose levels in females, but there was no clear treatment effect on this lesion in males. Tubular necrosis was observed in the ≥250 mg/kg females, but no active necrosis was found in the corresponding male groups. Tubular mineralization, consistent with previous necrosis, was present in the 500 mg/kg males, as well as being increased in incidence and severity in most treated female groups. The absolute and relative liver weights were increased in a dose-dependent manner in both sexes; there were no corresponding histopathologic changes even though there were some mild serum biochemical changes. There were no adverse effects on the testes or epididymides; sperm morphology and vaginal cytology was unaffected by treatment. The skin lesions were dose-related in incidence and severity, and consisted of ulcers, chronic active inflammation, acanthosis, and hyperkeratosis. Demyelination in the medulla oblongata was observed in the 500 mg/kg animals, and in seven 250 mg/kg females; the lesions were characterized by intramyelinic vacuoles arranged symmetrically around the medial medulla oblongata in the region of the tectospinal tract. The lesions were minimal in severity and there was no spinal cord involvement. The LOAEL for this study is 32 mg/kg-day; a NOAEL was not established (NTP, 1992; Melnick et al., 1994a). [Kl. score = 1]

Male and female $B6C3F_1$ mice were given daily dermal applications of 0, 80, 160, 320, 630, and 1,250 mg/kg diethanolamine, 5 days/week for 13 weeks. At 1,250 mg/kg, there were early deaths and reduced body weight gain. Skin lesions were seen in the ≥80 mg/kg groups, there was acanthosis at 80 mg/kg and with a dose-dependent increased incidence up to ulcerations, inflammation, and hyperkeratosis at the higher levels. Liver weights were increased in a dose-dependent manner in the ≥32 mg/kg groups and were associated with morphological alterations in the liver in the ≥32 mg/kg groups. Kidney weights were increased in a dose-dependent manner in the ≥32 mg/kg groups with an increased incidence of tubular necrosis only in the 1,250 mg/kg group. There was also degeneration in the heart and cytologic alterations in the salivary gland in the 1,250 mg/kg group only. The LOAEL for this study is 80 mg/kg-day; a NOAEL was not established (NTP, 1992;Melnick et al., 1994b) [Kl. score = 1]

G. Genotoxicity

In Vitro Studies

Table 2 presents the results of the *in vitro* genotoxicity studies on diethanolamine.

Table 2: *In vitro* Genotoxicity Studies on Diethanolamine

Test System	Results*	Klimisch	Reference

	-S9	+S9	Score	
Bacterial reverse mutation (*S. typhimurium* and *E. coli* strains)	-	-	2	Dean et al. (1985)
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	Haworth et al. (1983)
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	-	-	2	Myhr et al. (1986)
Chromosomal aberration (rat liver cells RL1 and RL4)	-	NA	2	Dean et al. (1985)
Chromosomal aberrations (CHO cells)	-	-	2	Loveday et al. (1989)
Sister chromatid exchange (CHO cells)	-	-	2	Loveday et al. (1989)

*+, positive; -, negative; NA, not applicable

In vivo Studies

Male and female B6C3F$_1$ mice were given daily dermal applications of 0, 80, 160, 320, 630, or 1,250 mg/kg diethanolamine for 13 weeks. There was no induction of micronuclei in the peripheral blood erythrocytes at any dose level (NTP, 1992; Witt et al., 2000) [Kl. score = 1].

H. Carcinogenicity

Oral

No studies are available.

Inhalation

No studies are available.

Dermal

Male and female F344/N rats were given dermal application of diethanolamine for 104 weeks. For males, the doses were 0, 16, 32 or 64 mg/kg-day; and for females, the doses were 0, 8, 16 or 32 mg/kg-day. There was no difference in survival rates between treated and control animals. Mean body weights were lower in the 64 mg/kg-day males from

week 8 to 89 and in the 32 mg/kg-day females from week 97 compared to the control animals. The incidences of tumors was not increased in the treated groups compared to the controls. (NTP, 1999). [Kl. score = 1]

Male and female B6C3F$_1$ mice were given dermal applications of 0, 40, 80 or 160 mg/kg-day diethanolamine by dermal application for 104 weeks. There was reduced survival in the treated female mice (88, 66, 66, and 46% for the 0, 40, 80 and 160 mg/kg-day groups, respectively). This was attributed to liver tumors. No differences were seen in survival rates in the treated male mice compared to the controls. Mean body weights in the 80 and 160 mg/kg-day males were lower than those in the control animals after week 88. Mean body weights in the treated female mice were lower than those of the controls from week 73 (40 and 80 mg/kg-day) and week 53 (160 mg/kg-day).

The incidence of hepatocellular adenomas and of hepatocellular adenomas and carcinomas (combined) were significantly increased in all male and female dose groups, while the incidences of hepatoblastoma was increased in the mid- and high-dose groups. In the female mice, the incidences of hepatocellular neoplasms were significantly higher in all dosed groups compared to the control. Non-neoplastic lesions were seen only in the liver of all male and female dose groups and consisted of cytoplasmic alteration, characterized by mild to moderate enlargement of centrilobular hepatocytes, and syncytial alteration, characterized by scattered hepatocytes with three or more small nuclei.

The incidence of renal tubule adenomas was also increased in males with a positive trend, but the incidences of carcinoma and hyperplasia did not follow this pattern. A step section evaluation found additional adenomas and hyperplasias in all treated male groups. The combined analysis of single and step sections indicated a dose-related increase in the incidence of renal hyperplasia and renal tubule adenoma or carcinoma (combined), and increase in the incidences of renal tubule adenoma in male mice (NTP, 1999). [Kl. score = 1]

<u>Mode-of-Action for Mouse Liver Tumors in DEA-exposed Mice</u>

Effects of DEA on choline homeostasis

Dietary choline deficiency or deprivation induces liver tumors in rodents (Newberne *et al.*, 1982). In contrast, dietary supplementation of choline with or without methionine reduces the incidence of liver tumors in carcinogen-treated mice (Fullerton *et al.* 1990; Newberne *et al.*, 1990). DEA is structurally similar to ethanolamine and choline, important endogenous precursors for normal membrane structure and function. Choline is also oxidized to betaine, an essential methyl group donor in 1-carbon metabolism. The mechanisms by which choline deficiency is thought to be carcinogenic include enhanced cell proliferation, altered methylation status, and altered signal transduction (Rogers, 1995; Zeisel, 1996; Zeisel and Blustjazn, 1994). The development of intracellular

choline deficiency as the mode of action by which DEA cause the mouse liver tumors observed in the NTP bioassay is supported by the following experimental evidence:

1. $B6C3F_1$ mice dosed dermally with 160 mg/kg DEA, 5 days/week for 2 weeks showed a marked decrease in choline metabolites and S-adenosylmethionine (SAM) levels in their livers similar to animals kept on a choline-devoid diet, indicating the development of choline deficiency. These effects were reversed following a 2-week recovery period (Lehman-MeKeeman *et al.*, 2002). A significant reduction in the hepatic levels of choline metabolites, including choline, phosphocholine, and glycerophospho-choline, and SAM levels was also reported by Stott *et al.* (2000) with $B6C3F_1$ mice dosed in a similar regimen with DEA via dermal and/or oral routes.

2. $B6C3F_1$ mice have a much lower ability than C57Bl/6 mice to maintain nascent methylation capacity, a characteristic that is believed to contribute to a higher spontaneous liver tumor incidence in $B6C3F_1$ mice (Counts *et al.*, 1996). In a study by Lehman-McKeeman *et al.*, (2002), choline deficiency, as evidenced by changes in phosphocholine concentrations, was produced in both strains of mice. However, unlike the $B6C3F_1$ mouse, DEA did not alter SAM concentrations in the C57Bl/6 strain.

3. DEA is incorporated into rat liver phospholipids (Barbee and Hartung, 1979; Mathews *et al.*, 1995) and can alter the biosynthesis of hepatic phosphatidylethanolamine and phosphatidylcholine (PC). In cultured cells, DEA inhibited cellular uptake of choline, decreased PC synthesis, and became incorporated into phospholipid fractions. These *in vitro* effects were prevented by culturing cells in the presence of excess choline (Lehman-McKeeman and Gamsky, 1999).

4. DEA caused morphological transformation in Syrian hamster embryo (SHE) cell transformation assay. However, this response was prevented when SHE cells were cultured in a medium containing excess choline (Lehman-McKeeman and Gamsky, 2000).

5. DNA synthesis was increased in mouse and rat, but not human, hepatocytes incubated with DEA. Incubation of mouse and rat, but not human, hepatocytes in medium containing reduced choline increased DNA synthesis. Mouse and rat hepatocytes incubated in medium with excess choline reduced DEA-induced DNA synthesis to control levels or below (Kamendulis and Klaunig, 2005).

6. DNA hypomethylation in GC-rich promotor regions observed in primary mouse hepatocytes which have been treated with DEA are similar to those caused by choline-deficient medium (Bachman *et al.*, 2005).

In situ formation of N-nitrosodiethanolamine

DEA is a secondary amine and may react with a nitrosating agent under certain conditions to form N-nitrosodiethanolamine. This nitrosoamine has been shown to be mutagenic *in vitro* and cause liver tumors in rats and doses of 2 mg/kg-day and higher (ECETOC, 1990). Rats given high, often toxic, oral bolus doses of DEA and nitrite have

shown or inferred to produce N-nitrosodiethanolamine (Preussman *et al.*, 1981; Yamamoto *et al.*, 1995). Studies by Stott *et al.* (2000) showed, however, that mimicking the dosing conditions in the NTP study (160 mg/kg DEA dermally) and drinking water supplemented with 170 ppm sodium nitrite to favor nitrosation did not result in N-nitrosodiethanolamine formation in the gastric contents, blood or urine of mice. The findings of Stott *et al.* (2000) suggest that the mouse liver tumors observed in the NTP bioassay were unlikely due to *in situ* nitrosamine formation.

Relevance to Humans

There are marked species differences in susceptibility to choline deficiency, with rats and mice being far more susceptible than other species including humans (Zeisel and Blusztajn, 1994). Rats and mice have a higher dietary choline requirement than humans in large part because rodents oxidize choline more rapidly than humans (Sidransky and Farber 1960). DEA was carcinogenic in mice, but not in rats, in the NTP dermal carcinogenicity studies. The fact that DEA was not carcinogenic to rats, a species highly susceptible to choline deficiency, should be an important consideration in the overall evaluation of human cancer risk. DEA is less readily absorbed across rat skin than mouse skin, and the resulting blood and tissue concentrations of DEA are at least three-times lower in rats than in mice at similar dosages (Mathews *et al.*, 1997). Lehman-McKeeman *et al.*, (2002) determined the NOAEL for DEA-induced choline deficiency in mice (based on phosphocholine concentrations) to be 10 mg/kg-day. Thus, there is a critical concentration of DEA that must be reached in order to affect choline homeostatis. In the rats, the lack of a carcinogenic response suggests that it is unlikely that exposure to DEA reached this concentration or that rats are not as susceptible as mice to the effects of DEA on hepatic choline metabolism. Overall, the results suggest that the hepatocarcinogenic effects of DEA in mice are not predictive of similar susceptibility in other laboratory animals or humans.

I. Reproductive Toxicity

No specific reproductive toxicity studies have been conducted on diethanolamine by any route of exposure.

In the NTP 13-week drinking water study, F344 rats were given 0, 160 (females only), 320, 630, 1,250, 2,500 or 5,000 ppm (males only) diethanolamine. All high-dose males and 3/10 of the 2,500 ppm males showed testicular degeneration; male rats in the higher dose groups also had atrophy of the seminal vesicles and prostate glands. Testis and epididymal weights in the $\geq$1,250 ppm males were decreased and were associated microscopically with degeneration of seminiferous epithelium, as well as hypospermia and reduced sperm motility in the $\geq$2,500 ppm males. The NOAEL for reproductive effects in males was 630 ppm (corresponding to 48 mg/kg-day). There were no effects noted in the female reproductive organs (NTP 1992; Melnick *et al.* 1994b).

In a 90-day inhalation study, some of the male Wistar rats exposed whole-body to 400 mg/m^3 showed diffuse testicular atrophy accompanied by oligozoospermia in the epididymides, and slight prostate atrophy (ECHA).

J. Developmental Toxicity

Oral

A Chernoff-Kavlok screen was conducted on diethanolamine. Initially, four female CD-1 mice were given by oral gavage 0, 200, 380, 720, 1,370, 2,605, and 2,605 mg/kg diethanolamine during GD 6-15; a subsequent study was conducted which consisted of dosing 50 female CD-1 mice with 450 mg/kg during GD 6-15. Mortality was seen at ≥720 mg/kg, with 100% mortality in the ≥1,370 mg/kg groups. Dams dosed with ≥200 mg/kg showed clinical signs of intoxication. There was no mortality in the 450 mg/kg dams; nor was there any effect on litter size and pup birth weight, but the number of viable litters, the percent of pup survival, and pup weight gain were reduced (York *et al.* 1988). Kl. score = 2]

Female SD rats were dosed by oral gavage with 0, 50, 125, 200, 250, or 300 mg/kg diethanolamine from GD 6-19. All dams in the 300 mg/kg group had to be killed early due to excessive toxicity. At 200 and 250 mg/kg, the dams exhibited either morbidity or died. Water intake was affected early in the gestation period in the 125 and 250 mg/kg dams; it was comparable to controls after GD 12. Reduced maternal body weight and weight change, as well as food intake, were seen in the ≥200 mg/kg dose groups. The ≥125 mg/kg dams had increased absolute kidney weights on postnatal day (PND) 21. There were no maternal effects in the 50 mg/kg dams. There was postimplantation deaths at ≥200 mg/kg on PND 0 and increased early postnatal mortality (PND 0-4) in the ≥125 mg/kg dose groups. Pup body weight was reduced at ≥200 mg/kg, with females affected more than males. Pup body weight gain was predominantly reduced during the early postnatal period. There were statistically significant differences at the end of the lactational period, which were flawed by the low number of animals. The NOAEL for maternal and postnatal developmental (screening) toxicity was 50 mg/kg-day (Price *et al.* 2005). [Kl. score = 2]

Inhalation

Pregnant female Wistar rats were exposed by inhalation to 0, 10, 50, or 200 mg/m^3 diethanolamine 6 hours/day on GD 6 to 15. Maternal toxicity was seen at 200 mg/m^3; there were vaginal hemorrhages in 8/21 pregnant rats on GD 14. There was also a markedly increased number of fetuses with skeletal variations (mainly cervical ribs) in the 200 mg/m^3 exposed group. The NOAEC for maternal and developmental toxicity is 200 mg/m^3 (ECHA). [Kl. score = 1]

Dermal

Pregnant female SD rats were given dermal applications of 0, 150, 500, or 1,500 mg/kg diethanolamine from GD 6 to 15. There was a dosing discrepancy and mid-dose was adjusted from 500 to 380 mg/kg. There was moderate skin irritation in the 380 mg/kg group, and severe skin irritation in the 1,500 mg/kg group. Body weight gain was lower in the 1,500 mg/kg group, and absolute and relative kidney weights were increased in the $\geq$380 mg/kg group All treated groups exhibited hematological effects that included anemia, abnormal red cell morphology (poikilocytosis, anisocytosis, polychromasia), and decreased platelet count. The 1,500 mg/kg group also had increased lymphocytes and total leukocytes. There were no treatment-related effects on body weight or incidences of malformations/abnormalities. In the 1,500 mg/kg litters, there were increased incidences of six skeletal variations involving the axial skeleton and distal appendages. The skeletal variations included poor ossification in the parietal bones; cervical centrum #5 and thoracic centrum #10; lack of ossification in all proximal hindlimb phalanges and some forelimb metacarpals; and callused ribs. The NOAELs for maternal and developmental toxicity are 150 and 380 mg/kg-day (Marty et al., 1999). [Kl. score = 2]

Pregnant female New Zealand rabbits were given dermal applications of 0, 35, 100, or 350 mg/kg diethanolamine on GD 6 to 18. At 350 mg/kg, maternal toxicity consisted of marked skin irritation, reduced feed consumption, and color changes in the kidneys. There were no hematologic changes. Body weight gain was reduced in the 100 mg/kg group. There was no evidence of developmental toxicity at any dose level. The NOAELs for maternal and developmental toxicity are 35 and 350 mg/kg-day (Marty et al., 1999). [Kl. score = 2]

K. Immunotoxicity

Female F344 rats were given oral gavage doses of 0, 50, 100, or 200 mg/kg diethanolamine for 14 days. Body weights and/or body weight changes were significantly decreased in the $\geq$100 mg/kg dose groups; liver and kidney weights were increased in a dose-dependent manner. A dose-dependent increase in urea nitrogen was seen in all dose groups. Erythrocytes, hematocrit, hemoglobin and reticulocytes were dose-dependently decreased. The reticulocytes were the most sensitive erythroid parameter, which was decreased at all dose levels. Besides an increase in the proliferative response to allogenic cells (MLR), several immune functional assays were decreased including the natural killer cell response and the cytotoxicity of resident macrophages. Conversely, the cytotoxicity of peptone-elicited macrophages was increased. The LOAEL was 50 mg/kg-day based on a significant decrease in reticulocyte number and increase in urea nitrogen (Munson *et al.* 1992a). [Kl. score = 2]

Female B6C3F$_1$ mice were given oral gavage doses of 0, 100, 300, or 600 mg/kg diethanolamine for 14 days. There was no effect of body weights. The liver weights were increased and red blood cell count parameter were dose-dependently decreased at all dose levels. Diethanolamine treatment increased the number of B-cells, decreased the number of CD4+CD8- (18%) T-cell subsets. A dose-dependent decrease in the antibody-

forming cell response to sheep erythrocytes at the high-dose was seen, as well as a decreae in the cytotoxic T-cell response at the highest effector/target ratio. The cytotoxicity of resident macrophages was decreased, but the cytotoxicity of resident macrophages stimulated with gamma interferon was not affected nor the cytotoxicity of peptone-elicited macrophages with or without stimulation. Among the three host resistance studies, a decrease in host resistance was observed to *Streptococcus pneumonia* and in the B16F10 melanoma tumor model. The LOAEL for this study was considered to be 100 mg/kg-day based on significantly reduced cytotoxic T lymphocytes (CTL) activity, an increase in tumor burden following challenge with the B16F10 melanoma tumor and a clear decrease in red blood cell parameter at the lowest dose (Munson *et al.* 1992b). [Kl. score = 2]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for diethanolamine follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

In a 13-week study conducted by the National Toxicology Program, F344 rats were given diethanolamine in their drinking water for 13 weeks. The doses were 0, 25, 48, 97, 2,202, or 436 mg/kg-day for males; and 0, 14, 32, 57, 124, or 242 mg/kg-day for females. The most sensitive endpoints were the microcytic anemia in both sexes and kidney effects in females (weight, nephrotoxicity) and males (weight). The LOAELs were 25 and 14 mg/kg-day) for males and females, respectively (NTP 1992; Melnick et al., 1994a).

In a 13-week study conducted by the National Toxicology Program, $B6C3F_1$ mice were given diethanolamine in their drinking water for 13 weeks. The doses were 0, 104, 178, 442, 807, or 1,674 mg/kg-day for males; and 0, 142, 347, 884, 1,154, or 1,128 mg/kg-day for females. The most sensitive endpoint was the increase in liver weights with the corresponding histopathological changes. The LOAELs were 104 and 142 mg/kg-day in males and females, respectively (NTP, 1992; Melnick *et al.*, 1992b).

The lowest NOAEL of 14 mg/kg-day from the rat 13-week drinking water study will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 10
UF_{Sub} (subchronic to chronic) = 10
UF_D (database uncertainty) = 1

[maximum UF = 3,000]

Oral RfD = 14/3,000 = <u>0.005 mg/kg-day</u>

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (0.005 x 70 x 0.1)/2 = <u>0.02 mg/L</u>

B. Cancer

Diethanolamine was not carcinogenic to rats in the two-year NTP dermal bioassay; but, in the mice, there was an increased incidence of liver tumors in males and females and kidney tumors in males (NTP, 1999). As discussed above, the mouse liver tumors from DEA exposure are unlikely to be predictive of the carcinogenic risk to humans based on choline deficiency as a mechanism of carcinogenesis. No mode-of-action has been proposed for the kidney tumors in male mice.

NICNAS conducted a human health tier III assessment on diethanolamine (NICNAS). Regarding the classification for carcinogenicity, NICNAS concluded that "[t]he data on the mode of action are insufficient to conclude that diethanolamine-induced tumours in mice are relevant for humans and, therefore, based on the available information, diethanolamine is not classified for carcinogenicity."

Thus, a cancer reference value for diethanolamine was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Diethanolamine does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Diethanolamine exhibits moderate acute toxicity to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies on diethanolamine.

Table 3: Acute Aquatic Toxicity Studies on Diethanolamine

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Oncorhynchus mykiss	96-h LC_{50}	460	2	ECHA
Pimephales promelas	96-h LC_{50}	1,460*	2	Mayes et al. (1983)
Pimephales promelas	96-h LC_{50}	1,664	2	ECHA
Lepomis macrochirus	48-h LC_{50}	1,850	2	Turnbull et al. (1954)
Carassius auratus	24-h LC_{50}	>5,000 (neutralised) 800 (non-neutralised)	2	Bridlé et al. (1979)

Ceriodaphnia dubia	48-h EC_{50}	30.1 (24°C) 89.9 (20°C)	2	Cowgill et al. (1985)
Daphnia magna	48-h EC_{50}	55	2	LeBlanc (1980)
Daphnia magna	48-h EC_{50}	171	2	Zurita et al. (2005)
Pseudokirchneriella subcapitata	72-h EC_{50} (growth rate)	9.5 (Test 1) 19 (Test 2)	2	ECHA
Desmodesmus subspicatus	72-h EC_{50}	14.9 (growth rate) 6.2 (biomass)	2	ECHA
Desmodesmus subspicatus	72-h EC_{50}	107.3 (growth rate) 74.5 (biomass)	2	ECHA
Chorella vulgaris	72-h EC_{50}	778 (growth rate)	2	ECHA

*Geometric mean of 96-h LC_{50} values of fry, juvenile, and subadult fish. Not neutralized.

Chronic Studies

Table 4 lists the results of chronic aquatic toxicity studies on diethanolamine.

Table 4: Chronic Aquatic Toxicity Studies on Diethanolamine

Test Species	**Endpoint**	**Results (mg/L)**	**Klimisch score**	**Reference**
Daphnia magna	EC_{10} NOEC	1.05 0.76	1	ECHA
Pseudokirchneriella subcapitata	EC_{10} (growth rate)	1.4 (Test 1) 1.1 (Test 2)	2	ECHA
Desmodesmus subspicatus	EC_{10} (neutralized)	2.4 (growth rate) 2.0 (biomass)	2	ECHA
Desmodesmus subspicatus	EC_{10} (non-	85.7 (growth rate)	2	ECHA

	neutralized)	41.3 (biomass)		
Pseudokirchneriella subcapitata	7-d NOEC	10	2	ECHA

C. Terrestrial Toxicity

In an earthworm (*Eisenia Andrei, Eisenia fetida*, or *Lumbricus terrestris*) study, the 35-day LC_{50} was 4,141 mg/kg soil dry weight (mortality); the 63-day EC_{50} was 776 mg/kg soil dry weight (reproduction); and the 63-day EC_{25} was 171 mg/kg soil dry weight (reproduction) (ECHA). [Kl. score = 2]

In a springtails (*Folsomia candida*) study, the 28-day LC_{50} was 8,301 mg/kg soil dry weight (mortality); the 28-day EC_{50} was 4,205 mg/kg soil dry weight (reproduction); and the 28-day EC_{25} was 2,102 mg/kg soil dry weight (reproduction) (ECHA). [Kl. score = 2]

D. Calculation of PNEC

The PNEC calculations for diethanolamine follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (460 mg/L), *Daphnia* (30.1 mg/L), and algae (9.5 mg/L). Results from chronic studies are also available for two trophic levels, with the lowest EC_{10} value being 1.1 mg/L for *Daphnia* and algae. On the basis that the data consists of short-term results from three trophic levels and long-term results from three trophic levels, an assessment factor of 50 has been applied to the lowest reported EC_{10} of 1.1 mg/L for algae. The $PNEC_{water}$ is 0.02 mg/L.

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 0.016 mg/kg sediment wet weight.

The calculations are as follows:

$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$
$= (0.99/1280) \times 1000 \times 0.02$
$= 0.016$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$K_{sed\text{-}water} = 0.8 + [(0.2 \times Kp_{sed})/1000 \times BD_{solid}]$
$= 0.8 + [(0.2 \times 0.4/1000 \times 2400]$
$= 0.99$

Where:
Kp_{sed} = solid-water partition coefficient (L/kg).
BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$Kp_{sed} = K_{oc} \times f_{oc}$
$= 10 \times 0.04$
$= 0.4$

Where:
K_{oc} = organic carbon normalized distribution coefficient (L/kg). The K_{oc} for diethanolamine (as the charged molecule) was calculated to be 10 L/kg.
F_{oc} = fraction of organic carbon in sediment = 0.04 [default].

PNEC soil

Experimental results are available for chronic toxicity on two trophic levels. Although $E(L)C_{50}$ values are available from these studies, there are no EC_{10} or NOEC values. Therefore, the PNECsoil was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is 0.027 mg/kg soil dry weight.

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
$= (0.2/1500) \times 1000 \times 0.02$
$= 0.027$

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
$= 10 \times 0.02$
$= 0.2$

Where:

K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for diethanolamine (as the charged molecule) was calculated to be 10 L/kg.
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Diethanolamine is readily biodegradable; thus, it does not meet the screening criteria for persistence.

The estimated BCF value for diethanolamine calculated from a QSAR model is 2.3; thus, it does not meet the criteria for bioaccumulation.

The EC_{10} or NOEC values from the chronic aquatic toxicity studies on diethanolamine are >0.1 mg/L. Thus, diethanolamine does not meet the screening criteria for toxicity. In a mouse dermal carcinogenicity study, there was an increased incidence of liver tumors in males and females and kidney tumors in males. NICNAS has concluded that "[t]he data on the mode of action are insufficient to conclude that diethanolamine-induced tumours in mice are relevant for humans and, therefore, based on the available information, diethanolamine is not classified for carcinogenicity." Thus, diethanolamine does not meet the criteria for toxicity.

The overall conclusion is that diethanolamine is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Acute Toxicity Category 4 [Oral]
Skin Irritant Category 2
Eye Damage Category 1
STOT RE Category 2 [Target organs: liver, blood, kidney]

[Aquatic Acute Category 2]

B. Labelling

Danger

C. Pictogram



X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
Immediately flush open eyes with plenty of water for at least 15 minutes. Remove contacts, if present and easy to do. Get medical attention immediately, preferably a physician for an ophthalmologic examination.

Skin Contact
Remove contaminated clothing. Wash thoroughly with soap and water.

Inhalation
If inhaled, remove from area to fresh air. Give artificial respiration if victim is not breathing. Get medical attention.

Ingestion
Rinse mouth with water and then drink plenty of water. Get medical attention. Never give anything by mouth to an unconscious person.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
Keep product and empty container away from heat and sources of ignition. May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: nitrogen oxides, carbon monoxide, carbon dioxide.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus and chemical-protective clothing.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Use appropriate protective equipment. Handle in accordance with good industrial hygiene and safety practice. Avoid contact with skin, eyes, and clothing.

Environmental Precautions
Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled
For large amounts: dike spillage and pump off product. For residues: pick up with suitable absorbent material. Dispose of contaminated material as prescribed.

D. STORAGE AND HANDLING

General Handling
Keep product and empty container away from heat and sources of ignition. Ensure adequate ventilation, especially in confined areas.

Storage
Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
Workplace Australia has not established an occupational exposure standard for diethanolamine.

Engineering Controls
Good general ventilation should be used.

Personal Protection Equipment

Respiratory Protection:
Use respiratory protection in case of vapor or aerosol release.

Hand Protection:
Chemical resistant protective gloves.

Skin *Protection*:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Safety glasses with side-shields.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Wearing of closed work clothing is recommended. Ensure that eyewash stations and safety showers are close to the workstation location.

F. TRANSPORT INFORMATION

Diethanolamine is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

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DISODIUM OCTABORATE TETRAHYDRATE

This dossier on disodium octaborate tetrahydrate does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of disodium octaborate tetrahydrate in its use in drilling muds and hydraulic fracturing fluids. Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC) [Disodium octaborate]: disodium;(9,11-dioxido-5-oxoboranyloxy-2,4,6,8,10,12,13-heptaoxa-1,3,5,7,9,11-hexaborabicyclo[5.5.1]tridecan-3-yl)oxy-oxovorane

CAS RN: 12280-03-4

Molecular formula: $Na_2B_8O_{13}\bullet 4H_2O$

Molecular weight: 412.4

Synonyms: Disodium octaborate tetrahydrate; disodium octaborate

SMILES (disodium octaborate): B(=O)OB1OB2OB(OB(OB(O2)OB(O1)OB=O)[O-])[O-].[Na+].[Na+]

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Disodium Octaborate Tetrahydrate

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	White, odorless, crystalline powder	1	ECHA
Melting Point	>1,000°C	1	ECHA
Density	1.874 g/cm^3	1	ECHA
Vapor Pressure	9.9 x 10^{-17} Pa @ 25°C	1	ECHA
Water Solubility	223.65 g/L @ 20°C	1	ECHA
Auto flammability	Not a self-heating substance	1	ECHA

Exposure to borates are often expressed in terms of boron (B) equivalents based on the fraction of boron in the source substance on a molecular weight basis. The B equivalents used are a generic designation rather than a designation of the element boron. The factor for converting disodium octaborate tetrahydrate to B-equivalents is 0.2096.

III. ENVIRONMENTAL FATE PROPERTIES

Many minerals contain boron, which is present as the sodium or calcium borate salt. Thus, boron is ubiquitous and widely distributed in the environment. It is present in rocks, soil and water and is released into the environment primarily from the weathering of rock and soil, volatilization of sea water, and anthropogenic activity.

Disodium octaborate tetrahydrate ($Na_2B_8O_{13} \bullet 4H_2O$) is very soluble in water, with the main species in freshwater being the borate ion $[B(OH)_4]^-$ and boric acid $B(OH)_3$, depending on the pH. The relative proportion of boric acid and borate ions is controlled by pH: $B(OH)_3 + 2H_2O \Leftrightarrow [B(OH)_4]^- + H_3O^-$. In dilute aqueous solutions, boric acid does not dissociate at pH <7; at pH values between 7 and 11, both boric acid and borate ions are present. In dilute aqueous solutions and physiological conditions, the predominant species present is un-dissociated boric acid. So, the consideration of boric acid addresses the relevant environmental stability properties for borates.

In natural waters, boron forms stable species and exists primarily as un-dissociated boric acid [$B(OH)_3$] and complex polyanions (*e.g.*, $[B(OH)_4]^-$). These forms of boron are highly soluble and not easily removed from solution by natural mechanisms. Borate and boric acid are in equilibrium depending on the pH of the water. At an acidic pH, boron exists in solution mainly as un-dissociated boric acid, whereas at alkaline pH it is present as borate ions.

Degradation is not applicable to inorganic borates, such as disodium octaborate tetrahydrate. It is not subject to hydrolysis, photodegradation, or biodegradation (ECHA). Inorganic borates are subject to chemical transformation processes (adsorption, complexation, precipitation, fixation) once released into the environment (ECHA).

The WHO review of boron (WHO, 1998) noted that “highly water soluble materials are unlikely to bioaccumulate to any significant degree and that borate species are all present essentially as un-dissociated and highly soluble boric acid at neutral pH”. A BCF of <0.1 was reported in Chinook salmon fed boron-supplemented diets for 60 to 90 days (Hamilton and Wiedmeyer, 1990).

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Disodium octaborate tetrahydrate exhibits low acute toxicity by the oral and dermal routes. It is not a skin or eye irritant, or a skin sensitizer. Toxicity studies on boric acid, borax (disodium tetraborate decahydrate), and boron oxide have been used to read-across to disodium octaborate tetrahydrate. This is justified because, in aqueous media at physiological pH, all of these inorganic borate compounds will predominantly exist as un-dissociated boric acid. The developing fetus and the testes are the two most sensitive targets of boron toxicity in multiple species. The testicular effects include reduced organ weight and organ to body weight ratio, atrophy, degeneration of the spermatogenic epithelium, impaired spermatogenesis, reduced fertility, and sterility. The developmental effects from boron exposure include high prenatal mortality; reduced fetal body weight; and malformations and variations. Repeated inhalation exposure to boron oxide resulted in slight irritation to the respiratory tract, but no systemic toxicity. Boric acid was not genotoxic; and boric acid and borax was not carcinogenic to rodents.

B. Acute Toxicity

The oral LD_{50} of disodium octaborate tetrahydrate in rats is 2,550 mg/kg (ECHA) [Kl. score = 1]. The oral LD_{50} of boric acid in rats is 3,450 mg/kg (ECHA) [Kl. score = 1]. The oral LD_{50} of anhydrous boric acid in rats is >2,500 mg/kg. [Kl. score = 1].

There are no acute inhalation studies on disodium octaborate tetrahydrate. The 4-hour inhalation LC_{50} value for boric acid in rats is >2.01 mg/L. The mass median aerodynamic diameter (MMAD) was 2.8 μm (ECHA) [Kl. score = 1]. In another study, the 4-hour inhalation LC_{50} value for boric acid in rats was >2.03 mg/L (ECHA) [Kl. score = 1]. The 4-hour inhalation LC_{50} value for disodium tetraborate pentahydrate in rats is >2.04 mg/L (ECHA) [Kl. score = 1].

The dermal LD_{50} of disodium octaborate tetrahydrate in rabbits is >2,000 mg/kg (ECHA) [Kl. score = 1]. The dermal LD_{50} of boric acid in rabbits is >2,000 mg/kg (ECHA) [Kl. score = 1]. The dermal LD_{50} of sodium tetraborate pentahydrate in rabbits is >2,000 mg/kg (ECHA) [Kl. score = 1].

C. Irritation

Application of 0.5 g. of disodium octaborate tetrahydrate to the skin of rabbits for 4 hours under occlusive conditions was not irritating. The mean of the 24, 48, and 72 hour scores were: 0.22 for erythema and 0.00 for edema (ECHA) [Kl. scores = 1].

Application of 0.5 g. of boric acid to the skin of rabbits for 24 hours under occlusive conditions was not irritating. The mean of the 24 and 72 hour scores were: 0.13 for erythema and 0.00 for edema (ECHA) [Kl. scores = 1]. Application of 0.5 g. of sodium tetraborate pentahydrate to the skin of rabbits for 4 hours under occlusive conditions was not irritating. The mean erythema and edema scores were 0.00 (ECHA) [Kl. scores = 2].

Disodium octaborate tetrahydrate was not considered to be an eye irritant when 0.053 or 0.049 g. was instilled into the eyes of rabbits (ECHA) [Kl. scores = 1]. Instillation of 0.08 mL boric acid into the eyes of rabbits was slightly irritating. The mean of 24, 48, and 72 hours scores were: 0.22 for corneal opacity; 0.22 for iridial lesions; 2.8 for conjunctival redness; and 1.89 for chemosis (ECHA) [Kl. score = 1].

D. Sensitization

Disodium octaborate tetrahydrate was not a skin sensitizer to guinea pigs in a Buehler test (ECHA) [Kl. score = 1].

Boric acid was not a skin sensitizer to guinea pigs in a Buehler test (ECHA) [Kl. score = 1]. Sodium tetraborate pentahydrate was not a skin sensitizer to guinea pigs in a Buehler test (ECHA) [Kl. score = 1]. Sodium tetraborate decahydrate was not a skin sensitizer to guinea pigs in a Buehler test (ECHA) [Kl. score = 1].

E. Repeated Dose Toxicity

Oral

Male and female SD rats were given in their feed boric acid at doses of 0, 52.5, 175, 525, 1,750 or 5,250 ppm B equivalents for 90 days. The average intake has been estimated to be approximately 0, 2.6, 8.8, 26, 87.5 or 262.5 mg B/kg-day, respectively (EPA, 2004). By week 6, all of the animals in the highest dose died. Clinical signs in the top two dose levels were rapid respiration, inflamed eyes, swollen paws, and desquamated skin on the paws and tails. There was also reduced food consumption and body weight gain. The 1,750 ppm females showed reduced liver, spleen ovary, and adrenal weights; the 1,750 ppm males showed reduced liver, spleen, kidney, testes, and adrenal weights. The adrenals of 4 of the 1,750 ppm males showed minor increases in lipid content and size of the cells in the zona reticularis. Atropied testis (complete atrophy of the spermatogenic epithelium and decreased in the size of the seminiferous tubules) was seen in all of the 1,750 ppm males. One 525 ppm male had partial testicular atrophy. The NOAEL for this study is 175 ppm boron or 8.8 mg B/kg-day (Weir and Fisher, 1972). [Kl. score = 2]

Male and female SD rats were given in their diet borax at doses of 0, 52.5, 175, 525, 1,750 or 5,250 ppm B equivalents for 90 days. The average intake has been estimated to be approximately 0, 2.6, 8.8, 26, 87.5 or 262.5 mg B/kg-day, respectively (EPA, 2004). By week 6, all of the animals in the highest dose died. Clinical signs in the top two dose levels were rapid respiration, inflamed eyes, swollen paws, and desquamated skin on the paws and tails. There was also reduced food consumption and body weight gain. The 1,750 ppm females showed reduced liver, spleen and ovary weights; the 1,750 ppm males showed reduced liver, spleen, kidney, testes, and brain weights. The adrenals of the majority of the 1,750 ppm males and females showed slight to moderate increases in lipid content and size of the cells in the zona reticularis. Atropied testis (complete atrophy of the spermatogenic epithelium and decreased in the size of the seminiferous tubules) was

seen in all of the 1,750 ppm males. Four 525 ppm males had partial testicular atrophy. Spermatogenic arrest was found in one 525 ppm male. The NOAEL for this study is 175 ppm boron or 8.8 mg B/kg-day (Weir and Fisher, 1972). [Kl. score = 2]

Male and female B6CF1$_1$ mice were given in the diet 0, 1,200, 2,500, 5,000, 10,000 or 20,000 ppm boric acid for 13 weeks (control and highest dose group) or 16 weeks (remaining dose groups). These dietary levels correspond to approximately 0, 34, 70, 141, 281 and 563 mg B/kg-day for males, respectively; and 0, 47, 97, 194, 388 and 776 mg B/kg-day for females, respectively (EPA, 2004). There was mortality (8/10 males; 6/10, females) in the 20,000 ppm, as well as hyperkeratosis and acanthosis. One male also died in 10,000 ppm group. Degeneration or atrophy of the seminiferous tubules occurred in the $\geq$5,000 ppm males. Minimal to mild extramedullary hematopoiesis of the spleen was observed in all dose groups. The LOAEL for this study is 1,200 ppm, corresponding to 34 and 47 mg B/kg-day for males and females, respectively (NTP 1987). [Kl. score = 2]

Male and female SD rats were given in their diet 0, 117, 350 or 1,170 ppm boric acid for two years. The average intake has been estimated to be approximately 0, 5.9, 17.5 or 58.5 mg B/kg-day, respectively (EPA, 2004). The 1,170 ppm rats had decreased food consumption during the first 13 weeks of the study and suppressed growth throughout the study. Signs of toxicity in the 1,170 ppm animals included swelling and desquamation of the paws, scaly tails, inflammation of the eyelids, and bloody discharge from the eyes. All of the 1,170 ppm males had testicular atrophy at the 6, 12 and 24 month time points. The seminiferous epithelium was atrophied, and the tubular size in the testes was decreased. There were significant decreases in the absolute and relative testes weights. Brain and relative thyroid weights were increased. The NOAEL for this study is 350 ppm B equivalents or 17.5 mg B/kg-day (Weir and Fisher, 1972). [Kl. score = 2]

Male and female B6C3F$_1$ mice were given 0, 2,500 or 5,000 ppm boric acid in their feed for 103 weeks (NTP, 1987). These dose levels were equivalent to 0, 275 or 550 mg/kg-day boric acid or 0, 48 or 96 mg B/kg-day (EPA, 2004). There was reduced survival in the male mice, which was significantly different from the controls in the 2,500 ppm mice after week 63 and in the 5,000 ppm mice after week 84. The survival rates by the end of the study were 82, 60 and 44% in the 0, 2,500, and 5,000 ppm males, respectively; and 66, 66 and 74% in the 0, 2,500, and 5,000 ppm females, respectively. Mean body weights were 10-17% lower in the 5,000 ppm animals after 32 (males) or 52 (females) weeks compared to the controls There was testicular atrophy and interstitial cell hyperplasia in the testes of the 5,000 ppm males. A dose-related increase in the incidences of splenic lymphoid depletion in male mice was also observed. NTP considered this lesion to be associated with stress and debilitation, and it is reflected in the increased mortality in these groups of male mice. The NOAEL for this study is (NTP, 1987). [Kl. score = 2]

Inhalation

Male and female rats were exposed by inhalation to 0, 77, 175, or 470 mg/m^3 boron oxide. The exposures were 6 hours/day, 5 days/week for 24, 12, and 10 weeks for the 77, 175, and 470 mg/m^3 concentrations groups, respectively. The MMAD were 2.5, 1.9, and 2.4 μm for the 77, 175, and 479 mg/m^3 concentrations groups, respectively. There was no evidence of systemic toxicity. Some of the 470 mg/m^3 had reddish exudate from the nose. As these animals were covered with dust, this effect may have been local irritation of the nose and from the animals scratching the nose. The NOAEL for systemic toxicity is 470 mg/m^3, the highest exposure concentration tested. The NOAEL for localized effects (irritation) is 175 mg/m^3 (ECHA). [Kl. score = 2]

Dermal

No studies are available.

F. Genotoxicity

In Vitro Studies

There are no *in vitro* genotoxicity studies on disodium octaborate tetrahydrate. Table 2 presents the results of the *in vitro* genotoxicity studies on boric acid.

Table 2: *In vitro* Genotoxicity Studies on Boric Acid

Test System	**Results***		**Klimisch Score**	**Reference**
	-S9	**+S9**		
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	1	ECHA
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	ECHA
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	-	-	1	ECHA
Chromosomal aberrations (Chinese Hamster Ovary cells)	-	-	1	ECHA
Chromosomal aberrations (Chinese Hamster Ovary cells)	-	-	1	ECHA
Chromosomal aberrations (Human peripheral lymphocytes)	NS	+	2	ECHA

Unscheduled DNA synthesis (rat liver cells)	NA	-	1	ECHA

*+, positive; -, negative; NA, not applicable; NS, not specified.

In Vivo Studies

No studies are available on disodium octaborate tetrahydrate.

Male and female Swiss Webster mice were given two daily doses of 0, 225, 450, 900, 1,800, or 3,500 mg/kg boric acid. The frequency of micronucleated polychromatic erythrocytes were not increased at any dose level (ECHA) [Kl. score = 1].

G. Carcinogenicity

Oral

No studies have been conducted on disodium octaborate tetrahydrate.

Male and female SD rats were given in their diet disodium tetraborate decahydrate (Borax) or boric acid at doses of 0, 117, 350, or 1,170 ppm as B equivalents (approximately 0, 5.9, 17.5, or 58.5 mg B/kg-day) for two years. There was no mention of tumors in the report. Nevertheless, NTP (1987) concluded that this study provided adequate data on the lack of carcinogenic effects of boric acid in rats (Weir and Fisher, 1972; EPA, 2004).

Male and female $B6C3F_1$ mice were given in their diet 0, 2,500, or 5,000 ppm boric acid for 103 weeks. The dietary levels are equivalent to 0, 446, or 1,150 mg/kg-day boric acid or 0, 78.1, or 201.3 mg B/kg-day. There was no evidence of carcinogenicity (NTP, 1987). [Kl. score = 2]

H. Reproductive Toxicity

A three-generation reproductive toxicity study was conducted in albino rats (strain not specified) with boric acid. Male and female rats were fed a diet containing 0, 117, 350 or 1,170 ppm boron (approximately 0, 5.9, 17.5 or 58.5 mg B/kg-day, respectively). In the lower two dose groups, there were no treatment-related effects on reproduction. Litter size, progeny weights, fertility, live birth indices, lactation, appearance were similar to the controls. No gross abnormalities were noted in these two dose groups. The 1,170 ppm dose group were found to be sterile, and there were no litters from mating the treated females with control males. Lack of viable sperm was found in the atrophied testes of all 1,170 ppm males. Decreased ovulation was also seen in the majority of the ovaries of the 1,170 ppm females. The NOAEL for this study is 350 ppm boron or approximately 17.5 mg B/kg-day (Weir and Fisher, 1972). [Kl. score = 2]

A three-generation reproductive toxicity study was conducted in albino rats (strain not specified) with disodium tetraborate decahydrate. Male and female rats were fed a diet containing 0, 117, 350 or 1,170 ppm boron (approximately 0, 5.9, 17.5 or 58.5 mg B/kg-day, respectively). In the lower two dose groups, there were no treatment-related effects on reproduction. Litter size, progeny weights, fertility, live birth indices, lactation, appearance were similar to the controls. No gross abnormalities were noted in these two dose groups. The 1,170 ppm dose group were found to be sterile, and there were no litters from mating the treated females with control males. Lack of viable sperm was found in the atrophied testes of all 1,170 ppm males. Decreased ovulation was also seen in the majority of the ovaries of the 1,170 ppm females. The NOAEL for this study is 350 ppm boron or approximately 17.5 mg B/kg-day (Weir and Fisher, 1972). [Kl. score = 2]

In a continuous breeding protocol, male and female CD-1 mice were given in their diet 0, 1,000, 4,500 or 9,000 ppm boric acid in their feed. The authors estimated that the average daily intakes were: 0, 26.6, 111, and 220 mg B/kg-day to males; and 0, 31.8, 152, 257 mg B/kg-day to females. Boric acid consumption did not differ among the groups. There were no litters in the 9,000 ppm breeding pairs. At 4,500 ppm, there was a successful first litter, after which there was a progressive decrease in fertility; only one pair produced a fourth and fifth litter. All fertility indices were affected in the 4,500 ppm group. A complete crossover mating trial was conducted using control mice and the 4,500 ppm mice. The results showed that the probable cause of the reduced fertility was a decrement in male fertility. A dose-related decrease in body, testicular and epididymal weights was observed in the 4,500 and 9,000 ppm F_0 males. Sperm count was significantly decreased in these two dose groups, and percent motile sperm was decreased in all dose groups. Testicular histopathology showed seminiferous tubular atrophy in the 9,000 ppm males and partial atrophy of the seminiferous tubules in the 4,500 ppm males. There were no histopathologic changes in the 4,500 ppm females. No statistically significant decreases in mating index, fertility index, or live pups/litter in the 4,500 ppm females, but the number of days to litter in this dose group was increased. Estrous cyclicity was unaffected. Reproductive organ weights were unaffected, but relative maternal liver and kidney/adrenal weights were reduced. An F_1 fertility trial was performed using offspring from the 1,000 ppm groups. There was no decreases in mating, fertility or reproductive performance. The F_2 adjusted live pup weight was slightly, but significantly, reduced from controls. A clear NOAEL for reproductive toxicity in males was not seen in this study. The 1,000 ppm males had decreased sperm motility in the F_0 generation and decreased sperm concentration in the F_1 generation. Decreased F_2 pup relative body weight was statistically significant from controls. The NOAEL in this study for females is 1,000 ppm boric acid or 32 mg B/kg-day). The LOAEL in this study for males is 1,000 ppm or 27 mg B/kg-day; a NOAEL was not established (Fail *et al.* 1991). [Kl. score = 2]

I. Developmental Toxicity

Pregnant female SD rats were given 0, 0.1, 0.2 or 0.4% boric acid in their feed on gestational days (GD) 0 to 20 or 0.8% boric acid on GD 6 to 15. The average amounts of boric acid ingested were estimated to be 0, 78, 163, 330 or 539 mg/kg-day (0, 13.6, 28.5 or 57.7 mg B/kg-day), respectively. Effects on the pregnant rats were altered food and/or water intake at ≥0.2% boric acid, increased liver and kidney weights relative to body weights at ≥0.2%, reduced weight gain at ≥0.4%, and increased corrected weight gain at 0.4% boric acid. There was a reduction in fetal body weights in all treated groups (94, 87, 63, and 47% of control weight, respectively). Increased malformations occurred at ≥0.2%, and prenatal mortality was increased at 0.8%. There was a dose-response for altered skeletal morphology in rats (≥0.1%), and specific findings were significantly elevated above controls at ≥0.2%. Specifically, there was an increased incidence of short rib XIII (a malformation) and a decreased incidence or rudimentary or full rib(s) at lumbar I (an anatomical variation) (Heindel *et al.* 1992). [Kl. score = 2]

Pregnant female SD rats were given in their feed 0, 0.025, 0.005, 0.075, 0.1 or 0.2% boric acid on GD 0 to 20. Approximately half of the dams were terminated on GD 20, and the remaining dams delivered their litters. Pup growth and viability were monitored until postnatal day (PND) 21. The average amounts of boron ingested on GD 20 were: 0, 3.3, 6.3, 9.6, 13.3, and 25 mg B/kg-day], respectively. The average amounts of boron ingested on PND 21 were : 0, 3.2, 6.5, 9.7, 12.9, and 25.3 mg B/kg-day, respectively. There were no maternal deaths and no treatment-related clinical signs. Maternal body weights were similar across all groups during gestation. However, decreased maternal body weights (GD 19 and 20 at sacrifice) and decreased maternal body weight gain (GD 15-18 and GD 0-20) were statistically significant in trend tests. There was a 10% reduction in gravid uterine weight (statistically significant) in the 0.2% group. Corrected maternal weight (maternal gestational weight minus reduced gravid uterine weight) was unaffected by treatment. Feed intake in the 1,000 ppm dams was minimally affected and only during the first three days of dosing. Water consumption was higher in the treated groups after GD 15. The number of corpora lutea and uterine implantation sites, and the percentage of preimplantation loss were similar across all groups. Increased relative kidney weights were increased in the 0.2% group. There were no differences in the viability of the offspring between treated and controls. On GD 20, fetal body weight was 94% and 88% of controls in the 0.1% and 0.2% groups, respectively; recovery was complete at birth (~GD 22). The incidence of short rib XIII was increased on GD 20 in the ≥0.1% groups, but only in the 0.2% group at PND 21. The incidence of wavy rib was increased on GD 20 in the ≥0.1% group; the reversibility of this effect was confirmed on PND 21. There was a slight decrease in extra lumbar ribs in the 0.2% group on GD 20, and extra lumbar ribs were seen in the 0.2% group on PND 21. The developmental NOAEL was considered to be 0.075% boric acid or 9.6 mg B/kg-day on GD 20; and 0.1% boric acid or 12.9 mg B/kg-day on PND 21 (Price *et al.* 1996a). [Kl. score = 1]

Pregnant Swiss mice were given in their diet 0, 0.1, 0.2 or 0.4% boric acid on gestational days (GD) 0 to 17. The average amounts of boric acid ingested were estimated to be 248, 452 or 1,003 mg/kg-day (0, 43.4, 79.0 or 175.3 mg/B/kg-day), respectively. Maternal toxicity consisted of mild kidney lesions (≥0.1%), increased water intake and relative kidney weights (0.4%), and decreased water intake during treatment. Fetal body weights

were reduced in the ≥0.2% groups, and there were increased incidences of resorptions and malformed fetuses per litter in the 0.4% group. The LOAEL for maternal toxicity is 248 mg/kg-day boric acid or 43.4 mg B/kg-day; a NOAEL was not established. The NOAEL for developmental toxicity is 248 mg/kg-day boric acid or 43.4 mg B/kg-day (Heindel *et al.* 1992). [Kl. score = 2]

Pregnant female New Zealand rabbits were dosed by oral gavage with 0, 62.5, 125 or 250 mg/kg boric acid (0, 10.9, 21.9 or 43.7 mg B/kg) during GD 6-19. Feed intake was in the 250 mg/kg maternal animals during the exposure period, but it was increased in the ≥125 mg/kg dose groups. In the 250 mg/kg group, maternal body weights during GD 9-30, weight gain during GD 6-19, gravid uterine weight, and number of corpora lutea per dam were significantly reduced. In the ≥125 mg/kg groups, maternal corrected gestational weight gain was increased compared to controls. Maternal liver weights were unaffected by treatment. In the 250 mg/kg group, relative, but not absolute, kidney weights were increased, although no effects in the kidney were noted in the histopathological examination. Prenatal mortality was increased in the 250 mg/kg group (90% resorptions/litter versus 6% for controls); the proportion of pregnant females with no live fetuses was increased (73% versus 0%), and live litter size was reduced (2.3 fetuses versus 8.8). Thus, there were only 14 live fetuses (6 live litters) available for evaluation in the 250 mg/kg group. The percentage malformed fetuses/litter was increased in the 250 mg/kg group, primarily due to cardiovascular defects (72% versus 3% of controls). There was no definitive maternal or developmental toxicity in the 62.5 or 125 mg/kg dose groups. The NOAEL for maternal and developmental toxicity is 125 mg/kg-day boric acid or 21.9 mg B/kg-day (Price *et al.* 1996b). [Kl. score = 1]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for disodium octaborate tetrahydrate follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

The developing fetus and the testes are the two most sensitive targets of boron toxicity in multiple species (EPA, 2004; ECHA, 2010). The testicular effects include reduced organ weight and organ to body weight ratio, atrophy, degeneration of the spermatogenic epithelium, impaired spermatogenesis, reduced fertility, and sterility (EPA, 2004). The developmental effects from boron exposure include high prenatal mortality; reduced fetal body weight; and malformations and variations (EPA, 2004).

The U.S. Environmental Protection Agency (U.S. EPA) derived an Oral Reference Dose

(RfD) for boron of 0.2 mg B/kg-day (U.S. EPA 2004) based on developmental effects in rats from two studies (Price *et al.* 1996a; Heindel *et al.* 1992).

The RfD was derived using the benchmark dose (BMD) method ($BMDL_{05}$ from Allen *et al.* 1996) using a data derived uncertainty factor of 66. Decreased fetal body weight ($BMDL_{50}$ = 59 mg boric acid/kg-day or 10.3 mg B/kg-day) was considered by Allen *et al.* (1996) as the most suitable endpoint for developing a point of departure, because the benchmark doses calculated for the other endpoints (incidence of total malformations, enlarged lateral ventricles in the brain, shortening of rib XIII, and variations of the first lumbar rib) were higher.

Derivation of an Oral Reference Dose

Oral RfD = $BMDL_{05}$ / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 7.9 [3.16, toxicodynamics; 3.3, toxicokinetics]
UF_H (intraspecies variability) = 6.2 [3.16, toxicodynamics; 2.0, toxicokinetics]
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 10.3/(7.9 x 6.3 x 1 x 1 x 1) = 10.3/66 = <u>0.2 mg B/kg-day</u>

Derivation of a drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (0.2 x 70 x 0.1)/2 = <u>0.7 mg/L</u>

Australian drinking water guideline

The Australian drinking water guideline for boron is 4 mg/L (ADWG, 2011).

B. Cancer

There was no evidence of carcinogenicity in rat and mouse chronic studies conducted on disodium tetraborate decahydrate and/or boric acid. Thus, a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Disodium octaborate tetrahydrate does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Aquatic Toxicity

The summary of the data used by ANZECC to develop a water quality guideline for boron is as follows:

Freshwater Fish
The chronic values for four species ranged from 40 μg/L (32-day LOEC in *O. mykiss*) to 27,600 μg/L (32-day LOEC in *O. mykiss*). Other *O. mykiss* data were order of magnitude higher than 40 μg/L, including those from the same paper (2,100 μg/L for a 87-day NOEC and 27,600 μg/L for a 32-day LC_{50}). All other geometric means were >4,000 μg/L.

Freshwater Crustaceans
The chronic data ranged from a 21-day MATC value of 4,665 μg/L for *Daphnia magna* based on growth to an LC_{50} value of 54,200 μg/L from a 21-day *Daphnia* study. A measured NOEC of 6,000 μg/L based on reproduction was also reported.

Freshwater Algae
The data ranged from a 14-day NOEC of 400 μg/L for *Chlorella pyrenoidosa* to a NOEC of 5,200 μg/L for *Chlorella vulgaris*. Both values are based on population growth.

C. Terrestrial Toxicity

There are considerable number of terrestrial toxicity studies on borates. See the ECHA REACH database (ECHA) for summaries of the relevant studies.

D. Calculation of PNEC

PNEC water

The ANZECC water quality guideline (2000) used a "freshwater high reliability trigger value for boron of 370 μg/L was calculated using the statistical distribution method at 95% protection."

"Although the 95% protection level is higher than the 32-day LOEC of 100 μg/L for O. mykiss, this figure appeared anomalous and other data on this species showed much less toxicity. The low figure may need to be checked. The 95% figure is considered sufficiently protective for slightly-moderate disturbed ecosystems" (ANZECC, 2000).

PNEC sediment

No experimental toxicity data on sediment organisms are available. Disodium octaborate tetrahydrate dissociates completely in water and its environmental distribution is dominated by its high water solubility. K_{ow} and K_{oc} parameters do not readily apply to inorganics, such as disodium octaborate tetrahydrate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sed}$. Based on the its properties, no adsorption of disodium octaborate tetrahydrate to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

PNEC Soil

In the ECHA REACH database (ECHA), a $PNEC_{soil}$ was derived for boron using the species sensitivity distribution method and an assessment factor of 2. The $PNEC_{soil}$ was determined to be 5.7 mg/kg soil dry weight.

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Disodium octaborate tetrahydrate is an inorganic compound that dissociates completely to boric acid and the borate anion in aqueous media. Biodegradation is not applicable to these inorganic compounds; both boric acid and borate are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria are not considered applicable to disodium octaborate tetrahydrate.

Disodium octaborate tetrahydrate is a water-soluble substance that is not expected to bioaccumulate. Limited data indicate that bioaccumulation (BCF values are low) is not significant in aquatic and terrestrial food chains. Thus, it does not meet the criteria for bioaccumulation.

Boric acid and inorganic borates are reproductive toxicants and have been classified under GHS as known or presumed human reproductive toxicants (Category 1B). Thus, disodium octaborate tetrahydrate meets the PBT criteria of toxicity.

The overall conclusion is that disodium octaborate tetrahydrate is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Reproductive Toxicant Category 1B

B. Labelling

Danger

C. Pictogram



X. SAFETY AND HANDLING

A. First Aid

Eye Contact
Immediately flush open eyes with plenty of water for at least 15 minutes. Remove contacts, if present and easy to do. Get medical attention.

Skin Contact
Wash thoroughly with soap and water.

Inhalation
If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Ingestion
Swallowing small quantities (one teaspoon) will not cause any harm to adults. If larger amounts are swallowed, give two glasses of water to drink and seek medical attention. Never give anything by mouth to an unconscious person.

Notes to Physician
Observation only is required for adult ingestion of <5 grams. For ingestion of >5 grams, maintain adequate kidney function and force fluids.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
Disodium octaborate tetrahydrate is a flame retardant. It is not flammable, combustible, or explosive.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus and chemical-protective clothing.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Use personal protective clothing. Avoid dust formation. Ensure adequate ventilation. Do not breathe dust. Wear respiratory protection if ventilation is inadequate. Avoid contact with skin, eye, and clothing.

Environmental Precautions
Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled
Scoop up and remove.

D. STORAGE AND HANDLING

General Handling
No special measures necessary provided product is used correctly.

Other Handling Precautions
Avoid eye and skin contact. Avoid creating or inhaling dust.

Storage

Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
Workplace Australia has not established an occupational exposure standard for disodium octaborate tetrahydrate.

[The workplace exposure standard for disodium tetraborate decahydrate (borax) in Australia is 5 mg/m^3 as an 8-hour TWA. The workplace exposure standard for disodium tetraborate pentahydrate in Australia is 1 mg/m^3 as an 8-hour TWA.]

Engineering Controls
Ensure adequate ventilation. Localized ventilation should be used to control dust levels below permissible exposure limits.

Personal Protection Equipment

Respiratory Protection:
Use respiratory protection when airborne concentrations are expected to exceed exposure limits.

Hand Protection:
Chemical resistant protective gloves.

Skin *Protection*:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Safety glasses with side-shields.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible.

F. TRANSPORT INFORMATION

Disodium octaborate tetrahydrate is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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ETHANOL

This dossier on ethanol does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of ethanol in its use in drilling muds and hydraulic fracturing fluids. Ethanol consumption in alcoholic beverages is out of the scope of this dossier. The information presented in this dossier was obtained from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC): Ethanol

CAS RN: 64-17-5

Molecular formula: C_2H_6O

Molecular weight: 46.069

Synonyms: Ethyl alcohol, grain alcohol, alcohol, methylcarbinol, ethyl hydroxide, ethyl hydrate, algrain, alkohol, anhydrol, tecsol

SMILES: CCO

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Ethanol

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Colorless liquid with a mild odor.	2	ECHA
Melting point	-114°C	2	ECHA
Boiling point	78.2°C	2	ECHA
Density	0.789 g/cm^3 @ 20°C	2	ECHA
Vapor pressure	57.26 hPA @ 19.6°C	2	ECHA
Partition coefficient (log K_{ow})	-0.35 @ 24°C	2	ECHA
Water solubility	789 g/L @ 20°C	2	ECHA
Flash point	13°C	2	ECHA

Property	Value	Klimisch score	Reference
Auto flammability	>363 and <425ºC	2	ECHA
Viscosity	1.17 mPa s @ 20ºC	2	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Ethanol is readily biodegradable and not expected to bioaccumulate.

B. Biodegradation

Ethanol is readily biodegradable. The degradation of ethanol was approximately 74% and 84% (O_2 consumption) within 10 and 20 days, respectively, in a biodegradation test using a non-adapted domestic inoculum in a freshwater medium (ECHA) [Kl. score = 2].

C. Environmental Distribution

Adsorption/desorption

No experimental data are available for ethanol. Using KOCWIN in EPISUITE™ (EPA, 2019), the estimated K_{oc} value from log K_{ow} is 2.199 L/kg. The estimated K_{oc} value from the molecular connectivity index (MCI) is 1.045 L/kg.

D. Bioaccumulation

There are no bioaccumulation studies on ethanol. Ethanol is not expected to bioaccumulate based on a log K_{ow} of -0.35 (ECHA).

IV. HUMAN HEALTH HAZARD ASSESSMENT

Human health toxicological information was obtained from Inventory Multi-Tiered Assessment and Prioritisation (IMAP), which is an assessment framework conducted via Australia's National Industrial Chemicals Notification and Assessment Scheme (NICNAS), unless otherwise cited. Statements regarding toxicity are based solely on the determination of applicable regulatory agency.

A. Summary

Ethanol has a low acute toxicity by the oral, dermal, and inhalation routes of exposure, as measured by lethality. Sublethal doses, however, have been shown to produce central nervous system depression, respiratory depression, and coma. Deaths were reported in rodent studies due to cardiorespiratory failure. Ethanol is not irritating to the skin, but it is slightly irritating to the eyes. Repeated exposures by the oral route have not resulted in any systemic toxicity to rodents, except from exposure to high doses. Evidence of the carcinogenicity of ethanol is confined to epidemiological studies assessing the impact of alcoholic beverage consumption. These do not indicate any such hazard exists from potential exposure to ethanol in the workplace or from the use of ethanol in consumer products (OECD, 2004). Ethanol is not genotoxic or mutagenic. Ethanol does not show specific reproductive or developmental toxicity. Any reproductive and developmental effects were only observed secondary to maternal toxicity.

B. Acute Toxicity

Oral

The chemical has low acute toxicity by oral exposure in animal tests. The median lethal dose (LD50) in rats is >2000 mg/kg bw. Observed sub-lethal effects included central nervous system depression, e.g. inebriation, disturbances of gait, dose-related decreases in responses to painful stimuli, respiratory depression, and coma. Deaths were reported due to cardiorespiratory failure (OECD, 2005; HSDB; REACH).

Dermal

Few studies are available on the dermal toxicity of the chemical. A poorly documented rabbit study reported death in one of four animals following a dose of 20000 mg/kg bw. Although limited data are available, the apparent low dermal toxicity from this study is regarded as consistent with low uptake of ethanol through intact skin. The median lethal dose (LD50) in rats is greater than 2000 mg/kg bw. Observed sub-lethal effects were not reported for the study (OECD, 2005; REACH).

Inhalation

The chemical has low acute toxicity by inhalation exposure in animal tests. The lowest reported median lethal concentration (LC50) is 124.7 mg/L/four hours in rats. Observed sub-lethal effects included attempts to escape, reddish-watery eyes, nasal secretions, closing of eyelids, snout wiping, intermittent respiration, loss of pain reflex, abdominal position, and apathy (OECD, 2005; REACH).

C. Irritation

The chemical is not regarded as irritating to skin. The chemical is frequently applied to skin as a biocidal surgical wipe (70–80 % concentration) and as a component of cosmetics, personal care, and household cleaning products. There appear to be few documented concerns regarding skin irritation arising from these uses. Direct contact of the eye with the liquid chemical causes immediate discomfort accompanied by reflexive closure of the eye. Even though the acute effect subsides rapidly and the recovery is complete, foreign body type discomfort may persist for a day or two. Although inhaling the chemical at 5000 ppm (9600 mg/m^3) has been reported as irritating in humans;

lacrimation and coughing are only induced at a much higher concentrations (OECD, 2005).

Concentrations of the chemical attained in humans in the upper gastrointestinal tract after consumption of alcoholic beverages can cause local irritation.

The chemical produced irritant effects in several eye irritation studies in rabbits. While the severity of these effects was not consistent across all the studies, these were sufficiently severe in some studies to support classification, particularly under the Globally Harmonised System of Classification and Labelling of Chemicals.

D. Sensitization

The available data indicate that the chemical does not induce skin sensitisation in animals. An ear swelling study was used to examine the skin sensitising potential of ethanol. Ethanol was applied twice on the right ear after an induction procedure involving two scapular subcutaneous injection of adjuvant and multiple topical ethanol applications to the abdomen over a period of 14 days. The degree of contact hypersensitivity is deduced from ear swelling measured 24 and 48 hours after application. Ethanol was found not to cause any statistical increase in ear swelling, in contrast to 3 positive controls which all caused a statistically significant increase.

Data is also available from studies using ethanol as a vehicle. In a guinea pig maximisation study that used ethanol as a carrier solvent for the substance being tested (polyakylene glycol block copolymers) no positive reactions were obtained. It can be concluded that ethanol cannot have any significant skin sensitising properties since it was used as a solvent in this study at levels of up to 75%. A study was carried out to evaluate the effect of vehicles (e.g. ethanol) for use in the mouse local lymph node assay (LLNA), and their influence on the skin sensitization potential of fragrance materials. Groups of mice were treated with each test fragrance in ethanol (1:3 or 3:1 mixtures of the two), or with ethanol alone. Although there were no true control data for comparison with the ethanol-alone treated animals, the level of induced T-lymphocyte proliferation was low for ethanol when compared with that for fragrance materials known to be mild to moderate skin sensitizers, and comparable to other inert vehicles tested.

E. Repeated Dose Toxicity

<u>Oral</u>

Many repeated dose studies of chemical have been conducted in many species, predominantly with the aim of assessing adverse effects associated with the consumption of alcoholic beverages. Consequently, these are mostly conducted through oral exposure and with doses well in excess of those that might be encountered in occupational exposure or consumer products (OECD, 2005), or unintentional public exposures from environmental contamination.

In a 90-day study, SD rats were fed a mixture containing 16.25% USP ethanol at 3 dose levels (Kl =2). A single dose of 4 ml/kg of pure ethanol and water were used as controls. No significant differences were noted in body weight, haematology, opthamology, clinical chemistry or urine chemistry. Dose-related increases in liver to body weight ratios of female rats were seen at final sacrifice although the absolute liver weights of the high dose ethanol treated group, while significantly increased relative to the 100% ethanol treated group, was not different from the water control group. In addition, increased liver weights were observed in the male rats. Significant increases in kidney weights were observed in the mid and high dose groups. No histopathologic findings were attributed to ethanol treatment with exception of increased minimal focal to multifocal renal tubular epithelial hyperplasia in the high dose 20 ml/kg mixture containing 16.25% ethanol and the 100% USP ethanol control treated rats versus the water treated controls. It should be noted however that renal tubular epithelial hyperplasia is a common incidental finding in laboratory rats and it is uncertain whether the higher incidence of this lesion in the ethanol dosed rats compared with water controls is due to a random variation or to ethanol. Gonadal tissues were examined for both gross pathology and histopathology and no treatment-related effects were detected. The NOAEL for the study was determined at 10 ml/Kg for a mixture containing 16.25% ethanol for increased kidney weight and renal tubular epithelial hyperplasia in males (equivalent to 1.73g/kg). The LOAEL for this study was determined at 4 ml/kg for 100% USP ethanol (3.16g/kg) for increased kidney weight and renal tubular epithelial hyperplasia in males.

Inhalation

As properly conducted studies in animals are not available, there are no valid data on the effects of repeated inhalation exposure to the chemical. However, limited information is presented below to indicate that the chemical is likely to be of low toxicity following repeated inhalation exposure.

Dermal

No data are available.

F. Genotoxicity

Overall, ethanol is not considered to be mutagenic or genotoxic (OECD, 2005; REACH).

In Vitro Studies

Table 2: *In vitro* Genotoxicity Studies on Ethanol

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* and *E. coli* strains)	-	-	1	Zeiger et al., 1992
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	-	-	2	Wangenheim and Bolcsfoldi, 1988

*+, positive; -, negative;

In Vivo Studies

Several in vivo micronucleus assays have assessed the potential for the chemical to induce damage to chromosomes of erythroblasts. No effect was reported in rats when administered 5 % of the chemical (approximately 4 g/kg bw/day) in drinking water, or in mice at up to 40 % (approximately 31 g/kg bw/day). Chemical-related mortality was observed in the latter study. Marginally statistically significant increases in the incidence of micronucleated bone marrow erythrocytes were reported in rats fed for six weeks with a diet containing ethanol at 12–16 g/kg/day. Although there is very limited evidence that the chemical induces micronuclei in the bone marrow of rodents, the chemical has the potential to induce micronuclei in bone marrow erythrocytes at very high doses. KI scores were not listed for these studies (IMAP, 2014).

G. Carcinogenicity

Oral

A significant number of carcinogenicity studies have been identified, but the majority of these are only partial studies designed to look at aspects of the carcinogenic hazard resulting from drinking ethanol containing beverages and are judged unreliable for assessing the cancer hazard of ethanol as a chemical substance. Only two studies were identified as reliable.

In a study to assess the carcinogenic potential of ethanol, groups of rats were exposed to ethanol at concentrations of 1% and 3% in a liquid semi-synthetic diet for a period of 2 years, approximately equivalent to 1 and 3g/kg respectively. Each dose group used a control matched for caloric content using glucose. From the data it was possible to conclude that ethanol did not cause any treatment related increase in tumours and the no effect level was identified as > 3g/kg.

In a study designed and conducted to determine the long-term toxicity and carcinogenicity of urethane in ethanol, groups of mice were exposed to ethanol at concentrations up to 5% in drinking water for a period of 2 years, with control groups consuming drinking water alone. The only significant cancer finding was a dose related increase in the rate of hepatocellular adenomas for male mice in comparison with the concurrent controls. The species of mouse used in this study is known to have a high spontaneous incidence of these tumours. In comparison to historic controls, the incidence rate in the ethanol dosed animals was not high and the controls were significantly lower (although it should be noted that no historic control information was available for animals on the study diet used.) Analysis of the data using the Benchmark dose approach showed a BMDL10 of 1400mg/kg for liver adenomas in males. There was no significant increase in tumour rates (including mammary tumours) in females.

The International Agency for Research on Cancer (IARC) has concluded that there is sufficient evidence in humans and experimental animals to establish carcinogenicity of alcohol consumption and ethanol, respectively. It was also concluded that there is sufficient evidence in experimental animals to establish carcinogenicity of acetaldehyde (major metabolite of ethanol). Consequently, IARC has classified that ‘alcohol

consumption is carcinogenic to humans (Group 1)' and that 'ethanol in alcoholic beverages is carcinogenic to humans (Group 1)'. This conclusion was supported by an analysis of the expanded human dataset that carcinogenic effects appeared independent of the type of alcoholic beverage (IARC, 2010; IARC, 2012). As the use of the chemical in alcoholic beverages is not considered in this report, the above assessment of carcinogenicity of alcohol beverages may not be relevant to occupational exposure to the chemical or from using the chemical in consumer products (OECD, 2005). Furthermore, studies in animals conducted mostly through oral exposure at very high doses, exceeding the 'maximum tolerated dose', may be of little relevance when assessing risks associated with occupational exposure or using consumer products containing the chemical (OECD, 2005). Thus, classification is not considered appropriate (IMAP).

Inhalation
No information available (IMAP, REACH).

H. Reproductive and Developmental Toxicity

The chemical does not show specific reproductive or developmental toxicity. Any reproductive and developmental effects were only observed secondary to maternal toxicity. As results of inhalation studies showed no developmental toxicity from chemical exposures even at maternally toxic doses, it can be concluded that deliberate oral consumption of alcoholic beverages is required for any reproductive or developmental toxicity (OECD, 2005).

The most reliable study (Kl = 1) performed to the most appropriate protocol and the one given the greatest weight as well as the key study is a two-generation study investigated the effects of 5%, 10% and 15% ethanol in drinking water in reproduction and fertility. Male and female CD-1 mice were continuously treated for 1 week prior to mating and for a 14-week breeding period followed by a 21-day holding period when they were separated and housed individually. The F1 offspring of the 15% ethanol pairs had fewer live pups per litter but ethanol treatment had no effect on the proportion of breeding pairs producing at least 1 litter during the continuous breeding phase or the number of litters per pair. The F1 offspring from the 15% group had decreased bodyweight at weaning and mating, and a decreased weight of testis, epididymides and seminal vesicles which was no longer evident when these were adjusted for body weight. There was also a significantly decreased percentage motile sperm but no changes in sperm concentration, and percentage of abnormal sperm or tailless sperm. When reproductive performance of F1 control and 15% ethanol-treated breeding pairs was assessed at 74 days of age, there was no significant difference in mating and fertility between the groups. However, adjusted live pup weight for the ethanol group was significantly reduced compared to controls which was likely due to generalized maternal toxicity.

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for ethanol follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

The lowest NOAEL from these studies is 1,730 mg/kg-day based on increased relative and absolute liver weight and absolute heart, liver, kidney and lung weight in male mice from a 90-day dietary study (1996). The NOAEL of 1,730 mg/kg-day will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD):

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 3
UF_D (database uncertainty) = 1

Oral RfD = 1730/(10 x 10 x 1 x 3 x 1) = 1730/300 = 6 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:

Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (6 x 70 x 0.1)/2 = 21 mg/L

B. Cancer

Evidence of the carcinogenicity of ethanol is confined to epidemiological studies assessing the impact of alcoholic beverage consumption. These do not indicate any such hazard exists from potential exposure to ethanol in the workplace or from the use of

ethanol in consumer products (OECD, 2004). Therefore, no cancer reference value was derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Ethanol is a flammable liquid.

Ethanol does not exhibit the following physico-chemical properties:
- Explosivity
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies conducted on ethanol.

Table 3: Acute Aquatic Toxicity Studies on Ethanol

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Pimephales promelas	96-hr LC_{50}	15,300	2	ECHA
Pimephales promelas	96-hr LC_{50}	14,200	2	ECHA
Ceriodaphnia dubai	48-hr EC_{50}	5012	2	ECHA
Chlorella vulgaris	72-hr EC_{50}	275	2	ECHA

Chronic Studies

The 5-d NOEC to *Brachydanio rerio* in an OECD 212 embryo and sac-fry stage test is 250 mg/L (ECHA) [Kl. score = 2].

The 10-d NOEC to *Ceriodaphnia dubia* in a *Daphnia* reproduction test is 9.6 mg/L (ECHA) [Kl. score = 2].

The 72-hr EC_{10} to algae *Chlorella vulgaris* is 11.5 mg/L (ECHA) [Kl. score = 2].

C. Terrestrial Toxicity

No data are available.

D. Calculation of PNEC

The PNEC calculations for ethanol follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (14,200 mg/L), invertebrates (5,012 mg/L), and algae (275 mg/L). Results from chronic studies are available for fish (250 mg/L), invertebrates (9.6 mg/L), and algae (11.5 mg/L). On the basis that the data consists of short- and long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported NOEC or EC_{10} value of 9.6 mg/L for invertebrates. The $PNEC_{aquatic}$ is 0.96 mg/L.

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the PNECsoil was calculated using the equilibrium partitioning method. The PNECsoil is 0.013 mg/kg soil dry weight.

The calculations are as follows:

$$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$$
$$= (0.02/1500) \times 1000 \times 0.96$$
$$= 0.013$$

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$$Kp_{soil} = K_{oc} \times f_{oc}$$
$$= 1.05 \times 0.02$$
$$= 0.02$$

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for ethanol based on the molecular connectivity index (MCI) is 1.05 L/kg (EPA, 2019).
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Ethanol is readily biodegradable; thus, it does not meet the screening criteria for persistence.

Based on a measured log K_{ow} of -0.35, ethanol does not meet the screening criteria for bioaccumulation.

No chronic aquatic toxicity studies are available on ethanol. The acute $E(L)C_{50}$ values for ethanol are >1 mg/L. Thus, ethanol does not meet the criteria for toxicity.

The overall conclusion is that ethanol is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Flammable liquid, Category 2
Eye irritation, Category 2B
Acute Toxicity, Category 3
Reproductive toxicity, Category 2
Specific target organ toxicity – Repeated exposure, Category 2
Specific target organ toxicity – Single exposure, Category 3

B. Labelling

Danger

C. Pictogram



X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact

Protect unexposed eye. Rinse/ flush exposed eye(s)s gently using water for 15-20 minutes. Remove contact lens(es) if able to do so during rinsing. Seek medical attention if irritation persists or if concerned.

Skin Contact
Wash affected area with soap and water. Rinse thoroughly. Seek medical attention if irritation, discomfort, or vomiting persists.

Inhalation
Move exposed individual to fresh air. Loosen clothing as necessary and position individual in a comfortable position. Seek medical advice if irritation persists.

Ingestion
Rinse mouth thoroughly. Do not induce vomiting. Have exposed individual drink sips of water. Seek medical attention if irritation, discomfort, or vomiting persists.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
For small fires, use dry chemicals, CO_2, water spray or alcohol-resistant foam. For large fire, use water fog or alcohol-resistant foam. Use appropriate fire suppression agents for adjacent combustible materials or sources of ignition.

Specific Exposure Hazards
Combustion products may include carbon oxides or other toxic vapors. Dangerous fire hazard when exposed to hear, sparks, and open flames.

Special Protective Equipment for Firefighters
Wear protective equipment. Use NIOSH-approved respiratory protection/ breathing apparatus. Use spark-proof tools and explosion-proof equipment. Move product containers away from fire or keep cool with water spray as a protective measure, where feasible.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Beware of vapors accumulating to form explosive concentrations. Vapors can accumulate in low areas. Keep unprotected persons away.
Wear protective equipment. Use respiratory protective device against the effects of fumes/ dust/ aerosol. Ensure adequate ventilation. Keep away from ignition sources. Protect from heat.
For large spills, wear splash goggles, full suit, respirator, boots and gloves and use self-contained breathing apparatus.

Environmental Precautions

Prevent from reaching drains, sewer, or waterway. Collect contaminated soil for characterisation. Collect spilled liquid for recovery, treatment, or disposal.

Steps to be Taken if Material is Released or Spilled
Eliminate sources of ignition. Stop the spill, if possible. Contain spill material by diking or using inert absorbent. Spill may also be contained by using electrically protected vacuum cleaner or by wet-brushing. Transfer to a disposal or recovery container.

D. STORAGE AND HANDLING

General Handling
Prevent formation of aerosols. Use only in well ventilated areas. Avoid splashes or spray in enclosed areas. Prevent exposure to ignition sources; use non-sparking tools and explosion-proof equipment.

Other Handling Precautions
Avoid contact with eyes, skin, and clothing. Avoid breathing vapor. Follow good hygiene procedures when handling chemical materials. Do not eat, drink, smoke, or use personal products when handling substances. Wash hands before breaks and at the end of work.

Storage
Store in a cool location. Provide ventilation for containers. Avoid storage near extreme heat, ignition sources, or open flame. Store away from foodstuffs. Store away from oxidizing agents. Store in cool, dry conditions in well-sealed containers. Keep containers tightly sealed. Store in secure flammable storage area away from sources of ignition. Protect from freezing and physical damage.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
The workplace exposure standard for ethanol in Australia is 1000 ppm (1880 mg/m^3) as an 8-hr TWA. No STEL is listed.

Engineering Controls
Good general ventilation should be used. If applicable, use process enclosures, local exhaust ventilation, or other engineering controls to maintain airborne levels below recommended exposure limits. Avoid storage near extreme heat, ignition sources, or open flame. Use non-sparking tools and explosion-proof equipment.

Personal Protection Equipment

Respiratory Protection: Not required under normal conditions of use. Use suitable respiratory protective device when high concentrations are present. Use suitable respiratory protective devise when aerosol mist is formed. For spills, respiratory protection may be advisable.

Hand Protection: Gloves that are impermeable and resistant to the substance

Skin Protection: Wear chemical resistant gloves (rubber, neoprene or vinyl). Use personal protection equipment that is chemical resistant and prevents skin contact.

Eye protection: Goggles or safety glasses with side shields

Other Precautions:

- Use other PPE as required by the situation.
- Ethanol is a flammable liquid; keep away from ignition sources. Wash hands, forearms, and face thoroughly after handling chemical products, before eating, smoking, and using the lavatory and at the end of the working period.
- Appropriate techniques should be used to remove potentially contaminated clothing. Wash contaminated clothing before reusing.
- Ensure that eyewash stations and safety showers are close to the workstation location.

F. TRANSPORT INFORMATION

UN Number: 1170
UN proper shipping name: Ethanol (mixture)

Transport hazard class: 3 Flammable liquids
Packing group: II

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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ETHYLENE GLYCOL

This dossier on ethylene glycol does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of ethylene glycol in its use in drilling muds and hydraulic fracturing fluids. Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC): Ethane-1,2-diol

CAS RN: 107-21-1

Molecular formula: $C_2H_6O_2$ ($HOCH_2CH_2OH$)

Molecular weight: 62.07

Synonyms: Ethylene glycol; ethane-1,2-diol; 1,2-ethanediol, 2-hydroxyethanol; monoethylene glycol; MEG; glycol alcohol; EG

SMILES: C(CO)O

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Ethylene Glycol

Property	**Value**	**Klimisch score**	**Reference**
Physical state at 20°C and 101.3 kPa	Colourless and odourless syrupy liquid	2	ECHA
Melting Point	-13°C	2	ECHA
Boiling Point	197.4°C	2	ECHA
Density	1.11 g/cm^3	2	ECHA
Vapor Pressure	0.123 hPa	2	ECHA
Partition Coefficient (log K_{ow})	-1.36 (calculated)	2	ECHA
Water Solubility	1,000 g/L @ 20°C	2	ECHA

Flash Point	111°C	2	ECHA
Auto flammability	398°C	2	ECHA
Viscosity	16.1 mPa s @ 25°C	2	ECHA
Henry's Law Constant	0.133 @ 25°C (QSAR)	2	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Ethylene glycol is readily biodegradable, and it is not expected to bioaccumulate. Ethylene glycol has low potential to adsorb to soil and sediment.

B. Biodegradation

Ethylene glycol was readily biodegradable in an OECD 301A test. After 10 days, degradation was 90-100% (ECHA) [Kl. score = 1]. There was 97% degradation after 20 days in a BOD test; and 96% degradation after 28 days in an OECD 301D test (Waggy et al., 1994; OECD, 2004a,b) [Kl. score = 2].

The aerobic degradation of ethylene glycol was measured from grab river water samples at 4, 8, and 20°C. At 20°C, ethylene glycol was completely degraded in three days in all river waters tested; at 8°C, degradation was complete within 14 days. Degradation at 4°C was substantially slower, with degradation of <20% after 14 days in river samples with limited suspended matter and a starting concentration of 10 mg/L (Evans and David, 1974).

C. Environmental Distribution

<u>Adsorption/desorption</u>

No experimental data are available for ethylene glycol. Using KOCWIN in EPISUITE™ (EPA, 2017), the estimated K_{oc} values from the molecular connectivity index (MCI) and from the log K_{ow} are 1 and 0.2239 L/kg, respectively.

D. Bioaccumulation

The calculated log K_{ow} for ethylene glycol is -1.36 (ECHA). The BCF for ethylene glycol in golden ide (*Leuciscus idus melanotus*) after three days of exposure was determined to be 10 (Freitag *et al.*, 1985).

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Following acute ingestion of ethylene glycol, the critical effects in humans in three subsequent stages are central nervous system toxicity, metabolic acidosis, and kidney toxicity. The lethal effects of ethylene glycol in human adults occur at oral doses of ≥1,600 mg/kg. Ethylene glycol is not a skin irritant or a skin sensitizer in laboratory animals. In humans, ethylene glycol may cause skin irritation; there is also a low potential for skin sensitization. It is not an eye irritant. The kidney is the primary target organ from repeated exposures. The proposed mode-of-action (MOA) for the kidney damage involves the formation of a precipitate or crystals from the ethylene glycol metabolite oxalic acid with calcium in the urine. Ethylene glycol is not genotoxic or carcinogenic to rodents. Ethylene glycol did not affect fertility in animal studies, but it did cause developmental effects. In rodents, the developmental effects caused by oral doses of ethylene glycol include teratogenic effects (craniofacial and axial-skeletal malformations and variations). In contrast, no developmental toxicity was seen in rabbit studies. The relevant metabolite for the developmental toxicity seen in rodent, but not rabbit, studies appears to be glycolic acid. This metabolite can be reached at higher concentrations in rats than in rabbits. Based on a physiologically-based pharmacokinetic (PBPK) model for ethylene glycol, humans are unlikely to achieve blood levels of glycolic acid necessary for developmental toxicity.

B. Metabolism

Ethylene glycol is almost completely absorbed in laboratory animals by the oral route (OECD, 2004; Frantz et al., 1996a). A range of 1-51% of ethylene glycol is absorbed by the dermal route based on *in vivo* studies in rodents (Frantz *et al.*, 1996a,b).

The main metabolic pathway for metabolism of ethylene glycol is oxidation via alcohol dehydrogenases and aldehyde dehydrogenases. The main metabolites of ethylene glycol are carbon dioxide, oxalic acid and glycolic acid (OECD, 2004a).

The relevant metabolite for the repeated dose toxicity studies is oxalic acid, which is slowly transported from the liver to the kidneys, where is forms calcium-oxalate crystals (Corley *et al.*, 2005a).

The relevant metabolite for the developmental toxicity seen in rodent, but not rabbit, studies appears to be glycolic acid. This metabolite can be reached at higher concentrations in rats than in rabbits (Carney *et al.*, 1998).

A physiologically-based pharmacokinetic (PBPK) model has been developed for ethylene glycol. When internal dose surrogates were compared in rats and humans over a wide range of exposures, it has been concluded that humans are unlikely to achieve blood levels of glycolic acid necessary for developmental toxicity (Corley *et al.*, 2005b).

C. Acute Toxicity

The oral LD_{50} in rats was reported to be 7,712 mg/kg (ECHA) [Kl. score = 2]. The 6-hour inhalation LC_{50} value for male and female rats was >2.5 mg/L (Tyl *et al.*, 1995a) [Kl. score = 2]. The dermal LD_{50} for male and female mice is >3,500 mg/kg (Tyl *et al.*, 1995b) [Kl. score = 2].

Following acute ingestion of ethylene glycol, the critical effects in humans in three subsequent stages are central nervous system toxicity, metabolic acidosis, and kidney toxicity (ECHA). The lethal effects of ethylene glycol in human adults occur at oral doses of $\geq$1,600 mg/kg (Hess et al., 2004).

D. Irritation

Application of 0.5 mL of ethylene glycol to the skin of rabbits for 23 hours under occlusive conditions was not irritating (Guillot *et al.*, 1982). [Kl. score = 2].

In a Human Repeated Insult Patch Test (HRIPT), ethylene glycol was applied to the skin for 24 hours under occlusive or semi-occlusive conditions for nine times during the induction phase. The induction phase was followed by a rest period of two weeks, followed by a 24-hour challenge on the sixth week of the study. Erythema was seen in a small proportion of the 401 subjects that completed the study. Under the conditions of the study, three subjects had reactions on challenge that were indicative of possible irritation and/or low-level sensitization. These three subjects were re-challenged under occlusive or semi-occlusive conditions one or two weeks later. Re-challenge testing was negative for one subject, but the other two subjects were judged to have irritant reactions to ethylene glycol since their reactions were similar or lesser compared to the skin responses observed during the induction period, and the skin reactions were not greater over time after the challenge or re-challenge (ECHA).

Instillation of 0.05 mL of ethylene glycol into the eyes of rabbits was not irritating (ECHA). [Kl. score = 2]

E. Sensitization

Ethylene glycol was not a skin sensitizer to guinea pigs in a Magnusson and Kligman test (Kurihara *et al.*, 1996) [Kl. score = 2]. In a HRIPT, ethylene glycol was considered to have a low potential for dermal sensitization in humans (ECHA).

F. Repeated Dose Toxicity

<u>Oral</u>

Male and female Fischer 344 rats were given in their feed 0, 0.32, 0.63, 1.25, 2.5, or 5% ethylene glycol for 13 weeks. Mortality was seen in the 5% males, but not in females. Mean weight gain was significantly decreased in the 2.5 and 5% males; there was no significant differences in female rats. Feed consumption was similar across all groups. A significant increase was seen in the left kidney weight in the 2.5 and 5% dose groups (both sexes); this was not seen in the right kidneys. Mean thymus ratio to terminal body weight was significantly decreased in the 5% males. Serum urea nitrogen levels were significantly increased in the 2.5 and 5% males, and significantly increased in the $\geq$0.32% females. Creatinine levels were decreased in the 0.32% groups and significantly increased in the 2.5 and 5% groups. The 2.5% and 5% male rats had kidneys that were rough, granular and/or pitted appearances. The 5% females showed nephrosis, and the 5% males had clusters of crystals in the brain. The NOAEL for this study is 1.25%, which was estimated to be 600 to 1,000 mg/kg-day (Melnick, 1984). [Kl. score = 2]

Male and female Sprague Dawley rats were given in their drinking water ethylene glycol for 90 days. The concentrations for females were 0, 0.5, 1.0, 2.0 or 4.0% (0, 597, 1,145, 3,087 or 5,744 mg/kg-day). The concentrations for males were 0, 0.25, 0.5, 1.0 or 2.0% (0, 205, 407, 947 or 3,134 mg/kg-day). In the 4% groups, there was mortality and decreased body weights (males only). Significant organ weights were noted only in males. Kidney weights were significantly increased in the 1% and 2% males; heart, liver, and lung were significantly decreased in the 2% males. The 4% males also had a significant increase in the brain and gonads relative to body weights. Leukocyte levels were significantly decreased in the 0.5, 2 and 4% females, but not in males. Significant differences were noted in LDH, creatinine, ALT, calcium and glucose in the 1% males; and phosphorus, BUN, and creatinine in the 2% males. There were significant increases in phosphorus in the 1% females and glucose in the 0.5 and 4% females. Kidney lesions were seen in the $\geq$2% females and in the $\geq$1% males, with the lesions more prominent in males than in females. The kidney changes consisted of tubular dilation, tubular degeneration, acute inflammation, birefringent crystals in tubules and pelvic epithelium. The NOAEL for this study is 407 mg/kg-day for males. The LOAEL for females is 597 mg/kg-day; a NOAEL was not established (Robinson *et al.*, 1990). [Kl. score = 2]

Male and female B6C3F$_1$ mice were given in their feed 0, 0.32, 0.63, 1.25, 2.5, or 5.0% ethylene glycol for 13 weeks. There was no mortality and no treatment-related effect on mean weight gain and feed consumption. Organ/body weight ratios were similar across all groups. Serum urea nitrogen and creatinine levels were unaffected. Kidney effects were seen in the male, but not female, mice. Kidney lesions were observed in half of the 5% male mice and one mouse in the 2.5% dose level. Lesions were tubular dilation, cytoplasmic vacuolization, and regenerative hyperplasia of tubular cells. There was no evidence of crystal formation in the tubules. These changes were focal, randomly distributed, and of minimal to mild severity. Hyaline degenerative of the liver was present in the centrilobular hepatocytes in all of the 2.5% and 5% males. These cells showed cytoplasmic accumulations of non bifringent, eosinophilic (hyaline), globular, or crystalline material which resembled erythrocytes in size, shape, and tinctorial properties.

The NOAEL for this study is 1.25%, which was estimated to be 600 to 1,000 mg/kg-day (Melnick, 1984). [Kl. score = 2]

Male Fischer 344 and Wistar rats were given in their feed 0, 150, 500 or 1,000 mg/kg ethylene glycol for 16 weeks. At 1000 mg/kg, the following effects were seen: mortality in Wistar strain (2/10) with prior clinical observations of emaciation and dermal atonia and macroscopic findings of changes in kidneys (pale, calculi) and small seminal vesicles in these animals; mean body weight losses, lower mean body weights and mean cumulative body weight changes in Wistar strain (weeks 2 – 16); lower mean food consumption in Wistar strain; higher mean water consumption in both F344 and Wistar strains; lower mean specific gravity and higher mean total urine volume in both F344 and Wistar strains; macroscopic findings of pale kidneys, presence of calculi, rough surface and dilated pelvis; higher mean absolute and relative kidney weights in both F344 and Wistar strains; renal macroscopic findings of crystal nephropathy in Wistar and F-344 rats, with more severe nephropathy in Wistar strain than in the F344 strain. At 500 mg/kg, the following effects were seen: lower mean body weights (study weeks 3, 6-8, and 10-12) and mean cumulative body weight changes in the Wistar strain throughout the study with slightly lower mean food consumption throughout the study; higher mean water consumption in the Wistar strain; lower mean urine specific gravity and higher mean total urine volume in the Wistar strain; macroscopic findings in the Wistar strain consisting of predominantly pale kidneys, presence of calculi, rough surface, and dilated pelvis; higher mean absolute and relative kidney weight in the Wistar strain; renal macroscopic findings of crystal nephropathy in Wistar and F-344 strains, with more severe nephropathy in the Wistar strain than in the F344 strain. The NOAEL in both the F344 and Wistar rats is 150 mg/kg-day (Cruzan *et al.*, 2004). [Kl. score = 2]

Male Wistar rats were given in their feed 0, 50, 150, 300 or 400 mg/kg ethylene glycol for 12 months. There was mortality in the 300 and 400 mg/kg dose groups (5/20 and 4/20, respectively); the remaining 400 mg/kg animals were euthanized early (day 203) due to excessive weight loss. The 300 mg/kg animals had increased water consumption and urine volume with decreased specific gravity, most likely due to osmotic diuresis. Calculi (calcium oxalate crystals) were found in the bladder and kidney pelvis in the $\geq$300 mg/kg animals. The $\geq$300 mg/kg rats that died prematurely had transitional cell hyperplasia with inflammation and hemorrhage of the bladder wall. Crystal nephropathy (basophilic foci, tubule or pelvic dilatation, birefringent crystals in the pelvic fornix, or transitional cell hyperplasia) was seen in all of the 400 mg/kg and most of the 300 mg/kg rats. These effects were not seen in the 50 or 150 mg/kg rats. Kidney oxalate levels, the metabolite responsible for the kidney toxicity, was not increased in the 50 and 150 mg/kg animals compared to the controls. The NOAEL for this study is 150 mg/kg/day (Corley *et al.*, 2005). [Kl. score = 1]

Male and female Sprague-Dawley rats were given in their feed 0, 0.1, 0.2, 0.5, 1.0 or 4.0% ethylene glycol for two years. There was significant reduction in growth in the 4% males after week 16, and in the 1% males after week 70. The 4% females did not gain any weight past the first year of the study. Water consumption was double that of the controls in the 4% males that initiated soon after the start of the study. The 1% males had

significant increases in water consumption after 6 months and some increase was observed in the 0.5% males. Females only showed increased water consumption in the 4% group. There was 100% mortality in the 1 and 4% males, while mortality of additional dose levels were below that of the controls. There was 100% mortality in the 4% females, while the 1% females were similar to the controls; the 0.1, 0.2 and 0.5% females were increased compared to the controls. Since the 1 and 4% males and the 4% females all died before the study termination date, there are no data for these groups on terminal organ weight. For males, the terminal organ weights were decreased in all dose levels compared to the controls. For females, the organ weights were similar to the controls. The 1 and 4% males and females had kidneys with stones and crystals. The NOAEL for this study is 0.2% (data was insufficient to calculate the dose) (Blood, 1965). [Kl. score = 2]

Male and female Fischer 344 rats were given in their feed 0, 40, 200 or 1,000 mg/kg ethylene glycol for 24 months. There were numerous adverse effects in the 1,000 mg/kg males and, to a lesser degree, in the 1,000 mg/kg females. The most remarkable effect was the production of urinary calculi in the kidneys, ureters, and urinary bladders of the 1,000 mg/kg males, along with the presence of high levels of calcium oxalate in the urine. Increased incidences of tubular cell hyperplasia, tubular dilation, peritubular nephritis, and focal granulomatous nephritis occurred in the 1,000 mg/kg males. Other significant findings in these males were markedly lower body weight gain, increased absolute and relative kidney weights, decreased absolute and relative liver weights, various hematopoietic changes, and increased water consumption (likely a result of impaired kidney function). Histopathological changes in the 1,000 mg/kg males were mineralization of the heart, lungs, stomach, and vas deferens being the most noteworthy. The various adverse effects in these males resulted in reduced survival; there was increased mortality which became apparent by 8 months, with all males in this group died by month 16. Although calcium oxalate crystals were found in the urine of the 1,000 mg/kg females, no urinary calculi were seen. Absolute and relative kidney weights were increased in these rats. The most significant histopathologic finding in the 1,000 mg/kg females was fatty metamorphosis of the liver. There were transient changes in organ weights, erythroid parameters, water consumption rates, and urine specific gravity in the 200 and 40 mg/kg rats; these effects were considered to be statistical artifacts attributable to chance. Focal soft mineralization was observed in certain organs of the 200 and 40 mg/kg rats, which were considered to be the result of altered calcium metabolism associated with ingestion of ethylene glycol. The NOAEL for this study is considered to be 200 mg/kg-day (DePass *et al.*, 1986a; ECHA). [Kl. score = 2]

Male and female B6C3F$_1$ mice were given in their feed 0, 6,250 ppm (males only), 12,500 and 25,000 ppm (males and females) or 50,000 ppm (females only) for 103 weeks. These concentrations are approximately equivalent to 0, 1,500, 3,000, 6,000 or 12,000 mg/kg-day. Survival, mean body weights, and feed consumption was similar across all groups. There were no treatment-related clinical signs of toxicity. Liver lesions (males only) and arterial hyperplasia (females only) were observed at 12,500 ppm, but no adverse effects were observed at 6,250 ppm. The NOAEL for this study is 6,250 ppm in males, which corresponds to 1,500 mg/kg-day (NTP, 1993). [Kl. score = 2]

Inhalation

No studies are available.

Dermal

No studies in rodents or rabbits are available.

G. Genotoxicity

In Vitro Studies

The *in vitro* genotoxicity studies on ethylene glycol are presented in Table 2.

Table 2: *In vitro* Genotoxicity Studies on Ethylene Glycol

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* and *E. coli* strains)	-	-	1	ECHA
Bacterial reverse mutation (*S. typhimurium* and *E. coli* strains)	-	-	2	ECHA
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	+/-	-	2	McGregor et al. (1991)
Chromosomal aberration (CHO cells)	-	-	2	ECHA

*+, positive; -, negative

In Vivo Studies

A dominant lethal study was conducted in F344 rats given 0, 40, 200, or 1,000 mg/kg-day ethylene glycol in feed. There were slight increases in the dominant lethal mutation index in the high-dose and low-dose groups; these appear to be random occurrences and were not considered to be treatment-related. It was concluded that ethylene glycol was not genotoxic in this study (DePass et al., 1986b). [Kl. score = 2]

H. Carcinogenicity

Oral

Male and female Fischer 344 rats were given in their feed 0, 40, 200 or 1,000 mg/kg ethylene glycol for 24 months. There was increased mortality in the 1,000 mg/kg males, starting at 8 months and resulting in all males in this group dead by 16 months. Survival for the 1,000 mg/kg females and the 200 and 40 mg/kg males and females were similar to the controls. The incidence of mononuclear cell leukemia was statistically significantly higher in the 200 mg/kg males compared to the male controls, but not when compared to the pooled controls (males and females). Evaluation of the data by the method of Thomas et al. (2007), however, showed no treatment-related effect. It was concluded that ethylene glycol was not carcinogenic to rats in this study (DePass et al., 1986). [Kl. score = 2]

Male and female B6C3F_1 mice were given in their feed 0, 6,250 ppm (males only), 12,500 and 25,000 ppm (males and females) or 50,000 ppm (females only) ethylene glycol. These concentrations were approximately equivalent to 0, 1,500, 3,000, 6,000 or 12,000 mg/kg-day. Body weights, survival, and incidence of tumors were similar between treated and control mice (NTP, 1993). [Kl. score = 2]

Inhalation

No studies are available.

Dermal

No studies are available.

I. Reproductive Toxicity

Ethylene glycol was assessed in a Reproductive Assessment by Continuous Breeding (RACB) protocol. The parental mice were administered ethylene glycol via drinking water during pre-mating exposure, cohabitation, pregnancy, and lactation. The F_1 generation received prenatal exposure via maternal exposure during gestation, with the exposure continuing during lactation, weaning, and mating of F_1 animals and production of an F_2 litter. The doses were 0, 0.25, 0.5 or 1% ethylene glycol, which corresponded to approximately 0, 410, 840 or 1,640 mg/kg-day. No adverse effects were noted in the parental animals at doses up to 1%. There was a small, but statistically significant, effects on the numbers of litters per fertile pair, the number of live pups per litter, and live pup weight in the 1% dose group. Neither the 0.25 nor 0.5% dose groups were significantly affected. The number of live pups per litter was lower in the treated groups, but differences were not statistically significant. Unusual facial features (*i.e.*, shorter snout and wide-set eye) and skeletal defects (shortened frontal, nasal, and parietal bones; fused ribs abnormally shaped or missing sternebrae, abnormally shaped vertebrae; and

twisting of the spine) were noted on some of the offspring of the treated mice in the 1% group, but not in the controls. The parental NOAEL is 1% (approximately 1,640 mg/kg-day), and the NOAEL for reproductive toxicity is 0.5% (approximately 840 mg/kg-day (Lamb *et al*., 1985). [Kl. score = 2]

In a three-generation reproductive toxicity study, Fischer 344 rats were given in their diet 0, 40, 200 or 1,000 mg/kg-day ethylene glycol. There were no treatment-related effects on clinical signs of toxicity or survival in the parental animals. There were no significant effects on fertility index, gestation index, gestation survival for all three generations. Mean pup weights in the all three generations were similar between treated and control animals. The NOAEL for parental and reproductive toxicity is 1,000 mg/kg/day (DePass *et al.*, 1986b). [Kl. score = 2]

J. Developmental Toxicity

Pregnant Sprague-Dawley rats were dosed by oral gavage with 0, 50, 150, 500, 1,000 or 2,500 mg/kg ethylene glycol during gestational days (GD) 6-15. Maternal toxicity was observed in the 2,500 mg/kg group and consisted of significantly decreased body weights, increased water consumption, decreased uterine weights, increased kidney weights, and increased relative liver weights. At 500 mg/kg, there were developmental effects, which included reduced fetal body weights, extra or missing ribs, missing arches, and poor ossification in thoracic and lumbar centra. In the 2500 mg/kg group, in addition to skeletal malformations, there was gastroschisis, hydrocephaly, lateral ventricle dilated (tissue depressed), umbilical hernia, and atelectasis. The NOAELs for maternal and developmental toxicity are 1,000 and 500 mg/kg-day, respectively (Neeper-Bradley *et al.*, 1995). [Kl. score = 2]

Pregnant CD rats were dosed by oral gavage with 0, 1,250 2,500 or 5,000 mg/kg ethylene glycol during GD 6-15. In the $\geq$2,500 mg/kg groups, the dams had increased relative kidney weights, decreased gravid uterine weight, and increased water consumption. Maternal body weight gain was significantly decreased in the 1,250 mg/kg group. Live litter size was significantly decreased in the 5,000 mg/kg group, and fetal body weights were decreased in the 1,250 and 5,000 mg/kg groups. Litters with malformed fetuses were observed in the $\geq$1,250 mg/kg groups. The LOAELs for maternal and developmental toxicity are 1,250 mg/kg/day; NOAELs were not established (Price *et al.*, 1985). [Kl. score = 2]

Pregnant Fischer 344 rats were given by oral gavage 0, 40, 200 or 1,000 mg/kg ethylene glycol during GD 6-15. No maternal toxicity was observed at any dose level. There were no significant effects on preimplantation loss, fetal length, fetal weight, total implantations or litter size. There was an increased incidence of skeletal alterations in the 1,000 mg/kg group, which consisted of poorly ossified and unossified vertebral centra. No significant increases in the incidence of major malformations were observed. The NOAELs for maternal and developmental toxicity are 1,000 and 400 mg/kg/day (Maronpot *et al.*, 1983). [Kl. score = 2]

Pregnant CD-1 mice were dosed by oral gavage with 0, 50, 150, 500 or 1,500 mg/kg ethylene glycol during gestational days (GD) 6 to 15. There was no maternal toxicity. At 1,500 mg/kg, there were reduced fetal body weights, fused ribs and arches, poor ossification in thoracic and lumbar centra, and increased occurrence of an extra 14^{th} rib. At 500 mg/kg, there was slight reductions in fetal body weight and increased incidences of extra ribs. The NOAELs for maternal and developmental toxicity were 1,500 and 150 mg/kg/day, respectively (Neeper-Bradley et al., 1995). [Kl. score = 2]

Pregnant CD-1 mice were dosed by oral gavage with 0, 750, 1,500 or 3,000 mg/kg ethylene glycol during GD 6 to 15. There was a significant decrease in maternal gain, gravid uterine weights, and liver weights in the 1,500 mg/kg group. A decreased number of implantation sites per litter was observed in the 1,500 mg/kg group. Significant decrease in liver litter size was observed in the 3,000 mg/kg group and decreased fetal body weights were seen at $\geq$750 mg/kg. Litters with a significant increase in malformed fetuses were observed in the $\geq$750 mg/kg groups. There was a significant dose-related increase in postimplantation loss per litter, though there were no significant pairwise comparisons. The NOAEL for maternal toxicity is 750 mg/kg-day. The LOAEL for developmental toxicity is 750 mg/kg-day; the NOAEL was not established (Price *et al.*, 1985). [Kl. score = 2]

In a short-term reproductive and developmental toxicity screen test, male and female Swiss Crl:CD-1 mice were allowed to mate over a three-day period. The males were dosed by oral gavage from study day 3 to study day 20. The Group A females were exposed throughout the 21-day test period; the Group B females were exposed during GD 8-14. The doses were 0, 250, 700 or 2,500 mg/kg ethylene glycol. The Group A females were sacrificed after 19 days of treatment, and the Group B females were allowed to litter and rear to postnatal day (PND) 4. There was no maternal or paternal toxicity. The 2,500 mg/kg females in Group A had significantly fewer liver implants and more dead implants. The 2,500 mg/kg in Group B had significantly lower total litter weights on PND 1 and 4. The NOAELs for parental and developmental toxicity are 2,500 and 700 mg/kg/day (Harris *et al.*, 1992). [Kl. score = 2]

In a Chernoff/Kavlock assay, pregnant CD-1 mice were dosed by oral gavage with 0 or 11,090 mg/kg ethylene glycol during GD 7-14. The females were allowed to litter and rear to PND 3. Ten percent of the maternal animals died. The number of surviving pups per litter (40% survived), birth weight and pup weight gain were reduced. The LOAELs for maternal and developmental toxicity are 11,090 mg/kg; NOAELs were not established (Schuler *et al.*, 1984; Hardin *et al.*, 1987). [Kl. score = 2]

Pregnant female New Zealand White rabbits were dosed by oral gavage with 0, 100, 500, 1,000, or 2,000 mg/kg ethylene glycol on GD 6 to 19. At 2,000 mg/kg, eight of the 17 does (42.1%) died. Maternal body weights and body weight gain were similar across all groups. There was no developmental toxicity. The NOAEL for maternal toxicity is 1,000 mg/kg-day. The NOAEL for developmental toxicity is 2,000 mg/kg-day, the highest dose tested (ECHA). [Kl. score = 2]

Pregnant female CD rats were dosed by oral gavage with 0, 250, 1,250, or 2,250 mg/kg ethylene glycol on GD 6 to 20. At 2,250 mg/kg, maternal body weight, body weight gain, kidney weight, and postpartum uterine weight were significantly reduced. At 1,250 mg/kg, the gestational period was lengthened and maternal kidney histopathological effects were noted. Developmental toxicity was noted in the 2,250 mg/kg group and included reduced pup weight, reduced viability, and increased malformations (primarily hydrocephaly and abnormalities of the axial skeleton). No developmental toxicity was seen in the 1,250 mg/kg group. The NOAEL for maternal and developmental toxicity is 250 mg/kg-day (ECHA). [Kl. score = 2]

Inhalation

Pregnant female CD rats were exposed by inhalation (whole-body) to 0, 150, 1,000, or 2,500 mg/m^3 ethylene glycol aerosol 6 hours/day on gestational days 6 to 15. There was no treatment-related mortality; a dose-related increased in clinical signs (red fur discoloration on the head and neck) was noted, which was considered to be a non-specific indication of stress. Body weights and body weight gain were unaffected by treatment. There was some evidence of treatment-related reductions in ossification of the fetal skeleton at 1,000 and 2,500 mg/m^3 (considered as fetotoxicity). The NOAECs from inhalation exposure cannot be determined due to confounding oral exposure during whole-body exposure. However, there was no maternal or embryotoxicity at 150 mg/m^3 and no teratogenicity at any aerosol concentration tested (Tyl et al., 1995a). [Kl. score = 2]

Pregnant female CD-1 mice were exposed by inhalation (whole-body) to 0, 150, 1,000, or 2,500 mg/m^3 ethylene glycol aerosol 6 hours/day on gestational days 6 to 15. Reduced maternal body weight was observed in the 2,500 mg/m^3 group on GD 12,15, and 18 and in the 1,000 mg/m^3 group on GD 18. Reduced maternal weight gain was also seen during GD 6-12, 6-15, and GD 6-18 for the $\geq$1000 mg/m^3 groups, and for GD 5-18 for the 2,500 mg/m^3 group. Terminal body weights were reduced in the $\geq$1,000 mg/m^3 groups. Gravid uterine weight was also reduced in the $\geq$1,000 mg/m^3 groups, so that body weight corrected for gravid uterine weight was unaffected. The number of viable implantations per litter was reduced at 2,500 mg/m^3. The number of non-viable implantations per litter was elevated at $\geq$1,000 mg/m^3 because of a significant increase in late resorptions at 1,000 mg/m^3, and a significant increase in late resorptions and in dead fetuses at 2,500 mg/m^3. The number of early resorptions at 2,500 mg/m^3 was also elevated but not statistically. Fetal body weights per litter (male, female, and total) were reduced at $\geq$1,000 mg/m^3. There was a significant increase in the incidence of a number of external, visceral, and skeletal malformation, as well as skeletal variations, at $\geq$1,000 mg/m^3. There was no observable maternal or developmental toxicity at 150 mg/m^3. However, a NOAEC cannot be determined because of the amount of ethylene glycol that may have been ingested from the presence of ethylene glycol on the fur (Tyl et al., 1995a). [Kl. score = 2]

Pregnant female CD-1 mice were exposed by inhalation (nose-only) to 0, 500, 1,000, or 2,500 mg/m^3. The study also included a group exposed to 2,100 mg/m^3 (not discussed

here). Reduced maternal body weight gain were seen in the 2,500 mg/m^3 for GD 9-12, 12-15, 6-15, and 0-18. Absolute kidney weights were increased in the ≥1,000 mg/m^3 groups. Fetal body weights per litter were significantly reduced for the 2,500 mg/m^3. In the 2,500 mg/m^3, there was a significant increase in one skeletal malformation (fusion of the ribs) and an increased incidence of skeletal variations. No other teratogenic effects were observed. The NOECs for maternal and developmental toxicity are 500 and 1,000 mg/m^3, respectively (Tyl et al., 1995c). [Kl. score = 2]

Dermal

Pregnant CD-1 mice were administered by dermal applications of 0, 400, 1,677 or 3,549 mg/kg ethylene glycol 6 hours/day on GD 6-15. There was minimal, if any, treatment-related maternal toxicity. Copora lutea, total implants, percentage of live fetuses per litter, fetal body weights, and incidence of external or visceral malformations were unaffected by treatment. There was, however, a significant increase in two skeletal variations in the 3,549 mg/kg group. The NOAELs for maternal and developmental toxicity were considered to be 3,549 mg/kg-day (Tyl *et al.*, 1995b). [Kl. score = 2]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for ethylene glycol follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

The NOAEL from a 24-month rat dietary study was reported to be 200 mg/kg-day based on kidney lesions in male F344 rats at 1,000 mg/kg-day (Depass et al., 1986b). A subsequent 12-month rat dietary study using male Wistar rats reported a NOAEL of 150 mg/kg-day also based on kidney toxicity at 300 mg/kg-day and higher (Corley et al., 2008). The Wistar rat strain was shown to be more sensitive (approximately three-fold) to the kidney toxicity of ethylene glycol than F344 rats (Cruzan et al., 2004). The NOAEL of 150 mg/kg-day will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Snellings et al. (2013) derived an oral reference dose for ethylene glycol using benchmark dose modeling, with toxicokinetic (PBPK modeling) and toxicodynamic data. The human equivalent dose ($[BMDL_{05}]_{HED}$) was calculated to be 150 mg/kg-day.

Oral RfD = $[BMDL_{05}]_{HED}$ / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 1
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 150/(1 x 10 x 1 x 1 x 1) = 150/10 = 15 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (15 x 70 x 0.1)/2 = 53 mg/L

B. Cancer

Ethylene glycol was not carcinogenic to rats and mice in two-year dietary studies. Thus, a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Ethylene glycol does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Ethylene glycol is of low toxicity concern to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies conducted on ethylene glycol.

Table 3: Acute Aquatic Toxicity Studies on Ethylene Glycol

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Pimephales promelas	96-h LC_{50}	>72,860	1	Pillard (1995)
Oncorhynchus mykiss	96-h LC_{50}	22,810 24,591	2	OECD (2004a,b)
Daphnia magna	48-h EC_{50}	>100	1	ECHA
Daphnia magna	48-h EC_{50}	46,300	2	Gersich et al. (1986)
Ceriodaphnia dubia-affinis	48-h EC_{50}	25,800 (20^oC) 10,000 (24^oC)	2	Cowgill et al. (1985)
Daphnia magna	48-h EC_{50}	46,300 (20^oC) 51,000 (24^oC)	2	Cowgill et al. (1985)
Selenastrum capricornutum	96-h IC_{50} NOEC	10,940 10,000	2	Pillard and DuFrescne (1999)

Chronic Studies

Table 4 lists the results of chronic aquatic toxicity studies conducted on ethylene glycol.

Table 4: Chronic Aquatic Toxicity Studies on Ethylene Glycol

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Pimephales promelas	7-day NOEC	15,380	2	Pillard (1985)
Ceriodaphnia dubia	7-day NOEC (reproduction)	8,590	2	Pillard (1985)

C. Terrestrial Toxicity

No guideline studies have been conducted on ethylene glycol.

D. Calculation of PNEC

The PNEC calculations for ethylene glycol follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute E(L)C_{50} values are available for fish (22,810 mg/L), *Daphnia* (>100 mg/L), and algae (10,940 mg/L). NOEC values from long-term studies are available for fish (15,380 mg/L), invertebrates (8,590 mg/L), and algae (10,000 mg/L). On the basis that the data consists of short-term and long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported E(L)C_{50} value of 100 mg/L for fish. The E(L)C_{50} value is used because the value for fish is lower than the NOEC values for all three trophic levels. The $PNEC_{aquatic}$ is 10 mg/L.

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 6.4 mg/kg sediment wet weight.

The calculations are as follows:

$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$
$= (0.82/1280) \times 1000 \times 10$
$= 6.4$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$K_{sed\text{-}water}$ = 0.8 + [(0.2 x Kp_{sed})/1000 x BD_{solid}]
= 0.8 + [(0.2 x 0.04/1000 x 2400]
= 0.82

Where:
Kp_{sed} = solid-water partition coefficient (L/kg).
BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

Kp_{sed} = K_{oc} x f_{oc}
= 1 x 0.04
= 0.04

Where:
K_{oc} = organic carbon normalized distribution coefficient (L/kg). The K_{oc} for ethylene glycol calculated from EPISUITE™ using the MCI is 1 L/kg.
F_{oc} = fraction of organic carbon in sediment = 0.04 [default].

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is 0.13 mg/kg soil dry weight.

The calculations are as follows:

$PNEC_{soil}$ = (Kp_{soil}/BD_{soil}) x 1000 x $PNEC_{water}$
= (0.02/1500) x 1000 x 10
= 0.13

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

Kp_{soil} = K_{oc} x f_{oc}
= 1 x 0.02
= 0.02

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for ethylene glycol calculated from EPISUITE™ using the MCI is 1 L/kg.
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Ethylene glycol is readily biodegradable and thus does not meet the screening criteria for persistence.

The measured BCF in fish is 10. Thus, ethylene glycol does not meet the criteria for bioaccumulation.

The NOECs from the chronic aquatic toxicity studies on ethylene glycol are >0.1 mg/L. The acute E(L)C_{50} values from the acute aquatic toxicity studies on ethylene glycol are >1 mg/L. Thus, ethylene glycol does not meet the criteria for toxicity.

The overall conclusion is that ethylene glycol is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

STOT RE Category 2 (target organ: kidney)

B. Labelling

Warning

C. Pictogram



X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
In case of contact, immediately flush eyes with plenty of water for at least 15 minutes.

Skin Contact
Wash thoroughly with soap and water.

Inhalation
If inhaled, remove from area to fresh air. Get medical attention.

Ingestion
Rinse mouth with water and then drink a glass of water. Get medical attention. Never give anything by mouth to an unconscious person.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
Keep product and empty container away from heat and sources of ignition. May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: carbon monoxide, carbon dioxide.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Use appropriate protective equipment. Handle in accordance with good industrial hygiene and safety practice.

Environmental Precautions
Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled
For large amounts: dike spillage and pump off product. For residues: pick up with suitable absorbent material. Dispose of contaminated material as prescribed.

D. STORAGE AND HANDLING

General Handling
Keep product and empty container away from heat and sources of ignition. Ensure adequate ventilation, especially in confined areas.

Storage
Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards

The workplace exposure standards for ethylene glycol in Australia is as follows: 10 mg/m^3 as an 8-hour TWA for ethylene glycol (particulate); 20 ppm (52 mg/m^3) as an 8-hour TWA for ethylene glycol (vapour). There is also a skin notation indicating that absorption through the skin may be significant source of exposure.

Engineering Controls
Good general ventilation should be used.

Personal Protection Equipment

Respiratory Protection:
Respiratory protection is not required.

Hand Protection:
Chemical resistant protective gloves.

Skin *Protection*:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Safety glasses with side-shields.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Wearing of closed work clothing is recommended. Ensure that eyewash stations and safety showers are close to the workstation location.

F. TRANSPORT INFORMATION

Ethylene glycol is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

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FATTY ACIDS, TALL OIL, ETHOXYLATED

This dossier on fatty acids, tall oil, ethoxylated does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of fatty acids, tall oil, ethoxylated in its use in drilling muds and hydraulic fracturing fluids. The information presented in this dossier was obtained from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name: Fatty acids, tall oil, ethoxylated

CAS RN: 61791-00-2

Molecular formula: UVCB

Molecular weight: UVCB

SMILES: UVCB

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Fatty Acids, Tall Oil, Ethoxylated (1 – 2.5 Moles Ethoxylated)

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Liquid	1	ECHA
Melting point	-85 to -5°C	1	ECHA
Boiling point	ca. 172°C	1	ECHA
Density	0.958 g/cm^3 @ 20°C	1	ECHA
Vapor pressure	Could not be determined experimentally.	1	ECHA
Partition coefficient (log K_{ow})	Could not be determined experimentally. 5.94 (QSAR)	1 2	ECHA
Water solubility	Could not be determined experimentally.	1	ECHA
Flash point	138°C	1	ECHA

Auto flammability	377°C	1	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Fatty acids, tall oil, ethoxylated is readily biodegradable; will adsorb to soil and sediment; but is not expected to bioaccumulate.

B. Biodegradation

Fatty acids, tall oil, ethoxylated is readily biodegradable. In an OECD 301 B test, degradation was 90 – 100% after 28 days (ECHA) [Kl. score = 1].

C. Environmental Distribution

Adsorption/desorption

Experimental data are available for fatty acids, tall oil, ethoxylated. The test material had different components which differed considerably in adsorption potential. The log K_{oc} values were: <1.8, 2.02, 2.9, 4.39, 5.24, and >5.63. The main constituents peak 4 (log K_{oc} = 4.39) and peak after determination of dead time (DDT) were 49.4% and 43.6% of the test substance.

The log K_{oc} values used to calculate the $PNEC_{soil}$ values are 4.39 and >5.63 (K_{oc} values of 24,547 to 426,580 L/kg, respectively).

D. Bioaccumulation

There are no bioaccumulation studies on fatty acids, tall oil, ethoxylated. Fatty acid, tall oil, ethoxylated contains constituents with log K_{ow} values in the range of 5 to >10 based on QSAR modeling using KOWWIN v1.68 (ECHA), suggesting a potential for bioaccumulation. Bioaccumulation is not expected because the constituents of fatty acids, tall oil, ethoxylated are rapidly biodegraded, metabolized enzymatically, and are sterically hindered from crossing biological membrane (at least for the diester constituents). QSAR modeling using BCFBAF (v. 3.01, Arnot-Gobas, including biotransformation, upper trophic) estimated low BCF values of <100 L/kg for different constituents and including mono- and diester EO1 to EO5 (ECHA).

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

The acute toxicity of fatty acids, tall oil, ethoxylated is low by the oral and inhalation routes. It is not an irritant to the skin and eyes; but it is a skin sensitizer. In a combined repeated dose toxicity study with a reproductive/developmental screening toxicity (OECD 422) test, there was no evidence of systemic, reproductive or developmental toxicity in rats at doses up to 1,000 mg/kg-day of fatty acids, tall oil, ethoxylated. In vitro genotoxicity studies on this substance were negative.

B. Acute Toxicity

The oral LD_{50} in rats is >10,000 mg/kg (ECHA) [Kl. score = 2].

The inhalation 8-hour LC_{50} in rats was greater than the saturated vapor concentration at 20°C (approximately 0.28 mg/L) (ECHA) [Kl. score = 2].

There are no acute dermal toxicity studies on fatty acids, tall oil, ethoxylated.

C. Irritation

Fatty acids, tall oil, ethoxylated was not considered an irritant in an in vitro reconstructed human epidermis test (ECHA) [Kl. score = 1].

Fatty acids, tall oil, ethoxylated was not considered an irritant in an in vitro reconstructed human cornea-like epithelium test (ECHA) [Kl. score = 1].

D. Sensitization

Fatty acids, tall oil, ethoxylated was not considered to be a skin sensitizer in a mouse local lymph node assay (ECHA) [Kl. score = 1].

In a guinea pig Buehler test, fatty acids, tall oil, induced a skin sensitizing response (ECHA) [Kl. score = 1].

E. Repeated Dose Toxicity

Oral

Fatty acids, tall oil, ethoxylated was tested in a combined repeated dose toxicity study with a reproductive/developmental screening toxicity (OECD 422) test. Male and female Wistar rats were dosed daily by oral gavage with 0, 100, 300, or 1,000 mg/kg fatty acids, tall oil, ethoxylated for at least 28 days, including 14 days of pre-mating. There was no indication of toxicity at any dose level. The NOAEL for systemic toxicity is 1,000 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 1].

Inhalation

No studies are available.

Dermal

No studies are available.

F. Genotoxicity

In Vitro Studies

The in vitro studies on fatty acids, tall oil, ethoxylated are presented below in Table 2.

Table 2: *In vitro* Genotoxicity Studies on Fatty Acids, Tall Oil, Ethoxylated

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* and *E. coli* strains)	-	-	1	ECHA
Mammalian cell gene mutation (Chinese hamster fibroblast cells)	-	-	1	ECHA
Chromosomal aberration (human lymphocytes)	-	-	1	ECHA

*+, positive; -, negative

In Vivo Studies

No studies are available.

G. Carcinogenicity

No studies are available.

H. Reproductive/Developmental Toxicity

Fatty acids, tall oil, ethoxylated was tested in a combined repeated dose toxicity study with a reproductive/developmental screening toxicity (OECD 422) test. Male and female Wistar rats were dosed daily by oral gavage with 0, 100, 300, or 1,000 mg/kg fatty acids, tall oil, ethoxylated for at least 28 days, including 14 days of pre-mating. There was no indication of parental toxicity, reproductive, or developmental toxicity at any dose level. The NOAEL for reproductive and developmental toxicity is 1,000 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 1].

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for fatty acids, tall oil, ethoxylated follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

The NOAEL for systemic, reproductive, and developmental toxicity from an OECD 422 study on fatty acids, tall oil, ethoxylated is 1,000 mg/kg-day, the highest dose tested (ECHA). The NOAEL of 1,000 mg/kg-day will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 10
UF_D (database uncertainty) = 1

Oral RfD = 1,000/(10 x 10 x 1 x 10 x 1) = 1,000/1,000 = 1.0 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (1 x 70 x 0.1)/2 = 3.5 mg/L

B. Cancer

There are no carcinogenicity studies on fatty acids, tall oil, ethoxylated. Thus, a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Fatty acids, tall oil, ethoxylated does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Fatty acids, tall oil, ethoxylated has a moderate concern for acute toxicity to aquatic life.

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies conducted on fatty acids, tall oil, ethoxylated.

Table 3: Acute Aquatic Toxicity Studies on Fatty Acids, Tall Oil, Ethoxylated

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Brachydanio rerio	96-hr LL_{50}	>100 [WAF]	1	ECHA
Daphnia magna	48-hr EL_{50}	12.41 [WAF]	1	ECHA
Pseudokirchneriella subcapitata	72-hr EL_{50} 72-hr EL_{10}	39.7 [WAF] 7.08 [WAF]	1	ECHA

Chronic Studies

No studies are available.

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for fatty acids, tall oil, ethoxylated follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)L_{50}$ values are available for fish (>100 mg/L WAF), invertebrates (12.41 mg/L WAF), and algae (39.7 mg/L). On the basis that the data consists of short-term studies for three trophic levels, an assessment factor of 100 has been applied to the lowest reported $E(L)L_{50}$ value of 12.41 mg/L [WAF] for *Daphnia*. The $PNEC_{water}$ is 0.12 mg/L.

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ values range from 39 to >683 mg/kg soil dry weight.

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
$= (491/1500) \times 1000 \times 0.12$
$= 39$

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
$= (8532/1500) \times 1000 \times 0.12$
$= 683$

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
$= 24{,}547 \times 0.02$
$= 491$

$Kp_{soil} = K_{oc} \times f_{oc}$
$= 426{,}580 \times 0.02$
$= 8{,}532$

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for fatty acids, tall oil, ethoxylated were experimentally determined to range from 24,547 to >426,580 (see Section IIIC).
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Fatty acids, tall oil, ethoxylated is readily biodegradable; thus, it does not meet the screening criteria for persistence.

Based on predicted BCF values of <100 L/kg for constituents, fatty acids, tall oil, ethoxylated does not meet the criteria for bioaccumulation.

There are no chronic aquatic toxicity data on fatty acids, tall oil, ethoxylated. The acute $E(L)L_{50}$ values are >1 mg/L. Thus, fatty acids, tall oil, ethoxylated does not meet the screening criteria for toxicity.

The overall conclusion is that fatty acids, tall oil, ethoxylated is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Skin Sensitizer Category 1
Aquatic Acute Toxicity Category 3

B. Labelling

Warning

C. Pictogram



X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
Rinse immediately with plenty of running water. If easy to do, remove contact lenses. Get medical attention if symptoms occur.

Skin Contact
Wash with soap and water. Get medical attention if symptoms persist.

Inhalation
Treat symptomatically. Move to fresh air. Get medical attention if symptoms occur.

Ingestion
Rinse mouth with water and then drink plenty of water. Never give anything by mouth to an unconscious person. Seek medical attention if symptoms occur.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, dry chemical, foam. Do not use water jet.

Specific Exposure Hazards
May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: carbon monoxide, carbon oxides.

Special Protective Equipment for Firefighters

Self-contained breathing apparatus and full protective clothing must be worn in case of fire.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Wear appropriate personal protective equipment. Do not breath mist or aerosol.

Environmental Precautions
Prevent from entering sewers, waterways, or low area

Steps to be Taken if Material is Released or Spilled
Absorb spill with inert absorbent material, then place in a container for chemical waste.

D. STORAGE AND HANDLING

General Handling
Provide adequate ventilation. Wear appropriate personal protective equipment. Observe good hygiene practices.

Other Handling Precautions
Wash hands thoroughly after handling. Avoid breathing mists or aerosols.

Storage
Keep container closed.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards

Workplace Australia has not established an occupational exposure standard for fatty acids, tall oil, ethoxylated.

Engineering Controls
Good general ventilation should be used.

Personal Protection Equipment

Respiratory Protection:
Wear respiratory protection if ventilation is inadequate.

Hand Protection:
Chemical resistant protective gloves.

Skin Protection:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*

Chemical safety goggles.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible.

F. TRANSPORT INFORMATION

Fatty acids, tall oil, ethoxylated is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

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European Chemicals Agency [ECHA] (2008). Guidance on Information Requirements and Chemical Safety Assessment, Chapter R11: PBT Assessment, European Chemicals Agency, Helsinki, Finland.

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GLUTARALDEHYDE

This dossier on glutaraldehyde does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of glutaraldehyde in its use in drilling muds and hydraulic fracturing fluids. The majority of information presented in this dossier was obtained from NICNAS (1994) and the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch et al., 1997).

I. SUBSTANCE IDENTIFICATION

Chemical Name (IUPAC): Glutaraldehyde

CAS RN: 111-30-8

Molecular formula: $C_7H_8O_2$

Molecular weight: 100.12

Synonyms: Pentanedial; glutaral; glutaric dialdehyde; 1,3-diformylpropane; 1,5-pentanedial; glutaric aldehyde; glutaric acid dialdehyde; dioxopentane; glutardialdehyde; 1,5-pentanedione; Algicide®C

SMILES: C(CC=O)CC=O

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Physico-Chemical Properties of Glutaraldehyde

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa*	Sweetish smelling, clear water liquid	1	ECHA
Melting Point*	-33°C	1	ECHA
Boiling Point*	101.5°C @ 987.1 hPa	1	ECHA
Density*	1.13 kg/m^3	1	ECHA
Vapour Pressure*	30 hPa @ 26.3°C	1	ECHA
Partition Coefficient (log K_{ow})*	-0.36	1	ECHA
Water Solubility*	miscible	2	ECHA
Flash Point*	Not measurable	1	ECHA
Auto flammability*	395°C @ ~1,000hPa	1	ECHA
Viscosity*	12.75 mm^2/s (static) at 25°C	1	ECHA
Henry's Law Constant	0.011 Pa m^3/mol at 25°C [QSAR]	2	ECHA

*ca. 50% glutaraldehyde solution (in water)
1 ppm = 4.095 mg/m^3
1 mg/m^3 = 0.244 ppm

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Glutaraldehyde is considered readily biodegradable. It is also expected to have a low potential for bioaccumulation. The K_{oc} values for glutaraldehyde indicate that it will have low potential for adsorption to suspended solids and sediment in water and moderate adsorption to soil. Glutaraldehyde

is not expected to undergo hydrolysis in the environment. Overall, glutaraldehyde shows limited persistence in the environment.

B. Abiotic Degradation

Hydrolysis

In an OECD TG 111 test (hydrolysis as a function of pH), glutaraldehyde was hydrolytically stable at pH 4 and pH 7, but decomposed at pH 9 (ECHA). [Kl. score = 2]

Phototransformation in Water

Photolytic degradation of glutaraldehyde occurred in water under sensitised conditions: the half-life was 18 days when equivalent to 36 days of natural sunlight (12 hours/day; sensitised acetone system); and 49 days when equivalent to 34 days of natural sunlight (12 hours/day; sensitised acetonitrile system). There was no photodegradation of glutaraldehyde under darkness or non-sensitised conditions (ECHA). [Kl. score = 2]

C. Biodegradation

Glutaraldehyde was considered readily biodegradable in an OECD 301A (DOC die away test). Degradation was 90-100% in 28 days (ECHA). [Kl. score = 1]

In a simulation test involving aerobic sewage treatment [activated sludge units] (OECD TG 303A), glutaraldehyde degraded 97% after 73 days based on DOC removal (ECHA). [Kl. score = 1]

In an aerobic aquatic metabolism test, [^{14}C]-glutaraldehyde had a half-life of 10.6 hours in the water/sediment system. A minor transformation product was glutaric acid: the maximum yield was 18.9 to 21.5% at 12 hours, which then declined rapidly to 10.1 to 11% by 24 hours; and was not observed at the end of the study period in the aqueous phase (ECHA). [Kl. score = 1]

In an anaerobic aquatic metabolism test, [^{14}C]-glutaraldehyde was rapidly metabolised with the first-order half-life being 7.7 hours. Glutaraldehyde was transformed to 5-hydroxypentanal (ca 37% of applied radioactivity) on day 1; after that, it declined to <10%; it was not detected at all after 30 days. The second stable transformation product was 1,5-pentanediol (35% of radioactivity on Day 1), which accounted for 70% of the radioactivity at the end of the test. A minor transformation product was a compound formed via Aldol condensation, cyclisation and dehydration. This compound accounted for about 10-20% of total radioactivity from day 1 onwards (ECHA). [Kl. score = 1]

In an aerobic soil metabolism test, the half-life of the degradation of [^{14}C]-glutaraldehyde was calculated to be 1.7 days, indicating rapid degradation in soil by microbial biotransformation. Degradation products were measured but not identified. (ECHA). [Kl. score = 1]

D. Environmental Distribution

Adsorption/desorption

The organic carbon/water partition coefficients (K_{oc}) values were determined for sediment and four types of soil. The values are as follows: 120 for sediment; 210 for sandy loam; 500 for silty clay loam; 340 for silt loam; and 460 for loamy sand (ECHA; Leung et al., 2001). [Kl. score = 1]

Distribution Modelling

No fugacity calculations were performed as glutaraldehyde has limited persistence. Its environmental fate is primarily determined by degradation rather than equilibration between compartments (OECD-SIDS, 1995).

E. Bioaccumulation

Glutaraldehyde is not expected to bioaccumulate. The measured log K_{ow} at pH 5, 7 and 9 are -0.41, -0.36 and -0.80, respectively (ECHA).

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Glutaraldehyde has moderate-to-high acute toxicity by the oral route, low-to-moderate toxicity by the dermal route, and moderate-to-high toxicity by the inhalation route. Acute inhalation exposure may cause respiratory irritation. Glutaraldehyde is corrosive to the skin and eyes; it is also a skin and respiratory sensitizer. Repeated oral exposures via drinking water to rats have resulted in general systemic toxicity, but no target organ effects. In contrast, the upper respiratory tract, particularly the nasal cavity, is the target organ in rodents from repeated inhalation exposure. Glutaraldehyde may exhibit weak genotoxic effects in some *in vitro* tests, whereas the *in vivo* studies consistently show no genotoxic activity. Glutaraldehyde is not a reproductive toxicant; developmental toxicity can occur at maternally toxic doses, but there is no teratogenicity.

B. Toxicokinetics

Dermal Absorption

[1,5-^{14}C]-glutaraldehyde was applied to the skin of male and female F344 rats. Doses were 0.75% and 7.5%: this corresponds to approximately 6.5 and 63 mg/kg for males; and approximately 8.7 and 102 mg/kg for females. The dermal absorption data are presented below in Table 2. The results indicate that glutaraldehyde has a low rate of absorption by the dermal route (ECHA).

Table 2: Dermal Absorption Data in Rats on Glutaraldehyde (ECHA)

Sex	Absorption rate constant/hr		% of applied dose	
	Low Dose	High Dose	Low Dose	High Dose
Males	1.5	0.7	0.7	1.3
Females	1.8	0.9	0.3	2.1

An *in vitro* percutaneous absorption study was conducted on glutaraldehyde using excised skin from rats, rabbits, mice, guinea pigs, and humans. The skin samples were placed in a flow-through skin penetration chamber, and [^{14}C]-glutaraldehyde was added at doses of 0.75% and 7.5%. The results are presented below in Table 3. Glutaraldehyde did not penetrate any of the skin samples to a significant degree, suggesting that only minimal amounts of glutaraldehyde may be available for systemic uptake and distribution after skin exposure. The results also show that skin absorption was greater for the animal species used in toxicity tests than human skin (ECHA; Frantz et al., 1993).

Table 3: *In vitro* Percutaneous Absorption (mg/cm^2) of Glutaraldehyde (ECHA; Frantz et al., 1993)

Species	Low Dose	High Dose
Animal*	0.006	0.08

Human	0.002	0.02

*Percutaneous absorption in rats, mice, guinea pigs, mice and rabbits were similar to each and were reported as a single value.

C. Acute Toxicity

The oral LD_{50} values are: 123 to 820 mg/kg in rats; 100 to 352 mg/kg in mice; and 50 mg/kg in guinea pigs (NICNAS, 1994).

The dermal LD_{50} values are: 640 to 2,000 mg/kg in rabbits; >2,500 mg/kg in rats; and >4,500 mg/kg in mice (NICNAS, 1994).

The 4-hour inhalation LC_{50} values for glutaraldehyde are listed in the table below:

Table 4: Acute inhalation LC_{50} values for Glutaraldehyde

Test Material	LC_{50} (males) [mg/L]	LC_{50} (females) [mg/L]	LC_{50} (both sexes) [mg/L]	Reference
50% aq. aerosol	0.52	0.45	-	OECD, 1995
25% aq. aerosol	-	-	0.8	OECD, 1995
50% aq. aerosol	0.35	0.28	-	OECD, 1995
5% soln. vapour	0.096	0.164	-	OECD, 1995

During the exposure period, the animals showed signs of eye and respiratory irritation, as indicated by laboured and audible breathing, and wetness and encrustation around the nose and eyes.

D. Irritation

Glutaraldehyde is corrosive to the skin and eyes of rabbits (NICNAS, 1994; ECHA). Signs of irritation occurred at a concentration of 2% for skin and 0.2% for eyes (NICNAS, 1994). In the acute inhalation studies, rats exposed to aerosols or vapours of glutaraldehyde showed signs of eye and respiratory irritation (OECD, 1995).

E. Sensitisation

Glutaraldehyde is a skin sensitiser to guinea pigs and humans. Information on the individual studies can be found in NICNAS (1994) and in the ECHA REACH database (ECHA).

Asthmatic symptoms, such as wheezing, coughing, chest tightness, breathing difficulties and non-specific hyper-responsiveness have been reported to occur in humans occupationally exposed to glutaraldehyde (NICNAS, 1994). It is unclear whether the asthma is an allergic hypersensitivity response or a result of the aggravation of pre-existing asthma due to the irritating properties of glutaraldehyde. Nevertheless, glutaraldehyde should be considered a respiratory sensitiser, although one of low potency.

F. Repeated Dose Toxicity

Oral

Male and female Wistar rats were given in their drinking water 0, 100, 500, or 2,000 ppm glutaraldehyde for 90 days. The approximate daily intakes were 0, 3, 15, or 53 mg/kg-day for males, and 0, 4, 19, or 72 mg/kg-day for females. There were no signs of neurotoxicity at any dose level. There was slight impairment of food consumption in the 2,000 ppm animals, as well as slight

impairment of body weight and body weight gain. Impaired water consumption was seen in the 100 and 500 ppm females. The NOAEL for males is 500 ppm (15 mg/kg-day). The NOAEL for females is 100 ppm (4 mg/kg-day), since the impaired water consumption in the 100 ppm females was considered a palatability problem and not an adverse effect (ECHA). [Kl. score = 1]

Male and female F344 rats were given in their drinking water 0, 50, 250, or 1,000 ppm glutaraldehyde for 13 weeks. Additional groups of animals were given in their drinking water 0 or 1000 ppm glutaraldehyde for 13 weeks followed by a 4-week recovery period. The approximate daily intakes were 0, 5, 25, or 100 mg/kg-day for males; and 0, 7, 35, or 120 mg/kg-day for females. Water consumption was reduced in a dose-dependent manner in the ≥250 ppm males and 1,000 ppm females, which was attributed to an aversion to the taste and/or odour of glutaraldehyde in the water. There was also a reduction in food consumption in the 1,000 ppm animals with a parallel reduction in body weights. It is unclear whether the reduction in food consumption was related to the decreased water consumption. Urine volume was decreased with an increase in specific gravity, along with a slight increase in protein and ketone concentration, in the ≥250 ppm animals, which was probably related to the decreased water consumption. There were no treatment-related changes in the haematology parameters measured. Blood urea nitrogen was increased in a dose-related manner in the ≥250 ppm females at the 6-week time point, but at the 13-week or 17-week time points. Relative kidney weights were increased in a dose-related manner in the ≥250 ppm males and females, and increased absolute kidney weights in the females. Histopathological examination showed no treatment-related effects. The NOAEL is 50 ppm (5 and 7 mg/kg-day for males and females, respectively) based on dose-related increase in kidney weights at ≥250 ppm (ECHA). [Kl. score = 2]

Male and female Wistar rats were given in their drinking water 0, 100, 500, or 2000 ppm glutaraldehyde for 12 months. The approximate daily intakes were: 0, 6.4, 30.5, or 116.6 mg/kg-day for males; and 0. 9.6, 46, or 153 mg/kg-day for females. There was no treatment-related mortality. At 2,000 ppm, treatment-related effects included respiratory sounds (both sexes), decrease in body weight (males), decrease in body weight gain (both sexes), decrease in food consumption (both sexes), reduced water consumption (both sexes), lesions within the glandular stomach (both sexes showed erosion/ulceration of the glandular stomach), increased incidence of clear cell foci in the liver (males), and a single case of slight diffuse squamous metaplasia in the epithelium of the larynx (male). At 500 ppm, water consumption was reduced in males which was considered to be a palatability (bad taste) problem and not an adverse effect. No effects were seen in the 100 ppm animals. The NOAEL for this study is 500 ppm, which corresponds to 30.5 and 46 mg/kg-day for males and females, respectively (ECHA). [Kl. score = 1]

Male and female Fischer 344 rats were given in their drinking water 0, 50, 250, or 1000 ppm glutaraldehyde for 104 weeks. The mean glutaraldehyde consumption was 0, 4, 17, and 64 mg/kg-day for males and 0, 6, 25 ,and 86 mg/kg-day for females. There were no treatment-related mortalities or clinical symptoms of toxicity. In the 250 and 1,000 ppm groups, there was reduction in body weight and body weight gain; reduction in food and water consumption; increased statistically significant incidence of nucleated erythrocytes and of large monocytes; decreases in alanine aminotransferase (ALT), aspartate aminotransferase (AST), and glutamate dehydrogenase; dose-related decrease in urine volume accompanied by a dose-related increase in osmolality; changes in absolute and relative kidney weight; gastric irritation; increases in bone marrow hyperplasia; and increased incidence of renal tubular pigmentation. The decreased water consumption was considered to be due to the bad taste, smell and/or irritancy of the test substance in the drinking water; thus, it is of no toxicological relevance. As a result of reduced water intake, there are renal physiological adaptation, such as decreased urine, increased osmolality and changes in kidney weight. The haematological and clinical chemistry parameter changes were marginal and were considered to be of not toxicological relevance. The main haematological finding seen at the end of the study and which consisted of the appearance of nucleated erythrocytes and large monocytes in all treated groups (statistically significant for the ≥250 ppm males) was related to the incidence of large granular lymphocytic leukaemia (LGLL) in the spleen. The bone marrow hyperplasia and renal tubular pigmentation are related to the

occurrence/incidence of LGLL, and were considered by the authors of the study as being secondary to a low grade haemolytic anaemia in animals with LGLL. The NOAEL for this study is 50 ppm which corresponds to 4 and 6 mg/kg-day for males and females, respectively (Van Miller *et al.* 2002). [Kl. score = 2]

Inhalation

Male and female F344 rats were exposed by inhalation to 0, 0.0625, 0.125, 0.25, 0.5, or 1.0 ppm (0, 0.26, 0.5, 1, 2, or 4.1 mg/m^3) glutaraldehyde for 6.5 hours/day, 5 days/week for 13 weeks. The study focused on the respiratory tract, using histopathology and epithelial cell labelling index as end points. Histopathological lesions in the nasal passages and turbinates were seen at ≥0.25 ppm. Treatment-related effects were primarily the respiratory mucosa (nasal cavity and tips of the turbinates) and the olfactory epithelium (dorsal meatus). Hyperplasia, squamous metaplasia, olfactory degeneration, squamous exfoliation (accumulation of keratin, cell debris and bacteria in the lumen of the nasal vestibule) and focal erosions were reported for both sexes, and the severity and incidence of the findings increased with increasing concentration of glutaraldehyde. The NOAEL for this study is 0.125 ppm (Gross et al., 1994). [Kl. score = 1]

Male and female B6C3F$_1$ mice were exposed by inhalation to 0, 0.0625, 0.125, 0.25, 0.5, or 1.0 ppm (0, 0.26, 0.5, 1, 2, or 4.1 mg/m^3) glutaraldehyde for 6.5 hours/day, 5 days/week for 13 weeks. The study focused on the respiratory tract, using histopathology and epithelial cell labelling index as end points. Histopathologic lesions in the nasal passages and turbinates were seen at all exposure concentrations (≥0.0625 ppm). Treatment-related lesions were primarily the respiratory mucosa (nasal cavity and tips of the turbinates) and the olfactory epithelium (dorsal meatus). Hyperplasia, squamous metaplasia, olfactory degeneration, squamous exfoliation (accumulation of keratin, cell debris and bacteria in the lumen of the nasal vestibule) and focal erosions were reported for both sexes, and the severity and incidence of the findings increased with increasing test concentration. Furthermore, neutrophilic inflammation was seen at ≥0.062 ppm, and squamous metaplasia as well as necrosis were seen in the larynx at 1 ppm). The LOAEL for this study is 0.0625 ppm; a NOAEL was not established (Gross et al., 1994). [Kl. score = 1]

Male and female B6C3F$_1$ mice were exposed by inhalation to 0 or 0.1 ppm (0 or 0.41 mg/m^3) glutaraldehyde for 6 hours/day, 5 days/week for 52 and 78 weeks. Survival was similar between treated and control groups. Hyperplasia of the squamous epithelium lining of the dorsal wall of the nasal passages and the lateral aspect of the atrioturbinate was seen in a greater number of exposed females than in controls. Epidermal erosion and ulceration as well as squamous and inflammatory exfoliation were also seen in the nasal lumens. All of these changes were dependent on the length of glutaraldehyde exposure. The authors concluded that, since the induced lesions occurred in the more anterior part of the nasal passages, that they were likely the result of an irritation mechanism (Zissu et al., 1998). [Kl. score = 2]

Male and female Fischer 344 rats were exposed by inhalation to 0, 0.25, 0.5, or 0.75 ppm (0, 1, 2, or 3.1 mg/m^3) glutaraldehyde for 6 hours/day, 5 days/week for two years. Survival in the mid- and high-dose females was statistically significantly decreased compared to controls. Mean body weights of all exposed males and the mid- and high-dose females were generally less than those of the controls. Non-neoplastic lesions were limited primarily to the most anterior region of the nasal cavity. Effects included hyperplasia and inflammation of the squamous epithelium; hyperplasia, goblet cell hyperplasia, inflammation, and squamous metaplasia of the respiratory epithelium; and hyaline degeneration of the olfactory epithelium. The LOAEL for this study is 0.25 ppm based on hyperplasia and inflammation of the squamous epithelium of the nose in both sexes. A NOAEL was not established (van Birgelen et al., 2000). [Kl. score = 2]

Male and female B6C3F$_1$ mice were exposed by inhalation to 0, 0.0625, 0.125, or 0.25 ppm (0, 0.26, 0.5, or 1 mg/m^3) glutaraldehyde for 6 hours/day, 5 days/week for two years. Survival of the treated

animals was similar to controls. Mean body weights of the high-dose females were generally lower than the controls. Non-neoplastic lesions were limited primarily to the anterior region of the nasal cavity; the effects were qualitatively similar to those seen in the rats (see accompanying summary on the two-year rat study by van Birgelen et al., 2000). Squamous metaplasia of the respiratory epithelium was observed in both sexes of mice while female mice also had inflammation and hyaline degeneration of the respiratory epithelium. The incidence and severity grade (in parentheses) of the hyaline degeneration were: 16/50 (1.4), 35/49 (1.4), 32/50 (1.3), and 30/50 (1.1) for the 0, 0.0625, 0.125, and 0.25 ppm dose groups, respectively. The LOAEL for this study is 0.0625 ppm based on hyaline degeneration of the respiratory epithelium in female mice. A NOAEL was not established (van Birgelen et al., 2000). [Kl. score = 2]

Dermal

Applications of a 50% solution of glutaraldehyde was applied to the skin of male and female SD rats for 13 weeks. The doses were 0, 50, 100, and 150 mg/kg glutaraldehyde. At the application site, there were signs of irritation (scabs, desquamation and very slight or well-defined erythema). There was no treatment-related mortality, clinical signs, body weights, feed consumption, and ophthalmoscopic effects. There were no changes in the haematology and clinical chemistry parameters that were considered to be biologically or toxicologically relevant. Organ weights were similar between treated and control animals. Histopathological examination showed a treatment-related effects in the skin associated with chronic irritation; no other changes were noted that were considered to be treatment-related. The NOAEL for this study is 150 mg/kg, the highest dose tested (ECHA). [Kl. score = 1]

G. Genotoxicity

In Vitro Studies

Glutaraldehyde may exhibit weak genotoxic effects in some *in vitro* tests. The bacterial reverse mutation assays have been the most consistent. Variable results have been reported for the forward gene mutation tests; and for sister chromatid exchange (SCE), chromosomal aberration and Unscheduled DNA Synthesis (UDS) tests (Vergnes and Ballantyne, 2002).

In Vivo Studies

The *in vivo* studies conducted on glutaraldehyde are presented below in Table 5. All of the studies show that glutaraldehyde is not mutagenic or genotoxic.

Table 5: *In Vivo* Genotoxicity Studies on Glutaraldehyde

Test System	Results*	Klimisch Score	Reference
Rat bone marrow (chromosomal aberration)	-	1	ECHA
Rat bone marrow (chromosomal aberration)	-	2	ECHA
Mouse bone marrow (micronucleus)	-	1	ECHA
Rat bone marrow (chromosomal aberration)	-	2	ECHA
Rat germ cell cytogenetic assay (alkaline elution)	-	2	ECHA
Drosophila SLRL Test	-	2	ECHA
Rat liver UDS Assay	-	1	ECHA
Rat germ cell cytogenetic assay (alkaline elution)	-	2	ECHA
Mouse peripheral blood micronucleus study	-	2	Vernes and Ballantyne (2002)

Rat liver UDS Assay	-	2	Mirsalis *et al.* (1989)

a+, positive; -, negative

H. Carcinogenicity

Oral

Male and female Fischer 344 rats were given in their drinking water 0, 50, 250, or 1,000 ppm glutaraldehyde for 104 weeks. The mean glutaraldehyde consumption was 0, 4, 17, and 64 mg/kg-day for males and 0, 6, 25, and 86 mg/kg-day for females. Mortality rates were 25-30% and 19-23% for males and females, respectively, with no dose-related increase. The major cause of death in all dose groups including the controls was LGLL. There was an increased incidence of LGLL in the liver and spleen in all treated females (≥50 ppm). The incidence of LGLL was not significantly increased in the treated males compared to the controls. No other treatment-related increased incidence of tumours was seen (Van Miller et al., 2002). [Kl. score = 2]

Male and female Wistar rats were given in their drinking water 0, 100, 500, or 2,000 ppm glutaraldehyde for two years. The mean daily intake of glutaraldehyde was as follows: 0, 6.1, 31.9, and 120.7 mg/kg-day for males; and 0, 10.5, 48.5, and 176.4 mg/kg-day for females. In the high-dose animals, there was mortality (2 males and 9 females) from asphyxia, and mean terminal body weights were significantly decreased compared to the controls. There were no treatment-related neoplastic effects (ECHA). [Kl. score = 1]

Inhalation

Male and female $B6C3F_1$ mice were exposed by inhalation to 0 or 0.1 ppm (0 or 0.4 mg/m^3) glutaraldehyde for 6 hours/day, 5 days/week for 52 and 78 weeks. No exposure-related neoplastic lesions were observed in either males or females (Zissu et al., 1998). [Kl. score = 2]

Male and female Fischer 344 rats were exposed by inhalation to 0, 0.25, 0.5, or 0.75 ppm (0, 1, 2, or 3.1 mg/m^3) glutaraldehyde for 6 hours/day, 5 days/week for two years. Survival in the mid- and high-dose females was statistically significantly decreased compared to controls. Survival of the treated males was similar to controls. No exposure-related neoplastic lesions were observed in either males or females (van Birgelen et al., 2000). [Kl. score = 2]

Male and female $B6C3F_1$ mice were exposed by inhalation to 0, 0.0625, 0.125, or 0.25 ppm (0, 0.26, 0.5, or 1 mg/m^3) glutaraldehyde for 6 hours/day, 5 days/week for two years. Survival of the treated animals was similar to controls. No exposure-related neoplastic lesions were observed in either males or females (van Birgelen et al., 2000). [Kl. score = 2]

I. Reproductive Toxicity

A two-generation reproductive toxicity study was conducted in Wistar rats given 0, 100, 500 and 2000 ppm glutaraldehyde in their drinking water. The approximately mean daily intake is 0, 12, 58, and 199 mg/kg-day for the parental males and females of the F_0 and F_1 generation during premating. There were no adverse effects on reproductive performance or fertility. Oestrous cycle data, mating behaviour, conception, gestation, parturition, lactation and weaning as well as sperm parameters, sexual organ weights, gross and histopathological findings of these organs were similar between treated and control groups. In the high-dose animals, there was decreased water and/or food consumption; and decreased body weights and/or reduced body weight gains during the premating periods in the F_0 and F_1 parental females during premating, gestation and/or lactation. The high-dose F_1 parental females also had increased the number of erosions/ulcers with microscopic erosion(s) or inflammatory oedema in the mucosa/submucosa of the glandular stomach. There were no adverse effects in the 500 ppm animals except for slight decreases in water consumption due to a palatability

(bad taste) problem. Treatment-related signs of developmental toxicity were seen in the progeny of the high-dose F_0 and F_1 parental generation, and included impairment in body weight and consequently in organ weights in the respective F_1 and F_2 pups. The NOAEL for reproductive toxicity is 2,000 ppm (199 mg/kg-day), the highest dose tested. The NOAEL for parental systemic toxicity is 500 ppm (58 mg/kg-day). The NOAEL for developmental toxicity is 500 ppm or 58 mg/kg-day (ECHA). [Kl. score = 1]

A two-generation reproductive toxicity study was conducted in Crj: CD(SD) rats given 0, 50, 250 and 1,000 ppm glutaraldehyde in their drinking water. Mean daily intake was not calculated. Parental body weights and body weight gains were significantly reduced at 1,000 ppm at some periods, particularly during pre-mating. Food consumption was significantly reduced at 1,000 ppm for the F_0 and F_1 parental animals during pre-mating and gestation, and F_1 females during lactation. Water consumption was reduced throughout the pre-mating period for the F_0 and F_1 250 and 1,000 ppm parental animals. There was no indication of adverse effects on reproductive performance or fertility at any dose level. For the F_1 1,000 ppm offspring, body weights were reduced from lactation days 21-28. The NOAEL for reproductive toxicity is 1,000 ppm, the highest dose tested. The NOAEL for parental systemic toxicity is 50 ppm. The NOAEL for developmental toxicity is 250 ppm (Neeper-Bradley and Ballantyne, 2000). [Kl. score = 2]

J. Developmental Toxicity

Pregnant Wistar rats were given in their drinking water 0, 50, 250, or 750 ppm (0, 5, 26, or 68 mg/kg) glutaraldehyde from GD 6 to 16. Water consumption was reduced in a dose-related manner in the $\geq$250 ppm dams, and was considered not to be a toxic response, but due to the palatability (bad taste) of the drinking test solution. No other maternal effects were seen in the study. There were no significant differences between treated and controls in the sex distribution, placental weights, fetal weights, malformations or variations. The NOAEL for maternal and developmental toxicity in this study is 68 mg/kg-day, respectively (ECHA). [Kl. score = 1]

Pregnant Wistar rats were dosed by oral gavage with 0, 25, 50, or 100 mg/kg glutaraldehyde on GD 6 to 15. Mortality was significantly increased in the high-dose group (5/26); there were 2/21 deaths in the mid-dose group. Clinical signs (piloerection) occurred in all treated groups in a dose-dependent manner. Maternal body weight gain and feed consumption were significantly reduced in the high-dose dams, but not at the lower doses. The necropsy findings showed evidence of stomach irritation in almost all of the animals that died during the study and in 12/21 of the surviving dams in the high-dose group. The number of implantation per litter, resorptions and dead foetuses per litter, live foetuses per litter, and incidence of post-implantation loss per litter was similar across all groups. The mean foetal body weights for male and female foetuses were significantly reduced in the high-dose group; this was attributed to the reduced food consumption of the dams during gestation rather than a direct effect of treatment. There was no evidence of a treatment-related teratogenic effect. The NOAEL for maternal and developmental toxicity is 50 mg/kg-day, respectively (Ema et al., 1992). [Kl. score = 2]

Pregnant Himalayan rabbits were dosed by oral gavage with 0, 5, 15 or 45 mg/kg glutaraldehyde on GD 7 to 19. In the high-dose group, 5/15 died on GD 9-11. Food consumption and body weight gain were also significantly reduced in the high-dose group. Clinical observations in 12/15 high-dose does included soft faces, diarrhoea, and blood in the bedding. The mean gravid uterus weight was significantly reduced in the high-dose group. Post-implantation loss was greatly increased (94.3%) in the high-dose group: no viable foetuses in 9/15 of the high-dose does, only early resorptions; only one female gave 4 alive foetuses on the scheduled date. There were reduced placental and foetal body weights in the only four foetuses. No significant maternal or developmental effects were seen in the mid- and low-dose groups. The NOAEL for maternal and developmental toxicity in this study is 15 mg/kg-day (ECHA). [Kl. Score = 2]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for glutaraldehyde follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

The lowest NOAEL values from key toxicity studies on glutaraldehyde are listed below in Table 6.

Table 6: Lowest NOAEL Values from Key Toxicity Studies on Glutaraldehyde by the Oral Route

Species/Sex	Study Duration	mg/kg-day	Endpoint	Reference
Rats, female	90-days	4	Decreased body weights, food and water consumption	ECHA
Rats, male	13-wk (drinking water)	5	Increased kidney weights	ECHA
Rats, male	12-months (drinking water)	30.5	Clinical signs; decreased body weights and food consumption; increased clear cell foci in liver	ECHA
Rats, male	2-yr (drinking water)	4	Reduced body weight, body-weight gain, and food consumption	Van Miller *et al.* (2002)
Rats	2-generation (drinking water)	58	Systemic toxicity	ECHA
Rats	GD 6-16 (drinking water)	68	Developmental toxicity	ECHA
Rats	GD 6-15 (oral gavage)	50	Developmental toxicity	Ema *et al.* (1992)
Rabbits	GD 7-19 (oral gavage)	15	Developmental toxicity	ECHA

The lowest NOAEL from these studies is 4 mg/kg-day based on reduced body weights, body weight gain, and feed consumption in male rats from the two-year drinking water study (Van Miller et al., 2002). The NOAEL of 4 mg/kg-day will be used for determining the oral Reference Dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1

UF_D (database uncertainty) = 1

Oral RfD = 4/(10 x 10 x 1 x 1 x 1) = 4/100 = 0.04 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD: Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

Where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2 L (ADWG, 2011)

Drinking water guidance value = (0.04 x 70 x 0.1)/2 = 0.14 mg/L

B. Cancer

Increased incidence of large granular cell lymphatic leukaemia (LGLL) was observed in all groups of male and female Fischer 344 rats given glutaraldehyde in their drinking water, including the controls (Van Miller *et al.* 2002). For the males, the incidence of LGLL was not statistically significantly increased. However, for the females, the incidence of LGLL was significantly increased in all treated females (≥50 ppm). Inhalation exposure of Fischer 344 rats to glutaraldehyde did not result in an increased incidence of tumours, including LGLL.

LGLL, also known as mononuclear cell leukaemia, is an extremely common spontaneous neoplastic disease of the ageing F344 rat (Stromberg 1985, Ward *et al.* 1990; Thomas et al. 2007). Consistent features are splenomegaly, anaemia, thrombocytopenia and leukemic infiltration of the spleen, liver lung, and in an advanced stage, of several other organs. The incidence is variable but has been increasing progressively with time and can exceed 70% in controls in some studies. This compares with background incidence of less than 1% in other strains of commonly used laboratory rats (Haseman et al., 1998; Thomas et al., 2007). The incidence in F344 rats is modulated by a variety of factors not clearly related to carcinogenicity. Corn oil gavage, for example, has been shown consistently to reduce the incidence of MCL in male, but not female, controls (reviewed in Thomas et al., 2007).

The neoplastic mononuclear cells appear to be derived from large granular lymphocytes (LULs) (reviewed in Thomas et al., 2007). The tumour cell is of the NK type in most, if not all, cases. LGL leukaemia, although uncommon, does occur in humans. There are two types: T-LGL leukaemia which has a chronic course characterised by neutropenia, recurrent infections, splenomegaly and accompanying rheumatoid arthritis, and the much rarer NK-LGL leukaemia which has an acute course, more pronounced splenomegaly, and thrombocytopenia. The latter type appears to resemble more closely the disease in the F344 rat than the former. The aetiology of human LGL leukaemia is unknown. There is some evidence that viral infection may play a role but no evidence that a chemically-related increased of LGLL in the F344 rat is indicative of the potential to induce LGL leukaemia in humans.

To extrapolate results from an animal model that has a clear predisposition (high spontaneous rates) to a tumour type to humans, of which this is not the case, seems inappropriate if the mechanism(s) for LGLL formation in that strain is not understood. Although that rat strain may be useful for understanding the disease process in humans, it does not seem reasonable to use the results from that

rat strain for risk assessment purposes. There should be confirmation of a putative leukemogenic effect in the F344 rat in another strain before any conclusions are made about the use of this tumour type for human health risk assessment purposes.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Glutaraldehyde does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidising potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Glutaraldehyde has a moderate acute toxicity concern to fish and invertebrates, but is highly toxic to algae. It is of low toxicity concern to terrestrial invertebrates and plants. To birds, glutaraldehyde is moderately toxic on an acute basis and slightly toxic on a subacute dietary basis.

B. Aquatic Toxicity

Acute Studies

Table 7 lists the results of acute aquatic toxicity studies conducted on glutaraldehyde.

Table 7: Acute Aquatic Toxicity Studies on Glutaraldehyde

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Bluegill sunfish	96-hr LC_{50}	13	2	ECHA
Oncorhynchus mykiss	96-hr LC_{50}	10	2	ECHA
Daphnia magna	48-hr LC_{50}	14.87	2	ECHA
Daphnia magna	48-hr LC_{50}	14	2	ECHA
Scenedesmus subspicatus	72-hr EC_{50}	0.375 (biomass) 0.6 (growth rate) 0.025 (NOEC)	1	ECHA
Scenedesmus subspicatus	72-hr EC_{50}	0.92 (growth rate) 0.61(biomass) 0.33 (NOEC)	2	ECHA; Leung et al., 2001
Scenedesmus subspicatus	72-hr EC_{50}	0.61 (growth rate)	2	ECHA

Chronic Studies

The chronic aquatic toxicity studies conducted on glutaraldehyde are listed in Table 8.

Table 8: Chronic Aquatic Toxicity Studies on Glutaraldehyde

Test Species	Endpoint	Results (mg/L)	Kl. score	Reference
Oncorhynchus mykiss	97-day (OECD 210)	LOEC = 5 NOEC = 1.6	1	ECHA
Daphnia magna	21-day	NOEC = 5	1	ECHA

C. Terrestrial Toxicity

Table 9 lists the results of toxicity studies conducted on glutaraldehyde with earthworms, soil microorganisms, and birds.

Table 9: Terrestrial Toxicity Studies on Glutaraldehyde

Test Species (method)	Endpoint	Results	Kl. score	Reference
Earthworm *Eisenia fetida* (OECD 207)	14-d LC_{50}	>500 mg/kg soil dw	1	ECHA
Soil microorganisms* (OECD 216)	28-d EC_{50} 28-d EC_{10}	360 mg/kg soil dw 11.5 mg/kg soil dw	1	ECHA
Soil microorganisms* (OECD 217)	28-d EC_{50} 28-d EC_{10}	>593 mg/kg soil dw 1.5 mg/kg soil dw	1	ECHA
Mallard ducks	Single-dose (oral gavage) LC_{50}	206 mg/kg	2	ECHA
Mallard ducks	5-d (dietary) NOEC	>2,500 ppm	1	ECHA

*organic carbon content of soil = 1.34% dry weight

Glutaraldehyde has also been evaluated in a terrestrial plants test: seedling emergence and seedling growth test (OECD TG 208). The test material contained 48.9% glutaraldehyde. The results are as follows:

Avena sativa (oats): 19-day EC_{50} value is >1,000 mg/kg soil dry weight based on emergence rate, dry weight and shoot length. The NOECs for *Avena sativa* (oats) were $\geq$1,000 mg/kg dry weight on all three parameters tested

Brassica napus (rapeseed): 19-day EC_{50} is >1,000 mg/kg soil dry weight based on emergence rate and shoot length and 994 mg/kg soil dry weight based on dry weight. The NOECs were $\geq$1,000, 500, and 250 mg/kg soil dry weight for emergence rate, dry matter, and shoot length, respectively.

Vicia sativa (vetch): 19-day EC_{50} is >1,000 mg/kg soil dry weight based on emergence rate and shoot length, and 901 mg/kg soil dry weight based on dry weight. The NOECs were $\geq$1,000, 125, and 125 mg/kg soil dry weight for emergence rate, dry matter, and shoot length, respectively (ECHA). [Kl. score = 1]

D. Calculation of PNEC

The PNEC calculations for glutaraldehyde follow the methodology discussed in DEWHA (2009).

PNECwater

Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (10 mg/L), *Daphnia* (14 mg/L), and algae (0.375 mg/L). Results from chronic studies are also available for all three trophic levels, with the lowest NOEC being 0.025 mg/L for algae. On the basis that the data consists of short-term and long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported NOEC of 0.025 mg/L for algae. The $PNEC_{water}$ is 0.0025 mg/L.

PNECsediment

There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 0.006 mg/kg wet weight.

The calculations are as follows:

$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$
$= (3.1/1280) \times 1000 \times 0.0025$
$= 0.006$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$K_{sed\text{-}water} = 0.8 + [0.2 \times Kp_{sed}/1000 \times BD_{solid}]$
$= 0.8 + [(0.2 \times 4.8)/1000 \times 2400]$
$= 3.1$

Where:
Kpsed = solid-water partition coefficient (L/kg).
BDsolid = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$Kp_{sed} = K_{0c} \times f_{oc}$
$= 120 \times 0.04$
$= 4.8$

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for glutaraldehyde in sediment is 120.
F_{oc} = fraction of organic carbon suspended sediment = 0.04 [default].

PNECsoil

Experimental results are available for three trophic level. An acute LC_{50} value is available for earthworms (>500 mg/kg). Results from long-term studies are available for two trophic levels, with the lowest NOEC or EC_{10} being 1.5 mg/kg soil dry weight for soil organisms.

The EC_{10} value is corrected for bioavailability of glutaraldehyde in soil by normalising the organic carbon content in the soil using the following equation:

$EC_{10(std)} = EC_{10(exp)} \times Fom_{soil(std)}/Fom_{soil(exp)}$

Where:
$Fom_{soil(std)}$ = 1% (www.scew.gov.au/node/941)
$Fom_{soil(exp)}$ = 1.34% (see Table 9)

$EC_{10(std)}$ = 1.5 mg/kg x 1/1.34 = 1.12 mg/kg

On the basis that the data consists of one short-term from one trophic level and two long-term results from two additional levels, an assessment factor of 50 has been applied to the lowest reported long-

term EC_{10} of 1.12 mg/kg soil dry weight [corrected for organic carbon content] for soil organisms. The $PNEC_{soil}$ is 0.02 mg/kg soil dry weight.

VIII. PBT ASSESSMENT

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Glutaraldehyde is readily biodegradable and thus does not meet the screening criteria for persistence.

The log K_{ow} for glutaraldehyde at different pH values ranges from -0.36 to -0.80. Thus, glutaraldehyde does not meet the screening criteria for bioaccumulation.

The lowest NOEC value from chronic aquatic toxicity studies is <0.1 mg/L. Thus, glutaraldehyde meets the screening criteria for toxicity.

The overall conclusion is that glutaraldehyde is not a PBT substance.

IX. CLASSIFICATION AND LABELLING

A. Classification

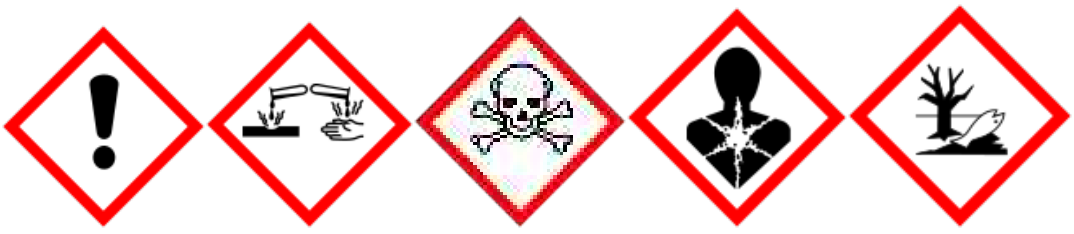
Acute Toxicity Category 3 [oral]
Acute Toxicity Category 2 [inhalation]
Skin Corrosion Category 1B
Eye Damage Category 1
Respiratory Sensitiser 1A
Skin Sensitiser 1A
STOT Single Exposure Category 3 [respiratory irritation]
Aquatic Acute Category 1
Aquatic Chronic Category 2

The appropriate hazard statements corresponding the GHS classifications are to be added to the SDS, including the non-GHS hazard statement “AUH071: Corrosive to the Respiratory Tract”.

B. Labelling

Danger

C. Pictograms



X. SAFETY AND HANDLING

A. First Aid

First aid information was obtained from the ECHA REACH database (ECHA).

Eye Contact

Wash immediately and continuously with flowing water for at least 30 minutes. Remove contact lenses after the first 5 minutes and continue washing. Obtain prompt medical consultation, preferably from an ophthalmologist. Eye wash fountain should be located in immediate work area.

Skin Contact

Take off contaminated clothing. Wash skin with soap and plenty of water for 15-20 minutes. Call a poison control centre or doctor for treatment advice. Wash clothing before reuse. Shoes and other leather items which cannot be decontaminated should be disposed of properly. Safety shower should be located in immediate work area.

Inhalation

Move person to fresh air. If a person is not breathing, call an emergency responder or ambulance, then give artificial respiration; if by mouth to mouth use rescuer protection (pocket mask, etc.). Call a poison control centre or doctor for treatment advice. If breathing is difficult, oxygen should be administered by qualified personnel.

Ingestion

If the person is fully alert and cooperative, have the person rinse mouth with plenty of water. In cases of ingestion have the person drink 4 to 10 ounces (120-300 mL) of water. Do not induce vomiting. Do not attempt mouth rinse if the person has respiratory distress, altered mental status, or nausea and vomiting. Call a physician and/or transport to an emergency facility immediately. See Note to Physician. Seek medical attention immediately.

Notes to Physician

Maintain adequate ventilation and oxygenation of the patient. May cause asthma-like (reactive airways) symptoms. Bronchodilators, expectorants, antitussives and corticosteroids may be of help. Glutaraldehyde may transiently worsen reversible airways obstruction including asthma or reactive airways disease. Chemical eye burns may require extended irrigation. Obtain prompt consultation, preferably from an ophthalmologist. If the burn is present, treat as any thermal burn, after decontamination. Due to irritant properties, swallowing may result in burns/ulceration of mouth, stomach and lower gastrointestinal tract with subsequent stricture. Aspiration of vomitus may cause lung injury. Suggest endotracheal/oesophagal control if lavage is done. Probable mucosal damage may contraindicate the use of gastric lavage. Inhalation of vapours may result in skin sensitization. In sensitised individuals, re-exposure to very small amounts of vapour, mist, or liquid may cause a severe allergic skin reaction. No specific antidote. Treatment of exposure should be directed at the control of symptoms and the clinical condition of the patient. Have the Safety Data Sheet, and if available, the product container or label with you when calling a poison control centre or doctor, or going for treatment.

Medical Conditions Aggravated by Exposure

Excessive exposure may aggravate pre-existing asthma and other respiratory disorders (e.g. emphysema, bronchitis, reactive airways dysfunction syndrome).

Emergency Personnel Protection

First Aid responders should pay attention to self-protection and use the recommended protective clothing (chemical resistant gloves, splash protection). If the potential for exposure exists, refer to Section 8 of the Safety Data Sheet for specific personal protective equipment.

B. Fire Fighting Information

Firefighting information was obtained from the ECHA REACH database (ECHA).

Extinguishing Media

Use water fog, carbon dioxide, dry chemical or foam to extinguish combustible residues of this product

Specific Exposure Hazards

This material will not burn until the water has evaporated. Residue can burn. Some components of this product may decompose under fire conditions. The smoke may contain unidentified toxic and/or irritating compounds. Combustion products may include and are not limited to carbon monoxide and carbon dioxide.

Special Protective Equipment for Firefighters

Wear positive-pressure self-contained breathing apparatus (SCBA) and protective firefighting clothing (includes firefighting helmet, coat, trousers, boots, and gloves). Avoid contact with this material during firefighting operations. If contact is likely, change to full chemical resistant firefighting clothing with self-contained breathing apparatus. If this is not available, wear full chemical resistant clothing with self-contained breathing apparatus and fight the fire from a remote location.

C. Accidental Release Measures

Information on accidental release measures was obtained from the ECHA REACH database (ECHA).

Personal Precautions

Use appropriate safety equipment. Evacuate area. Keep upwind of the spill. Ventilate area of leak or spill. Only trained and properly protected personnel must be involved in clean-up operations.

Environmental Precautions

Spills or discharge to natural waterways is likely to kill aquatic organisms. Prevent from entering into soil, ditches, sewers, waterways and/or groundwater.

Steps to be Taken if Material is Released or Spilt

Avoid making contact with spilt material; glutaraldehyde will be absorbed by most shoes. Always wear the correct protective equipment, consisting of splash-proof mono-goggles, or both safety glasses with side shields and a wraparound full-face shield, appropriate gloves and protective clothing. A self-contained breathing apparatus or respirator and absorbents may be necessary, depending on the size of the spill and the adequacy of ventilation. Small spills: Wear the correct protective equipment and cover the liquid with absorbent material. Collect and seal the material and the dirt that has absorbed the spilt material in polyethylene bags and place in a drum for transit to an

approved disposal site. Rinse away the remaining spilt material with water to reduce odour, and discharge the rinsate into a municipal or industrial sewer. Large spills: In the case of nasal and respiratory irritation, vacate the room immediately. Personnel cleaning up should be trained and equipped with a self-contained breathing apparatus, or an officially approved or certified full-face respirator equipped with an organic vapour cartridge, gloves, and clothing impervious to glutaraldehyde, including rubber boots or shoe protection. Deactivate with sodium bisulphite (2-3 parts [by weight] per part of active substance glutaraldehyde), collect the neutralised liquid and place in a drum for transit to an approved disposal site.

D. Storage and Handling

Information on storage and handling was obtained from the ECHA REACH database (ECHA).

General Handling

Do not get in eyes, on skin, on clothing. Avoid breathing vapour. Do not swallow. Keep container closed. Use with adequate ventilation. Wear goggles, protective clothing and butyl or nitrile gloves. Wash thoroughly with soap and water after handling. Remove contaminated clothing and wash before reuse.

Other Handling Precautions

Do not spray or aerosolize the undiluted form of the product. Full personal protective equipment (including skin covering and full-face SCBA respirator) is required for dilutions or mixtures of the product used in a spray application.

Storage

Do not store in: Aluminium. Carbon steel. Copper. Mild steel. Iron. Shelf life: Use within 12 Months.

E. Exposure Controls / Personal Protection

Occupational Exposure Standards

The workplace exposure standard for glutaraldehyde in Australia is 0.1 ppm (0.41 mg/m^3) as a peak limitation, with a sensitisation notation. A peak limitation is defined by Safe Work Australia as a maximum or peak airborne concentration of a substance determined over the shortest analytically practicable period of time which does not exceed 15 minutes.

The information below on exposure controls and personal protection was obtained from the Halliburton Safety Data Sheet (SDS) on ALDACIDE® G ANTIMICROBIAL (revision date: 11-Dec-2014).

Engineering Controls

Use in a well-ventilated area. Local exhaust ventilation should be used in areas without good cross ventilation. If vapours are strong enough to be irritating to the nose or eyes, the TLV is probably being exceeded, and special ventilation or respiratory protection may be required.

Personal Protection Equipment

Respiratory Protection: If engineering controls and work practices cannot keep exposure below occupational exposure limits or if exposure is unknown, wear an NIOSH-certified, European Standard EN 149, AS/NZS 1715:2009, or equivalent respirator when using this product. Selection of and

instruction on using all personal protective equipment, including respirators, should be performed by an Industrial Hygienist or other qualified professional. Full Facepiece Respirator with Organic vapour cartridge with particulate pre-filter.

Hand Protection: Chemical-resistant protective gloves (EN 374) Suitable materials for longer, direct contact (recommended: protection index 6, corresponding to > 480-minute permeation time as per EN 374): Butyl rubber gloves. (>= 0.7 mm thickness) This information is based on literature references and on information provided by glove manufacturers or is derived by analogy with similar substances. Please note that in practice the working life of chemical-resistant protective gloves may be considerably shorter than the permeation time determined in accordance with EN 374 as a result of the many influencing factors (e.g. temperature). If signs of wear and tear are noticed, then the gloves should be replaced. Manufacturer's directions for use should be observed because of the great diversity of types.

Skin Protection: Butyl coated apron or clothing.

Eye protection: Splash proof chemical mono-goggles or safety glasses with side shield in conjunction with a face shield. Do NOT wear contact lenses.

Other Precautions: Eyewash fountains and safety showers must be easily accessible.

F. Transport Information

For aqueous glutaraldehyde solutions at a concentration that is corrosive (i.e., 30% and higher):

Australia Dangerous Goods

UN3265, Corrosive Liquid, Acidic, Organic, N.O.S. (Contains Glutaraldehyde)
Class 8
Packing Group III

Environmentally Hazardous Substance

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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XIV. ACRONYMS AND GLOSSARY

°C	degrees Celsius
ADWG	Australian Drinking Water Guidelines
ALT	alanine aminotransferase
AST	aspartate aminotransferase
DEWHA	Department of the Environment, Water, Heritage and the Arts
ECHA	European Chemicals Agency
EU	European Union
GHS	Globally Harmonised System of Classification and Labelling of Chemicals
HHRA	enHealth Human Risk Assessment
IUPAC	International Union of Pure and Applied Chemistry
kg/m^3	kilogrammes per cubic metre
LGLL	large granular lymphocytic leukaemia
LOAEL	lowest observed adverse effect level
LULs	large granular lymphocytes
mg/kg	milligrams per kilogram
mg/L	milligrammes per litre
mg/m^3	milligrammes per cubic metre
NICNAS	The National Industrial Chemicals Notification and Assessment Scheme
NOAEL	no observed adverse effect level
NOEC	no observed effective concentration
OECD	Organisation for Economic Co-operation and Development
PBT	Persistent, Bioaccumulative and Toxic
ppm	parts per million
RfD	oral Reference Dose

SCE	sister chromatid exchange
SDS	Material Safety Data Sheet
SIDS	Screening Information Data Set
SMILES	simplified molecular-input line-entry system
UDS	Unscheduled DNA Synthesis
UVCB	unknown or variable composition, complex reaction product, or biological origin

GUAR GUM

This dossier on guar gum does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of guar gum in its use in drilling muds and hydraulic fracturing fluids. Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name: Guar Gum

CAS RN: 9000-30-0

Molecular weight: 200,000 to 300,000 daltons (Glickman, 1969)

Guar gum (CAS No. 9000-30-0) is a resinous material derived from milled endosperm from guar beans of the legume *Cyamopsis tetragonolobus*. Structurally, it is a galactomannan (high molecular weight carbohydrate polymer) consisting of a main chain of D-mannose with a side chain of D-galactose at approximately every second mannose unit. The mannose units are β-(l-4) linked, and the single D-galactose units are joined to the main chain by α-(1-6) linkages.

II. PHYSICO-CHEMICAL PROPERTIES

It is a beige powder.

III. ENVIRONMENTAL FATE PROPERTIES

Guar gum is a carbohydrate polymer consisting of D-mannose and D-galactose sugars from the guar plant or cluster bean. It is expected to be readily biodegradable and not bioaccumulate.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Guar gum is exhibits very low acute toxicity by the oral route. It is non-irritating to the skin and minimally irritating to the eyes. Repeated dose toxicity studies in rats showed minimal toxicity from exposure to guar gum in the diet. Guar gum is not genotoxic or carcinogenic. Oral exposure to guar gum did not affect fertility in rats; nor was there any indication of developmental toxicity in either rats or mice.

B. Acute Toxicity

The oral LD_{50} in rats was reported to be 7,060 mg/kg (Graham *et al.*, 1981). [Kl. score = 2]

C. Irritation

Guar gum is non-irritating to the skin and minimally irritating to the eyes (McCarty *et al.*, 1990).

D. Sensitization

There were reports of workers sensitized to guar gum in a carpet-manufacturing plant. Immediate skin reactivity to guar gum was observed in 8 out of 162 employees, and 11 of 133 participants had serum IgE antibodies to guar gum. These findings are difficult to interpret since carbohydrates, such as guar gum, are generally not associated with allergenicity (Maio, 1986).

E. Repeated Dose Toxicity

Oral

Male and female Osborne-Mendel rats were given diets containing 0, 1, 2, 4, 7.5, or 15% guar gum for 91 days. The average daily intakes are: 0, 580, 1,187, 2,375, 4,561, and 10,301 mg/kg-day for males; and 0, 691, 1,362, 2,762, 5,770, and 13,433 mg/kg-day for females. There were no deaths during the study. Body weights were significantly decreased in the $\geq$1% females and the $\geq$7.5% males; biologically significant changes (>10%) were seen in the 7.5% females and the 15% males. Liver weights were decreased in the $\geq$1% dietary groups. Kidney weights were decreased in the $\geq$7.5% dietary groups and were borderline significant in the 4% group. The 15% group males had reduced bone marrow cellularity; although the level was within normal limits, several of the rats were at the lower end of the normal range. The NOAEL for this study is 4% in the diet or 2,762 mg/kg-day based on reduced body weights in the female rats (Graham *et al.*, 1981). [Kl. score = 2]

Male and female F344 rats and $B6C3F_1$ mice were given diets containing 0, 6,300, 12,500, 25,000, 50,000 or 100,000 ppm guar gum for 13 weeks. Mean body weights were decreased in the 100,000 ppm male rats and in the $\geq$50,000 ppm female mice. A dose-related decrease in feed consumption was observed for male and female rats; male and female mice were comparable or higher than that of controls. There were no compound-related clinical signs or histopathological effects. The NOAELs for this study is 50,000 and 25,000 ppm for rats and mice, respectively. Using the fraction of body weight that rats and mice consume per day as food (0.05 and 0.13, respectively; U.S. EPA), the NOAELs corresponds to 2,500 mg/kg-day for rats and 3,250 mg/kg-day for mice (NTP, 1982). [Kl. score = 2]

Male and female F344 rats and B6C3F$_1$ mice were given diets containing 0, 25,000 ppm or 50,000 ppm guar gum for 103 weeks. Mean body weights of the high-dose females were lower than those of the controls after week 20 for mice and week 40 for rats. No compound-related clinical signs or adverse effects on survival were observed. Feed consumption by dosed rats and mice of either sex was lower than that of controls. There were no non-neoplastic histopathological effects in either rats or mice that were treatment-related. The NOAEL for both rats and mice is 25,000 ppm. Using the fraction of body weight that rats and mice consume per day as food (0.05 and 0.13, respectively; U.S. EPA), the NOAELs corresponds to 1,250 mg/kg-day for rats and 3,250 mg/kg-day for mice (NTP, 1982). [Kl. score = 2]

Inhalation

No studies are available.

Dermal

No studies are available.

F. Genotoxicity

In Vitro Studies

Guar gum was not mutagenic to *S. typhimurium* strains TA 97, TA 98, TA 100, TA 102, TA 104, TA 1535, TA 1537, and TA1538 in the presence or absence of metabolic activation (Zeiger *et al.*, 1992). [Kl. score = 2]

In Vivo Studies

Guar gum was inactive in a rat bone marrow cytogenetic assay at doses up to 5,000 mg/kg (CIR, 2015). [Kl. score = 4]

In a rat dominant lethal mutation test, rats were dosed by oral gavage with either a single or multiple doses of up to 5,000 mg/kg guar gum. There was no indication of a mutagenic effect by guar gum (Lee *et al.*, 1981). [Kl. score = 2]

G. Carcinogenicity

Male and female F344 rats were given diets containing 0, 25,000 ppm, or 50,000 ppm guar gum for 103 weeks in a NTP chronic bioassay. There were increased incidences of adenomas of the pituitary in male rats and pheochromocytomas of the adrenal medulla in female rats that were statistically significant, but these differences were considered to be unrelated to guar gum administration. When pituitary adenomas or carcinomas and when pheochromocytomas or malignant pheochromocytomas were combined, the statistical

differences disappeared. NTP concluded that, under conditions of this bioassay, guar gum was not carcinogenic for F344 rats (NTP, 1982). [Kl. score = 2]

Male and female $B6C3F_1$ mice were given diets containing 0, 25,000, or 50,000 ppm guar gum for 103 weeks in a NTP chronic bioassay. Hepatocellular carcinomas occurred in treated male mice at incidences that were significantly lower than that in controls. The combined incidence of male mice with either hepatocellular adenomas or carcinomas was also significantly lower in the high-dose group. NTP concluded that, under conditions of this bioassay, guar gum was not carcinogenic for $B6C3F_1$ mice (NTP, 1982). [Kl. score = 2]

H. Reproductive Toxicity

Oral

Male and female Osborne-Mendel rats were fed diets containing 0, 1, 3, 4, 7.5, or 15% guar gum for 13 weeks before mating, during mating and throughout gestation. The daily intakes for the female rats during gestation were 0, 700, 1,400, 2,700, 5,200, or 11,800 mg/kg-day. Fertility was unaffected by treatment. There were slightly fewer corpora lutea and implantations in the 15% dietary group, but implantation efficiency was unaffected. The NOAEL for reproductive toxicity is 5,200 mg/kg-day (Collins *et al.*, 1987). [Kl. score = 2]

I. Developmental Toxicity

Oral

Male and female Osborne-Mendel rats were fed diets containing 0, 1, 3, 4, 7.5, or 15% guar gum for 13 weeks before mating, during mating and throughout gestation. The daily intake for the female rats during gestation were 0, 700, 1,400, 2,700, 5,200, or 11,800 mg/kg-day. There were no deaths during the study. In the 15% group, the number of viable fetuses per litter were slightly reduced, but was not statistically significantly different from controls. The authors indicated that the reduction may have been an effect of the decreased number of corpora lutea because the number of resorptions was unaffected in this treatment group. There was no treatment-related effect on fetal development or sex distribution, and there were no teratogenic effects (Collins *et al.*, 1987). [Kl. score = 2]

Pregnant female rats were dosed by oral gavage with 0, 9, 42, 200, or 900 mg/kg guar gum on GD 6 to 15. There was no maternal or developmental toxicity at any dose level. The NOAEL for maternal and developmental toxicity is 900 mg/kg-day (FDRL, 1973). [Kl. score = 2]

Pregnant female CD-1 mice were dosed by oral gavage with 0, 8, 37, 170, or 800 mg/kg

guar gum on GD 6 to 15. A significant number of deaths (6 out of 29) occurred in the 800 mg/kg dose group. There were indications of maternal toxicity in the surviving high-dose dams. There was no developmental toxicity at any dose level. The NOAELs for maternal and developmental toxicity are 170 and 800 mg/kg-day, respectively (FDRL, 1973). [Kl. score = 2]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for guar gum follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

In a two-year NTP chronic bioassay, female rats and mice given 50,000 ppm guar gum in their feed had lower body weights. There were no treatment-related non-neoplastic lesions in either rats or mice. The NOAEL for this study is 25,000 ppm for rats and mice, which corresponds to 1,250 mg/kg-day for rats and 3,250 mg/kg-day for mice.

The NOAEL of 1,250 mg/kg-day will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 1,250/(10 x 10 x 1 x 1 x 1) = 1,250/100 = 13 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (13 x 70 x 0.1)/2 = 46 mg/L

B. Cancer

Guar gum was not carcinogenic to rats or mice in two-year dietary studies. Thus a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Guar gum does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Guar gum is a polysaccharide polymer. It has low acute toxicity concern for fish, but exhibits medium or possibly high acute toxicity to invertebrates (*Daphnia*).

B. Aquatic Toxicity

The 96-hour LC_{50} for *Oncorhynchus mykiss* is 218 mg/L (Biesinger *et al.*, 1976). [Kl. score = 2]

The 48-hour and 96-hour LC_{50} values for *Daphnia magna* are 42 mg/L and <6.2 mg/L, respectively (Biesinger *et al.*, 1976). [Kl. score = 2]

Chronic Studies

No studies are available.

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for guar gum follow the methodology discussed in DEWHA (2009).

PNEC water
Experimental results are available for two trophic levels. The acute $E(L)C_{50}$ values are available for fish (218 mg/L) and *Daphnia* (<6.2 mg/L). On the basis that the data consists of short-term results from two trophic levels, an assessment factor of 1,000 has been applied to the lowest reported $E(L)C_{50}$ value of 6.2 mg/L for *Daphnia*. The $PNEC_{water}$ is 0.006 mg/L.

PNEC sediment
No experimental toxicity data on sediment organisms are available. The K_{ow} and K_{oc} of guar gum cannot be calculated using EPISUITE because the molecular weight of guar gum greatly exceeds the limit of 1,000. Thus, the equilibrium partition method cannot be used to determine a $PNEC_{sediment}$ and the assessment of this compartment will be covered by the aquatic assessment.

PNEC soil
No experimental toxicity data on soil organisms are available. The K_{ow} and K_{oc} of guar gum cannot be calculated using EPISUITE because the molecular weight of guar gum greatly exceeds the limit of 1,000. Thus, the equilibrium partition method cannot be used to determine a $PNEC_{soil}$ and the assessment of this compartment will be covered by the aquatic assessment.

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Guar gum is a naturally occurring polysaccharide from the guar plant or cluster bean; it expected to be readily biodegradable. Thus it is not expected to meet the screening criteria for persistence.

The molecular weight of guar gum ranges from 200,000 to 300,000 daltons and is water-soluble. Thus guar gum is not expected to meet the criteria for bioaccumulation.

The 96-hour LC_{50} value for *Daphnia* is <6.2 mg/L. Thus guar gum may potentially meet the screening criteria for toxicity.

The overall conclusion is that guar gum is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

[Acute Aquatic Toxicity Category 2]

B. Labelling

No signal word.

C. Pictogram

None.

X. SAFETY AND HANDLING

Eye Contact
In case of contact, immediately flush eyes with plenty of water for at least 15 minutes.

Skin Contact
Remove contaminated clothing. Wash thoroughly with soap and water.

Inhalation
If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Ingestion
Rinse mouth with water and then drink plenty of water. Never give anything by mouth to an unconscious person.

Notes to Physician
May cause asthma-like (reactive airways) symptoms.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: carbon monoxide, carbon dioxide.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus for fire fighting.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Avoid dust formation.

Environmental Precautions
No special environmental precautions required.

Steps to be Taken if Material is Released or Spilled
Sweep up and dispose in suitable, closed containers.

D. STORAGE AND HANDLING

General Handling
Avoid creating or inhaling dust.

Storage
Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
Workplace Australia has not established an occupational exposure standard specifically for guar gum.

Engineering Controls
Ensure adequate ventilation.

Personal Protection Equipment

Respiratory Protection:
Respiratory protection is not required.

Hand Protection:
Handle with gloves.

Skin *Protection*:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Safety glasses with side-shields.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible.

F. TRANSPORT INFORMATION

Guar gum is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

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HEMICELLULASE ENZYME

This dossier on hemicellulase enzyme does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of hemicellulase enzyme in its use in drilling muds and hydraulic fracturing fluids. The information presented in this dossier was obtained primarily from the Human & Environmental Risk Assessment on Ingredients of European Household Cleaning Products: Alcohol Ethoxylates (HERA, 2005), and from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name: Not applicable

CAS RN: 9025-56-3

Molecular weight: 20,000 to 80,000 daltons (based on cellulase enzymes)

Synonyms: Hemicellulases; hemicellulase enzymes

Hemicellulases are a group of enzymes that break down hemicellulose, which are polysaccharides that are present in cell walls of all terrestrial plants. These polysaccharides have a β-(1→4)-linked backbone and are composed of pentoses (xylose, arabinoses), hexoses (mannose, glucose, galactose), and sugar acids. Unlike cellulose which are polysaccharides consisting of linear chains of several hundred to over ten thousand β-(1→4) linked D-glucoses, hemicellulases are not chemically homogeneous. The best characterized hemicellulases are the 1,4- β -D-xylanases and, in particular, those derived from fungal sources presumably because their substrates, xylans, constitute the largest proportion of hemicelluloses in pasture plants.

No information was found on hemicellulase enzyme; however, because of their similarity, information will be read-across from cellulase enzymes (HERA, 2005). Cellulases cleave the ß-1,4-glycosidic bonds in cellulose, and are used in the pulp and paper industry, the textile industry, and in detergents to remove deposits and stains. The molecular weight of cellulase is 20,000 to 80,000 daltons.

Enzymes are catalytic proteins or polypeptides and consist of amino acid residues coupled via peptide bonds. They are primarily characterized by their biocatalytic or enzymatic activity. There is a broad range of detergent cellulases used both from fungal as well as from bacterial origin; all are characterized by ß-1,4-endoglucanase activity. For the purposes of risk assessment, the structure of hemicellulases would be expected to be similar to that of cellulases, given that hemicellulases and cellulases are both enzyme families that hydrolyze polysaccharides, although differing in their

substrates. Thus, the toxicity data on cellulases will be used as read-across to hemicellulases.

II. PHYSICO-CHEMICAL PROPERTIES

Cellulases, as pure enzyme, are white crystals or powder (HERA, 2005).

An octanol-water partition coefficient (K_{ow}) for cellulases is not available. However, the log K_{ow} of glucoamylase, which cleaves 1,4–α-D-glycosidic linkages, was experimentally determined to be <1.3 at 20ºC (ECHA). [Kl. score = 1]

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Cellulases are readily biodegradable; they are not expected to bioaccumulate or adsorb to soil.

B. Biodegradation

A cellulase enzyme was readily biodegradable in an OECD 301F test. There was ~10% degradation after one day; ~60% after 5 days; and 129% after 28 days (ECHA). [Kl. score = 1]

Three different cellulase enzymes were considered readily biodegradable based on the results of OECD 301C and 301E tests (HERA, 2005) [Kl. scores = 1]. In an OECD 301E test, there was 84% DOC removal of the enzyme Carezyme after 28 days. In another OECD 301E test, there was 92% DOC removal of the enzyme Clazinase® after 28 days. In an OECD 301C test, BOD/COD was 78% after 28 days (HERA, 2005).

C. Environmental Distribution

<u>Adsorption/desorption</u>

Proteins, such as cellulase enzyme, would not be expected to adsorb to soil. HERA (2005) listed a K_{oc} value of <1.3 for detergent amylases, cellulases, and lipases that was calculated according to the EU Technical Guidance Document (EC, 2003). No further information was provided. The K_{oc} value of 1.3 will be used to calculate the PNEC values for sediment and soil using the equilibrium partitioning method (see section XII. D.).

D. Bioaccumulation

No bioaccumulation studies have been conducted on cellulase enzymes. Cellulase enzymes are not expected to bioaccumulate due to their high molecular weight and their octanol-water partition coefficient (log K_{ow} is <1.3). Moreover, cellulases are rapidly biotransformation in an organism to lower molecular-weight protein fragments by proteolytic enzymes (proteases), and eventually to the basic amino acids by peptidase enzymes.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Cellulase enzyme has low acute toxicity by the oral, dermal, or inhalation routes. It is not askin or eye irritant; and it is not a skin sensitizer. Although there are no specific studies on cellulase enzyme, a number of enzymes from bacteria, plants, and fungi have the potential to cause occupational respiratory allergy, even asthma. Minimal toxicity was seen in rats given repeated oral doses of cellulase enzyme either by gavage or in their diet for up to 13 weeks. Cellulase enzyme is not genotoxic. There are no carcinogenicity, reproductive, or developmental toxicity studies on cellulase enzyme.

B. Acute Toxicity

The oral LD_{50} of a cellulase enzyme was calculated to be 8,000 mg/kg for mice and >10,000 mg/kg for rats (HERA, 2005) [Kl. score = 4]. The oral LD_{50} in rats for a cellulase enzyme was >2,880 mg/kg, measured as total organic soilds (ECHA) [Kl. score = 1].

The inhalation LC_{50} of a cellulase enzyme in rats was >3.48 mg/L. The mass mean aerodynamic diameter (MMAD) was 7.8 μm with a geometric standard deviation of 2.1 μm (HERA, 2005) [Kl. score = 4]. The 4-hour inhalation LC_{50} of a cellular enzyme in rats was >4.86 mg/L, which corresponds to 4.44 mg total organic solids/L). The respirable fraction was 80% (44.8% of the particles were <6 μm (ECHA) [Kl. score = 1].

No dermal toxicity studies are available.

C. Irritation

Application of 0.5 ml of a cellulase enzyme to the skin of rabbits for 4 hours under semi-occlusive conditions was minimally irritating (ECHA). [Kl. score = 1]

Instillation of 0.1 ml of a cellulase enzyme to the eyes of rabbits was non-irritating (ECHA). [Kl. score = 1]

D. Sensitization

A cellulase enzyme was not a skin sensitizer to guinea pigs in a Buehler sensitization test (HERA, 2005). [Kl. score = 2]

Although there are no specific studies on cellulase enzyme, a number of enzymes from bacteria, plants, and fungi have the potential to cause occupational respiratory allergy, even asthma (Basketter et al., 2015).

E. Repeated Dose Toxicity

Oral

Male and female rats were dosed by oral gavage with 0, 300, 1,000 or 3,000 mg/kg of a cellulase enzyme for 4 weeks. There were no treatment-related clinical signs, but a slight dose-related increase in body weight gain (approx. 7%) was seen in the males. No treatment-related changes were noted in the hematology or clinical chemistry. There were no gross or histopathologic changes that were considered treatment-related. The NOAEL is 3,000 mg/kg-day (HERA, 2005). [Kl. score = 2]

Male and female rats were fed a diet containing 0, 120, 600 or 3,000 mg/kg of a cellulase enzyme for 13 weeks. There were no treatment-related clinical signs. A reduction in body weight gain was seen in both sexes at the 3,000 mg/kg dose level (10% in males and 20% in females). A slight reduction in food consumption was also noted for the 3,000 mg/kg rats. Alkaline phosphatase was increased in the 600 and 3,000 mg/kg females in a dose-dependent manner. There were no gross or histopathologic changes that were considered treatment-related. The NOAEL for this study is 600 mg/kg-day (HERA, 2005). [Kl. score = 2]

Male and female Wistar rats were dosed by oral gavage with 0, 100, 300, or 1,000 mg/kg β-glucanase (measured as total organic solids) for 13 weeks. There were no treatment-related effects on mortality, clinical signs, body weights, food or water consumption, ophthalmoscopic findings, hematology, clinical chemistry, neurobehavior (functional observation battery), organ weights, gross or microscopic pathology. The NOAEL is 1,000 mg/kg-day expressed as total organic solids (ECHA). [Kl. score = 1]

Inhalation

No studies are available.

Dermal

No studies are available.

F. Genotoxicity

The *in vitro* genotoxicity studies on cellulase enzymes are shown in Table 1.

Table 1: *In vitro* Genotoxicity Studies on Cellulase Enzyme

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* and *E. coli* strains)	-	-	1	ECHA
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	HERA (2005)
Chromosomal aberration (human lymphocytes)	-	-	1	ECHA

*+, positive; -, negative

In vivo Studies

Male and female SD rats were dosed by oral gavage with 0, 300, 1,000, or 3,000 mg/kg of a cellulase enzyme for five consecutive days. Chromosomal aberrations, excluding gaps, were not significantly increased at any dose level compared to controls. Chromosomal aberrations including gaps were increased in females from all dose groups, but there was no clear dose-response relationship and the difference was only statistically significant at 3,000 mg/kg. There was no treatment-related effect on the mitotic capacity of the bone marrow. It was concluded that the cellular enzyme was not genotoxic under the conditions of the assay (HERA, 2005). [Kl. score = 2]

G. Carcinogenicity

No studies are available.

H. Reproductive Toxicity

No studies are available.

I. Developmental Toxicity

No studies are available.

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for hemicellulase enzyme follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

There are two 13-week rat studies on cellulase enzyme. In a dietary study, rats were given 0, 120, 600, or 3,000 mg/kg cellulase enzyme. The LOAEL for this study is 3,000 mg/kg based on significant reduction in body weight gain in both sexes; the NOAEL is 600 mg/kg-day (HERA, 2005). In an oral gavage study, rats were dosed with 0, 100, 300, or 1,000 mg/kg β-glucanase. There were no treatment-related effects and the NOAEL for this study is 1,000 mg/kg-day, the highest dose tested (ECHA).

The NOAEL of 1,000 mg/kg-day from the 13-week rat oral gavage study will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 3
UF_D (database uncertainty) = 1

Oral RfD = 1,000/(10 x 10 x 1 x 3 x 1) = 1,000/300 = 3 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (1.0 x 70 x 0.1)/2 = 12 mg/L

B. Cancer

There are no carcinogenicity studies on cellulase enzyme. Thus, a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Hemicellulase and cellulase enzymes do not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Cellulase enzyme has a moderate acute toxicity concern to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

Table 2 lists the results of acute aquatic toxicity studies on cellulase enzyme.

Table 2: Acute Aquatic Toxicity Studies on Cellulase Enzyme

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Oncorhynchus mykiss	96-h LC_{50}	>100* >52.1**	1	ECHA
Brachydanio rerio	96-h LC_{50}	330*	4	HERA (2005)

Daphnia magna	48-h EC_{50}	>100* >52.1**	1	ECHA
Daphnia magna	48-h EC_{50}	>1,000**	4	HERA (2005)
Daphnia magna	48-h EC_{50}	1,000**	4	HERA (2005)
Pseudokirchneriella subcapitata	72-h EC_{50}	>100* >52.1**	1	ECHA
Scenedesmus subspicatus	72-h EC_{50}	>1,000**	4	HERA (2005)

*Total organic solids.
**Active enzyme protein.

Chronic Studies

No studies are available.

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for cellulase enzyme follow the methodology discussed in DEWHA (2009).

PNEC water
Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (>52.1 mg aep/L), *Daphnia* (>52.1 mg aep/L), and algae (>52.1 mg aep/L). No chronic toxicity studies are available. On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 100 has been applied to the lowest reported $E(L)C_{50}$ value of 52.1 mg aep/L for fish. The $PNEC_{aquatic}$ is 0.5 mg/L.

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 0.3 mg/kg sediment wet weight.

The calculations are as follows:

$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$
$= (0.825/1280) \times 1000 \times 0.5$
$= 0.3$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$K_{sed\text{-}water} = 0.8 + [0.2 \times Kp_{sed}/1000 \times BD_{solid}]$
$= 0.8 + [0.2 \times 0.052/1000 \times 2400]$
$= 0.825$

Where:
Kp_{sed} = solid-water partition coefficient (L/kg).
BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$Kp_{sed} = K_{oc} \times f_{oc}$
$= 1.3 \times 0.04$
$= 0.052$

Where:
K_{oc} = organic carbon normalized distribution coefficient (L/kg). The K_{oc} for cellulase enzymes is calculated to be <1.3 L/kg.
F_{oc} = fraction of organic carbon in sediment = 0.04 [default].

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is 0.009 mg/kg soil dry weight.

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
$= (0.026/1500) \times 1000 \times 0.5$
$= 0.009$

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
$= 1.3 \times 0.02$
$= 0.026$

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for cellulase enzymes is calculated to be <1.3 L/kg.
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008). The following PBT assessment on hemicellulase enzyme is based on read-across from cellulase enzyme.

Hemicellulase enzyme is readily biodegradable; thus, it does not meet the screening criteria for persistence.

Hemicellulase enzyme has a high molecular weight (20 to 80 kD), hydrophilic properties (high water solubility, log K_{ow} <1.3), and is readily biotransformed in organisms by proteases and peptidases. Thus, hemicellulase enzyme does not meet the screening criteria for bioaccumulation.

There are no chronic toxicity studies on hemicellulase enzyme. The acute $E(L)C_{50}$ values are >1 mg/L in fish, invertebrates and algae. Thus, hemicellulase enzyme does not meet the criteria for toxicity.

The overall conclusion is that hemicellulase enzyme is not a PBT substances.

IX. CLASSIFICATION AND LABELING

A. Classification

Respiratory sensitizer Category 1

[Aquatic Acute Category 3]

B. Labelling

Danger

C. Pictogram



X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
In case of contact, immediately flush eyes with plenty of water for at least 15 minutes.

Skin Contact
Remove contaminated clothing. Wash thoroughly with soap and water.

Inhalation
If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Ingestion
Rinse mouth with water and then drink plenty of water. Never give anything by mouth to an unconscious person.

Notes to Physician
May cause asthma-like (reactive airways) symptoms.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: carbon monoxide, carbon dioxide, nitrogen oxides, sulfur oxides.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus for fire-fighting.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Use appropriate protective equipment. Ensure adequate ventilation. Do not breathe vapors, mists, or gas.

Environmental Precautions
Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled
Collect spilled material by non-dispersive methods or with a vacuum cleaner equipped with a high efficiency filter. After spillage avoid generating aerosols or dust from dried preparation. Do not sweep, brush, use compressed air, which can create aerosols. Avoid splashing and high pressure washing. Provide for sufficient ventilation. Wash with plenty of water.

D. STORAGE AND HANDLING

General Handling
Use personal protective clothing. Avoid dust formation. Ensure adequate ventilation. Provide appropriate exhaust ventilation at places where dust is formed. Do not breathe dust. Wear respiratory protection if ventilation is inadequate. Avoid contact with skin, eye, and clothing.

Other Handling Precautions
Avoid creating or inhaling dust.

Storage
Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
Workplace Australia has not established an occupational exposure standard specifically for hemicellulase enzyme. However, Workplace Australia has established an occupational exposure standard of 0.00006 mg/m^3 (peak exposure with a sensitization notation) for the proteolytic enzymes of *B. subtilisins* as 100% pure enzyme. A peak limitation is defined by Safe Work Australia as a maximum or peak airborne concentration of a substance determined over the shortest analytically practicable period of time which does not exceed 15 minutes.

Engineering Controls

Ensure adequate ventilation. Localized ventilation should be used to control dust levels below permissible exposure limits.

Personal Protection Equipment

Respiratory Protection:
Use respiratory protection when airborne concentrations are expected to exceed occupational exposure limits.

Hand Protection:
Chemical resistant protective gloves.

Skin *Protection*:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Safety glasses with side-shields.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible. Remove and wash contaminated clothing before re-use. Contaminated work clothing should not be allowed out of the workplace.

F. TRANSPORT INFORMATION

Hemicellulase enzyme is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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HYDROCHLORIC ACID

This dossier on hydrochloric acid does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of hydrochloric acid in its use in drilling muds and in water treatment systems. The majority of information presented in this dossier was obtained from OECD-SIDS documents (OECD, 2002a,b), and the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch et al., 1997).

I. SUBSTANCE IDENTIFICATION

Chemical Name (IUPAC): Chlorane

CAS RN: 7647-01-0

Molecular formula: HCl

Molecular weight: 36.46

Synonyms: Hydrochloric acid, HCl, chlorane, hydrogen chloride, muriatic acid, chlorohydric acid,

SMILES: Cl

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Hydrochloric Acid

Property	Value	Klimisch score	Reference
Physical state at 20ºC and 101.3 kPa	Colourless to slightly yellow gas of fuming liquid with pungent, irritating odour.	2	ECHA
Melting Point	-114.22ºC	2	ECHA
Boiling Point	-85ºC	4	ECHA
Density	1.639 g/L @ 0ºC (gas) 1.194 g/mL @ 26ºC (liquid)	4	ECHA
Vapour Pressure	4,104 kPa 4,723 kPa @ 25ºC	4	ECHA
Partition Coefficient (log K_{ow})	Not applicable	-	-
Water Solubility	Very soluble	4	ECHA
Viscosity	1.7 x 10^{-6} m^2s @ 20ºC	1	ECHA

Hydrochloric acid can exist in a gaseous phase at room temperature and pressure. Hydrochloric acid is also very soluble in water and is a strong acid that dissociates completely in water to hydrogen (H^+) and chloride (Cl^-) ions.

III. ENVIRONMENTAL FATE PROPERTIES

Due to its high water solubility and low vapour pressure, hydrochloric acid will be found predominantly in the aquatic environment where it dissociates completely to hydrogen (H^+) and chloride (Cl^-) ions. Both ions are ubiquitous in the environment (UNEP, 1995).

The addition of hydrochloric acid to an aquatic ecosystem may decrease the pH depending on the buffer capacity of the receiving water. In general, the buffer capacity is regulated by the equilibria between CO_2, HCO_3^- and CO_3^{2-}:

$CO_2 + H_2O \leftrightarrow HCO_3^- + H^+$ ($pKa_1 = 6.35$)

$HCO_3^- \leftrightarrow CO_3^{2-} + H^+$ ($pKa_2 = 10.33$)

A release of hydrochloric acid into the aquatic environment from the use of HCl could potentially increase the chloride concentration and decrease the pH in the aquatic environment. Table 2 shows the amount of hydrochloric acid that would need to be added to bicarbonate solutions to obtain pH values of 6.0 and 4.0. The UNEP (1995) study reported that the 10th percentile, mean, and the 90th percentile of bicarbonate concentrations in 77 rivers in North America, South America, Asia, Africa, Europe, and Oceania were 20, 106, and 195 mg/L, respectively. The data show that the decrease in pH depends on the buffer capacity (bicarbonate concentration) of the receiving water. The calculated values in Table 2 were confirmed experimentally.

Table 2: Buffer capacity to maintain the pH based on bicarbonate concentration from UNEP monitoring data (de Groot and van Dijk, 2002; taken from OECD, 2002b)

Initial concentration of HCO_3^-	Final pH	Concentration of HCl required to obtain the final pH value
		Calculated [mg/L]
20 mg/LHCO_3^- (10th percentile 77 rivers)	6.0	8.28
	4.0	11.9
106 mg/L HCO_3^- (mean value of 77 rivers)	6.0	43.9
	4.0	63.2
195 mg/L HCO_3^- (90th percentile 77 rivers)	6.0	80.7
	4.0	116.3

H^+ and Cl^- ions will not adsorb on the particulate matter or surfaces and will not accumulate in living tissues (OECD, 2002a,b).

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Hydrochloric acid is a corrosive liquid. Depending on the concentration, aqueous solutions of hydrochloric acid (HCl) are either corrosive, irritating, or non-irritating to the skin, eyes, and gastrointestinal tract. Vapours from aqueous solutions of HCl can cause respiratory irritation. HCl is not a skin sensitiser. Subchronic inhalation studies show localised irritation to the upper respiratory tract of rats and mice, but no systemic toxicity. No repeated dose toxicity studies have been conducted by the oral route. Positive findings have been reported in some *in vitro* genotoxicity studies, which are considered to be the result of the pH change in the test system. A lifetime inhalation study showed no carcinogenicity in rats exposed to HCl. No adequate reproductive or developmental studies have been conducted on HCl.

B. Acute Toxicity

The oral LD_{50} values in rats were reported to be 238 to 277 mg/kg and 700 mg/kg (OECD, 2002a,b). [Kl. scores = 2 and 4, respectively]

The lethal dose by dermal exposure is >5,010 mg/kg for rabbits (OECD 2002a,b). [Kl. score = 4]

The LC_{50} values in rats for HCl gas are 40,989 and 4,701 ppm for 5 and 30 minutes, respectively (ECHA) [Kl. score = 2]. The LC_{50} values in rats for HCl aerosol are 31,008 and 5,666 ppm (45.6 and 8.3 mg/L) for 5 and 30 minutes, respectively (ECHA) [Kl. score = 2].

C. Irritation

Application of a 37% aqueous solution of HCl for 1 or 4 hours was corrosive to the skin of rabbits (OECD, 2002a,b) [Kl. score = 2). Application of 0.5 mL of a 17% solution of aqueous solution of HCl for 4 hours was corrosive to the skin of rabbits (OECD, 2002a,b) [Kl. score = 3]. Moderate skin irritation was observed in rabbits following an application of 0.5 mL of a 3.3% aqueous solution of HCl for five days; no irritation was observed with 0.5 mL of a 1% aqueous solution (OECD, 2002a,b) [Kl. score = 2]. In humans, an aqueous solution of 4% of HCl was slightly irritating, while a 10% solution was sufficiently irritating to be classified as a skin irritant (OECD, 2002a,b).

Instillation of 0.1 mL of a 10% aqueous solution of HCl to the eyes of rabbits resulted in severe eye irritation (ECHA) [Kl. score = 2]. Instillation of 0.1 mL of a 5% solution of HCl produced corneal opacity, iridial lesions, conjunctival redness and chemosis in 3/3 animals at 1 hour and at day one post-instillation. There was no recovery in any animal and the study was terminated on day two (ECHA) [Kl. score = 1].

D. Sensitisation

Hydrochloric acid was not a skin sensitiser in a guinea pig maximisation test (ECHA). [Kl. score = 2]

E. Repeated Dose Toxicity

Oral

No adequate studies were located.

Inhalation

Male and female SD rats and F344 rats were exposed by inhalation to 0, 10, 20, or 50 ppm 6 hours/day, 5 days/week for up to 90 days. Clinical signs were mainly indicative of the irritant/corrosive nature of HCl. Body weights were significantly decreased in the 50 ppm male F344 rats. There were no treatment-related effects on the haematology or clinical chemistry parameters or urinalysis. At study termination, heart, kidney and testes weights were increased in the 100 and/or 50 ppm groups; these changes were considered to be mainly related to the treatment-related effect on body weight. Histopathological examination showed minimal to mild rhinitis in the $\geq$20 ppm dose groups of both strains of rats (both sexes). The NOAELs for systemic toxicity and localised irritation (site-of-contact) are 20 and 10 ppm, respectively (ECHA). [Kl. score = 1]

Male and female $B6C3F_1$ mice were exposed by inhalation to 0, 10, 20, or 50 ppm HCl, 6 hours/day, 5 days/week for up to 90 days. Clinical signs were mainly indicative of the irritant/corrosive nature of HCl. Body weights were significantly decreased in the 50 ppm groups. At study termination, absolute liver weights were decreased in the 50 ppm males. Histopathologic examination showed only

eosinophilic globules in the nasal epithelium in the 50 ppm animals. The NOAEL for this study is 20 ppm (ECHA). [Kl. score = 1]

Male SD rats were exposed by inhalation to 0 or 10 ppm HCl 6 hours/day, 5 days/week for 128 weeks. Survival and body weights were similar between treated and control groups. There was a higher incidence of hyperplasia of the larynx compared to control, but no serious irritating effects of the nasal epithelium (ECHA). [Kl. score = 2]

Dermal

No studies were located.

F. Genotoxicity

In Vitro Studies

Table 3 presents the *in vitro* genotoxicity studies on hydrochloric acid.

Table 3: In Vitro Genotoxicity Studies on Hydrochloric Acid

Test System	Results[a]		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* and *E. coli* strains)	-	-	2	ECHA
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	-	+	2	ECHA
Chromosomal aberration (CHO cells)	+	+	2	ECHA
Saccharomyces cerevisiae (mitotic recombination	-	-	2	ECHA
E. coli W3110 (pol A+) and P3078 (pol A-) repair assay	-	-	2	ECHA

a+, positive; -, negative

In the mouse lymphoma assay, the mutant frequency increased as the pH was lowered to 6.5 to 6.0 (from increased HCl) in the presence of metabolic activation. A decrease in pH from the addition of HCl to the medium also resulted in clastogenic effects to CHO cells in the absence or presence of metabolic activation. The positive findings in these two studies are considered to be the result of the pH change in the test media.

In Vivo Studies

No adequate studies were located.

G. Carcinogenicity

Oral

No studies were located.

Inhalation

Male SD rats were exposed by inhalation to 0 or 10 ppm HCl 6 hours/day, 5 days/week for 128 weeks. Survival and body weights were similar between treated and control groups. There was a

higher incidence of hyperplasia of the larynx compared to control, but no serious irritating effects of the nasal epithelium. There was no increased incidence of tumours in the HCl-treated rats compared to controls (ECHA). [Kl. score = 2]

H. Reproductive Toxicity

No studies were located.

I. Developmental Toxicity

No adequate studies were located.

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

Repeated dose, reproductive, and developmental toxicity studies by the oral route have not been conducted on hydrochloric acid. These toxicity studies would have questionable usefulness because of the corrosive/irritating nature of hydrochloric acid, which would limit the amount of absorbed HCl. Hydrochloric acid dissociates to hydrogen and chloride ions in bodily fluids, and a significant amount of these ions are already ingested in foods. Furthermore, both ions are present in the body and are highly regulated by homeostatic mechanisms. Thus, an oral toxicological reference and drinking water guidance values were not derived from hydrochloric acid.

The Australian drinking water guideline values for pH (6.5 to 8.5) and chloride (250 ppm, aesthetics) may be applicable (ADWG, 2011).

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Hydrochloric acid does not exhibit the following physico-chemical properties:

- • Explosivity
- • Flammability
- • Oxidising potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

The hazard of hydrochloric acid for aquatic organisms is caused by the hydrogen ion (H^+). The toxicity values in terms of mg/L are not relevant because of the varying buffering capacity of different test systems and different aquatic ecosystems.

B. Aquatic Toxicity

Acute Studies

The acute aquatic toxicity studies on hydrochloric acid are listed in Table 4.

Table 4: Acute Aquatic Toxicity Studies on Hydrochloric Acid

Test Species	Endpoint	Results	Klimisch score	Reference
Oncorhynchus mykiss	96-hr LC_{50}	pH 4.12 (hard water) pH 3.98 (soft water)	2	ECHA; OECD 2002a,b

Test Species	Endpoint	Results	Klimisch score	Reference
Lepomis macrochirus	96-hr LC_{50}	pH 3.25 – 3.5	2	ECHA; OECD 2002a,b
Daphnia magna	48-hr EC_{50}	pH 4.92	1	ECHA
Chlorella vulgaris	72-hr EC_{50} 72-hr NOEC	pH 4.7 [growth rate] pH 4.82 [biomass] pH 5 [yield/growth rate	1	ECHA

Chronic Studies

No chronic studies are available.

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

PNEC values were not derived from hydrochloric acid because factors such as the buffer capacity, the natural pH, and the fluctuation of the pH are very specific for a certain ecosystem.

VIII. PBT ASSESSMENT

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Hydrochloric acid is an inorganic salt that dissociates completely to hydrogen and chloride ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both hydrogen and chloride ions are also ubiquitous and are present in water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria are not considered applicable to this inorganic salt.

Hydrogen and chloride ions are essential to all living organisms, and their intracellular, and extracellular concentrations are actively regulated. Thus, hydrochloric acid is not expected to bioaccumulate.

No chronic toxicity data exist on hydrochloric acid; however, the acute $E(L)C_{50}$ values are >1 mg/L in fish, invertebrates and algae. Thus, hydrochloric acid does not meet the screening criteria for toxicity.

The overall conclusion is that hydrochloric acid is not a PBT substance.

IX. CLASSIFICATION AND LABELLING

A. Classification

For HCl concentrations of >25%:

- Metal Corrosive Category 1
- Skin Corrosive 1B
- STOT SE Category 3 [Respiratory irritant]

In addition to the hazard statements corresponding the GHS classification for corrosive, the following non-GHS hazard statement is to be added to the SDS: AUH071: Corrosive to the Respiratory Tract.

B. Labelling

Danger

C. Pictogram



X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact

Immediately flush open eyes with plenty of water for at least 15 minutes. Remove contacts, if present and easy to do. Get medical attention immediately, preferably a physician for an ophthalmologic examination.

Skin Contact

For minor skin contact, avoid spreading material on unaffected skin. Remove and isolate contaminated clothing. Wash the contaminated area of the body with soap and fresh water. Get medical attention immediately.

Inhalation

Move person to fresh air. Administer oxygen if breathing is difficult. Do not use mouth-to-mouth method if victim inhaled the substance; give artificial respiration with the aid of a pocket mask equipped with a one-way valve or another proper respiratory medical device. Give artificial respiration if the victim is not breathing. Get medical attention immediately.

Ingestion

Rinse mouth and lips with plenty of water if a person is conscious. Do not induce vomiting. Do not use mouth-to-mouth method if the victim had ingested the substance. Obtain medical attention immediately if ingested.

Notes to Physician

Treat as a corrosive due to pH of the material. All treatments should be based on observed signs and symptoms of distress in the patient.

B. FIRE FIGHTING INFORMATION

Extinguishing Media

Use dry chemical, carbon dioxide, water spray or fog, or foam.

Specific Exposure Hazards

Containers may explode when heated. Emits toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following materials: halogenated compounds, may release dangerous gases (chlorine).

Special Protective Equipment for Firefighters

Structural firefighter's protective clothing provides limited protection in fire situations only; it is not effective in spill situations where direct contact with the substance is possible. Wear chemical protective clothing that is specifically recommended by the manufacturer. It may provide little or no thermal protection. Wear positive pressure self-contained breathing apparatus (SCBA). Move containers from fire area if you can do it without risk.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions

Ventilate enclosed areas. Do not walk through spilt material. Do not touch damaged containers or spilt material unless wearing appropriate protective clothing. Wear appropriate personal protective equipment, avoid direct contact. Do not breath mist, vapours, or spray. Do not get in eyes, on skin, or on clothing.

Environmental Precautions

Prevent entry into waterways, sewers, basements or confined areas.

Steps to be Taken if Material is Released or Spilt

ELIMINATE all ignition sources (no smoking, flares, sparks or flames in immediate area). As an immediate precautionary measure, isolate spill or leak area for at least 50 meters in all directions. Keep unauthorised personnel away. Stay upwind. Keep out of low areas. Do not get water inside container.

D. STORAGE AND HANDLING

General Handling

Handle and open container with care. Use only with adequate ventilation. Keep away from heat. Use caution when combining with water. DO NOT add water to corrosive liquid, ALWAYS add corrosive liquid to water while stirring to prevent the release of heat, steam, and fumes. Wear appropriate personal protective equipment, avoid direct contact. Do not breath mist, vapours, or spray. Do not get in eyes, on skin, or on clothing. Do not ingest. Wash thoroughly with soap and water after handling and before eating, drinking, or using tobacco.

Storage

Keep contain tightly closed. Store in a cool, dry, well-ventilated place. Keep away from incompatible materials. Keep from direct sunlight. Separate from alkalis. Do not store above 49^{o}C/120^{o}F.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards

The workplace exposure standard for hydrochloric acid in Australia is 5 ppm (7.5 mg/m^3 as a peak limitation, with a sensitisation notation. A peak limitation is defined by Safe Work Australia as a maximum or peak airborne concentration of a substance determined over the shortest analytically practicable period of time which does not exceed 15 minutes.

Engineering Controls

Good general ventilation should be used. Ventilation rates should be matched to conditions. If applicable, use process enclosures, local exhaust ventilation, or other engineering controls to maintain airborne levels below recommended exposure limits.

Personal Protection Equipment

Respiratory Protection: If workers are exposed to concentrations above the exposure limit, they must use appropriate, certified respirators. Use a properly fitted, air-purifying or air-fed respirator complying with an approved standard if a risk assessment indicates this is necessary. Respirator selection much is based on known or anticipated exposure levels, the hazard of the product and the safe working limits of the selected respirator.

Hand Protection: Chemical-resistant, impervious gloves complying with an approved standard should be worn at all times when handling chemical products if a risk assessment indicates this is necessary. Considering the parameters specified by the glove manufacturer, check during use that the gloves are still retaining their protective properties. It should be noted that the time to breakthrough for any glove material may be different for different glove manufacturers. In the case of mixtures, consisting of several substances, the protection time of the gloves cannot be accurately estimated.

Skin Protection: Personal protective equipment for the body should be selected based on the task being performed and the risks involved and should be approved by a specialist before handling hydrochloric acid.

Eye Protection: Wear chemical splash goggles and face shield.

Other Precautions: Wash hands, forearms, and face thoroughly after handling chemical products, before eating, smoking, and using the lavatory and at the end of the working period. Appropriate techniques should be used to remove potentially contaminated clothing. Wash contaminated clothing before reusing. Ensure that eyewash stations and safety showers are close to the workstation location.

F. TRANSPORT INFORMATION

Australian Dangerous Goods

UN 1789 (HYDROCHLORIC ACID)
Class: 8
Packing Group: II or III

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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XIV. ACRONYMS AND GLOSSARY

°C	degrees Celsius
ADWG	Australian Drinking Water Guidelines
API	American Petroleum Institute
DEWHA	Department of the Environment, Water, Heritage and the Arts
EC	effective concentration
ECHA	European Chemicals Agency
EU	European Union
GHS	Globally Harmonised System of Classification and Labelling of Chemicals

HHRA	enHealth Human Risk Assessment
HPV	High Production Volume
IUPAC	International Union of Pure and Applied Chemistry
Kl	Klimisch scoring system
LOAEL	lowest observed adverse effect level
mg/kg	milligrams per kilogram
mg/L	milligrammes per litre
mg/m^3	milligrammes per cubic metre
MW	molecular weight
NICNAS	The National Industrial Chemicals Notification and Assessment Scheme
NIOSH	National Institute for Occupational Safety and Health
NOAEC	No Observed Adverse Effect Concentration
NOAEL	no observed adverse effect level
NOEC	no observed effective concentration
OECD	Organisation for Economic Co-operation and Development
PBT	Persistent, Bioaccumulative and Toxic
PNEC	Predicted No Effect Concentration
ppm	parts per million
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RfD	Reference Dose
SDS	Material Safety Data Sheet
SMILES	simplified molecular-input line-entry system
TGD	Technical Guidance Document
USEPA	United States Environmental Protection Agency
UVCB Materials	Unknown or Variable Composition, Complex Reaction Products and Biological
WAFs	water accommodated fractions
WHO	World Health Organisation
µm	micrometre

HYDROXYPROPYL GUAR

This dossier on hydroxylpropyl guar does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of hydroxypropyl guar in its use in drilling muds and hydraulic fracturing fluids. Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name: Hydroxylpropyl Guar

CAS RN: 39421-75-5

Molecular weight: 200,000 to 300,000 daltons (Glickman, 1969)

Hydroxypropyl guar a propylene glycol ether derivative of guar gum. Guar gum is a resinous material derived from milled endosperm from guar beans of the legume *Cyamopsis tetragonolobus*. Structurally, it is a galactomannan (high molecular weight carbohydrate polymer) consisting of a main chain of D-mannose with a side chain of D-galactose at approximately every second mannose unit. The mannose units are β-(l-4) linked, and the single D-galactose units are joined to the main chain by α-(1-6) linkages.

SYNONYMS: Hydroxypropyl guar; hydroxypropyl guar gum; guar gum, 2-hydroxypropyl ether

II. PHYSICO-CHEMICAL PROPERTIES

Hydroxypropyl guar is a white to yellow fine powder that is very slightly soluble in water (Johnson et al., 2015).

III. ENVIRONMENTAL FATE PROPERTIES

No biodegradation studies are available on hydroxypropyl gum. Hydroxypropyl guar is the propylene glycol derivative of a carbohydrate polymer consisting of D-mannose and D-galactose sugars from the guar bean. It is expected to be readily biodegradable.

Hydroxypropyl guar is not expected to bioaccumulate based on its large molecular weight.

IV. HUMAN HEALTH HAZARD ASSESSMENT

As the propylene glycol derivative of guar gum, hydroxypropyl guar would be expected to have similar toxicological properties to guar gum. Thus, the toxicity data on guar gum have been used to read-across to hydroxypropyl guar.

A. Summary

There are no mammalian toxicity data available on hydroxypropyl guar, except for one *in vitro* genotoxicity study; thus data on guar gum have been used to read-across to hydroxypropyl guar. Guar gum is exhibits very low acute toxicity by the oral route. It is non-irritating to the skin and minimally irritating to the eyes. Repeated dose toxicity studies showed minimal toxicity in dietary studies. Unlike guar gum, hydroxylpropyl guar was mutagenic in an Ames test in the presence, but not absence, of metabolic activation. Oral exposure to guar gum did not affect fertility in rats; nor was there any indication of developmental toxicity in rats or mice.

B. Acute Toxicity

There are no acute toxicity studies available for hydroxypropyl guar. The oral LD_{50} for guar gum in rats was reported to be 7,060 mg/kg (Graham et al., 1981). [Kl. score = 2]

C. Irritation

There are no irritation studies available for hydroxypropyl guar. Guar gum is non-irritating to the skin, and minimally irritating to the eyes (McCarty *et al.*, 1990).

D. Sensitization

There are no animal sensitization studies available for either hydroxypropyl guar or guar gum.

E. Repeated Dose Toxicity

Oral

There are no repeated dose toxicity studies available for hydroxypropyl guar.

Male and female Osborne-Mendel rats were given diets containing 0, 1, 2, 4, 7.5, or 15% guar gum for 91 days. The average daily intakes are: 0, 580, 1,187, 2,375, 4,561, and 10,301 mg/kg-day for males; and 0, 691, 1,362, 2,762, 5,770, and 13,433 mg/kg-day for females. There were no deaths during the study. Body weights were significantly decreased in the $\geq$1% females and the $\geq$7.5% males. Liver weights were decreased in the $\geq$1% dietary groups. Kidney weights were decreased in the $\geq$7.5% dietary groups and were borderline significant in the 4% group. The 15% males had reduced bone marrow cellularity; although the level was within normal limits, several of the rats were at the

lower end of the normal range. The LOAEL for this study is 691 mg/kg-day based on reduced body weights in the female rats (Graham et al., 1981). [Kl. score = 2]

Male and female F344 rats and $B6C3F_1$ mice were given diets containing 0, 6,300, 12,500, 25,000, 50,000 or 100,000 ppm guar gum for 13 weeks. Mean body weights were decreased in the 100,000 ppm male rats and in the $\geq$50,000 ppm female mice. A dose-related decrease in feed consumption was observed for male and female rats; male and female mice were comparable or higher than that of controls. There were no compound-related clinical signs or histopathological effects. The NOAELs for this study is 50,000 and 25,000 ppm for rats and mice, respectively. Using the fraction of body weight that rats and mice consume per day as food (0.05 and 0.13, respectively; U.S. EPA), the NOAELs corresponds to 2,500 mg/kg-day for rats and 3,250 mg/kg-day for mice (NTP, 1982). [Kl. score = 2]

Male and female F344 rats and $B6C3F_1$ mice were given diets containing 0, 25,000 ppm or 50,000 ppm guar gum for 103 weeks. Mean body weights of the high-dose females were lower than those of the controls after week 20 for mice and week 40 for rats. No compound-related clinical signs or adverse effects on survival were observed. Feed consumption by dosed rats and mice of either sex was lower than that of controls. There were no non-neoplastic histopathological effects in either rats or mice that were treatment-related. The NOAEL for both rats and mice is 25,000 ppm. Using the fraction of body weight that rats and mice consume per day as food (0.05 and 0.13, respectively; U.S. EPA), the NOAELs corresponds to 1,250 mg/kg-day for rats and 3,250 mg/kg-day for mice (NTP, 1982). [Kl. score = 2]

Inhalation

No studies are available.

Dermal

No studies are available.

F. Genotoxicity

In Vitro Studies

Hydroxypropyl guar was not mutagenic to *S. typhiumurium* strains TA 98, TA 100, TA 1535, TA 1537, and TA 1538 in the absence of metabolic activation. In the presence of metabolic activation hydroxypropyl guar was mutagenic to S. typhimurium strains TA 98, TA 100, TA 1537, and TA 1538, but not to TA 1535 (Johnson et al., 2015).

In Vivo Studies

There are no studies available for hydroxypropyl guar.

G. Carcinogenicity

There are no studies available for hydroxypropyl guar.

H. Reproductive Toxicity

Oral

There are no studies available for hydroxypropyl guar.

Male and female Osborne-Mendel rats were fed diets containing 0, 1, 3, 4, 7.5, or 15% guar gum for 13 weeks before mating, during mating and throughout gestation. The daily intake for the female rats during gestation were 0, 700, 1,400, 2,700, 5,200, or 11,800 mg/kg-day. Fertility was unaffected by treatment. There were slightly fewer corpora lutea and implantations in the 15% dietary group, but implantation efficiency was unaffected. The NOAEL for reproductive toxicity is 5,200 mg/kg-day (Collins et al., 1987). [Kl. score = 2]

I. Developmental Toxicity

Oral

There are no studies available for hydroxypropyl guar.

Male and female Osborne-Mendel rats were fed diets containing 0, 1, 3, 4, 7.5, or 15% guar gum for 13 weeks before mating, during mating and throughout gestation. The daily intake for the female rats during gestation were 0, 700, 1,400, 2,700, 5,200, or 11,800 mg/kg-day. There were no deaths during the study. In the 15% group, the number of viable fetuses per litter were slightly reduced, but was not statistically significantly different from controls. The authors indicate that the reduction may have been an effect of the decreased number of corpora lutea because the number of resorptions was unaffected in this treatment group. There was no treatment-related effect on fetal development or sex distribution, and there was no teratogenic effects (Collins *et al.*, 1987). [Kl. score = 2]

Pregnant female rats were dosed by oral gavage with 0, 9, 42, 200, or 900 mg/kg guar gum on GD 6 to 15. There was no maternal or developmental toxicity at any dose level. The NOAEL for maternal and developmental toxicity is 900 mg/kg-day (FDRL, 1973). [Kl. score = 2]

Pregnant female CD-1 mice were dosed by oral gavage with 0, 8, 37, 170, or 800 mg/kg guar gum on GD 6 to 15. A significant number of deaths (6 out of 29) occurred in the 800 mg/kg dose group. There was indications of maternal toxicity in the surviving high-

dose dams. There was no developmental toxicity at any dose level. The NOAELs for maternal and developmental toxicity is 170 and 800 mg/kg-day, respectively (FDRL, 1973). [Kl. score = 2]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for guar gum follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

In a two-year NTP chronic bioassay, female rats and mice given 50,000 ppm guar gum in their feed had lower body weights. There were no treatment-related nonneoplastic lesions observed in either rats or mice. The NOAEL for this study is 25,000 ppm for rats and mice, which corresponds to 1,250 mg/kg-day for rats and 3,250 mg/kg-day for mice.

The NOAEL of 1,250 mg/kg-day will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 1,250/(10 x 10 x 1 x 1 x 1) = 1,250/100 = 13 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (13 x 70 x 0.1)/2 = 46 mg/L

B. Cancer

There are no carcinogenicity studies on hydroxypropyl guar. Thus, a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Hydroxypropyl guar does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

No studies are available on the aquatic or terrestrial toxicity of hydroxypropyl guar. As the hydroxypropyl derivative of guar gum, it would be expected to have similar properties to a non-ionic polymer and exhibit low to potentially moderate acute toxicity to aquatic organisms.

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Hydroxypropyl guar is a derivative of a naturally occurring polysaccharide from the guar plant or cluster bean; it expected to be readily biodegradable. Thus, it is not expected to meet the screening criteria for persistence.

The molecular weight of hydroxypropyl guar ranges from 200,000 to 300,000 daltons. Thus, guar gum is not expected to meet the criteria for bioaccumulation.

No aquatic toxicity data are available on hydroxypropyl guar. It is not possible to determine whether hydroxypropyl guar meets the toxicity criteria.

The overall conclusion is that hydroxypropyl guar is unlikely to be a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Not classified.

B. Labelling

No signal word.

C. Pictogram

None.

X. SAFETY AND HANDLING

Eye Contact
In case of contact, immediately flush eyes with plenty of water for at least 15 minutes.

Skin Contact
Remove contaminated clothing. Wash thoroughly with soap and water.

Inhalation
If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Ingestion
Rinse mouth with water and then drink plenty of water. Never give anything by mouth to an unconscious person.

Notes to Physician
May cause asthma-like (reactive airways) symptoms.

B. FIRE FIGHTING INFORMATION

Extinguishing Media

Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: carbon monoxide, carbon dioxide.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus for fire fighting.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Avoid dust formation.

Environmental Precautions
No special environmental precautions required.

Steps to be Taken if Material is Released or Spilled
Sweep up and dispose in suitable, closed containers.

D. STORAGE AND HANDLING

General Handling
Avoid creating or inhaling dust.

Storage
Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
Workplace Australia has not established an occupational exposure standard specifically for hydroxypropyl guar.

Engineering Controls
Ensure adequate ventilation.

Personal Protection Equipment

Respiratory Protection:
Respiratory protection is not required.

Hand Protection:

Handle with gloves.

Skin *Protection*:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Safety glasses with side-shields.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible.

F. TRANSPORT INFORMATION

Hydroxypropyl guar is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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LACTOSE

This dossier on lactose does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of lactose in its use in drilling muds and hydraulic fracturing fluids. Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC): β-D-galacto-hexopyranosyl-(1→4)-α-D-glucose

CAS RN: 63-42-3

Molecular formula: $C_{12}H_{22}O_{11}$

Molecular weight: 342.3

Synonyms: Lactose; alpha-lactose; lactose anhydrous; β-D-galacto-hexopyranosyl-(1->4)-α-D-gluco-hexopyranose; β-D-galactopyranosyl-4)-α-D-glucopyranose; α-D-glucopyranose, 4-O- β-D-galactopyranosyl-

SMILES: O=CC(O)C(O)C(OC(OC(C(O)C1O)CO)C1O)C(O)CO

Lactose is a disaccharide sugar composed of galactose and glucose. It is naturally synthesized in the mammary gland of virtually all mammals, occurring in milk at levels between 1 and 7%. Commercially, lactose is extracted from the whey of cow's milk (whey is the residual liquid of milk following cheese and casein production) and is purified extensively to remove fats, proteins, vitamins and minerals (Baldrick and Bamford, 1997; Goodhart, 1994).

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Lactose

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	White, crystalline powder	4	Lide (2007)
Melting Point	254°C	4	Lide (2007)
Density	1.59 g/cm^3 @ 20°C	4	Lide (2007)
Partition Coefficient (log	-5.03 (estimated)	-	EPA (2017)

K_{ow})			

III. ENVIRONMENTAL FATE PROPERTIES

No biodegradation studies were found on lactose. As a disaccharide of galactose and glucose sugars, lactose would be expected to be readily biodegradable. It would also not be expected to bioaccumulate or adsorb to sediments or soil.

Using KOCWIN in EPISUITE™ (EPA, 2017), the estimated K_{oc} values from the molecular connectivity index (MCI) is 1 L/kg.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Lactose has essentially no acute toxicity by the oral route. Many of the findings from the oral rat studies on lactose are due to high dietary levels used in the studies, which results in a significant proportion reaching the cecum and colon where it is readily fermented by the intestinal microflora. Consequently, there is increased production of volatile fatty acids and lactic acid, and a lowering of the pH and increased osmotic pressure. These changes facilitate calcium absorption. Lactose is not genotoxic. Animal studies show no reproductive or developmental toxicity from dietary intake of lactose.

B. Pharmacokinetics/Metabolism

Following oral ingestion, lactose is readily hydrolyzed in the gastrointestinal tract to galactose and glucose by the enzyme lactase (Hansen, 1974; Williams, 1986). Lactase is a β-galactosidase found in the brush border of the intestinal epithelium. Once hydrolyzed, the monosaccharides are then readily absorbed. Lactose can also be hydrolyzed by other enzymes, such as acid β-galactosidase.

C. Acute Toxicity

The acute oral LD_{50} in rats has been reported to be >10,000 mg/kg (Baldrick and Bamford, 1997).

D. Irritation

No studies are available.

E. Sensitization

No studies are available.

F. Repeated Dose Toxicity

Oral

Male and female Wistar rats were fed diets containing 20% lactose for 12 weeks before mating, and during pregnancy and lactation. At weaning, the animals were fed the same diet and the study was terminated at week 130. There were low body weights; increased blood alkaline phosphatase and urinary calcium; decreased pH of cecum contents; enlargement/increased weight of the cecum; pelvic nephrocalcinosis of the kidneys; and increased proliferation of the bile ducts; and adrenal medullary hyperplasia. The LOAEL is 20,000 ppm lactose. Using 0.05 as the fraction of body weight that rats consume per day as food (U.S. EPA), the NOAELs corresponds to 1,000 mg/kg-day (Sinkeldam *et al.*, 1992a).

Similar findings were also observed in another study in which rats were fed 20% lactose in their diet for 130 weeks. Findings included loose feces (week one and two only); decreased pH of the feces; low body weights; increased food and water consumption; increased blood alkaline phosphatase and decreased bicarbonate; increased calcium concentration and excretion; reduced urinary pH; increased cecum weight; mineralization of the renal pelvis; increased incidence of basophilic cell foci in the adrenal medulla; and Leydig cell hyperplasia. The LOAEL is 20,000 ppm lactose. Using 0.05 as the fraction of body weight that rats consume per day as food (U.S. EPA), the NOAELs corresponds to 1,000 mg/kg-day (De Groot *et al.*, 1995).

Inhalation

A brief summary of inhalation studies conducted in rats, dogs, monkeys, and macaques showed no findings of toxicological significance (Baldrick and Bamford, 1997).

Dermal

No studies were available.

G. Genotoxicity

In Vitro Studies

Lactose was negative in an *in vitro* chromosomal aberration study with cultured human lymphocytes with or without metabolic activation (Sinkeldam *et al.*, 1992a).

In Vivo Studies

No studies are available.

H. Carcinogenicity

Male and female Wistar rats were fed diets containing 20% lactose for 12 weeks before mating, during mating, and during pregnancy and lactation. At weaning, the animals were fed the same diet and the study was terminated at week 130. There were increased adrenal medulla pheochromocytomas and Leydig cell tumors (males only) in the treated rats (Sinkeldam *et al.*, 1992a).

I. Reproductive Toxicity

In a multi-generation study, rats were fed diets containing 20% lactose over three successive generations. There were no adverse effects on fertility or reproductive performance. There was a slight decrease in the number of pups born alive, litter size at birth, viability index and pup weight for F_0 and F_1 offspring. There were signs of low body weights in the parental animals, and enlargement and increased weight of the cecum (Sinkeldam *et al.*, 1992b).

J. Developmental Toxicity

Pregnant mice were given 10,000 mg/kg lactose during gestation days 8-12. No maternal toxicity was observed and there were no effects on litter size, body weight on days 1 and 3, or neonate survival (Seidenberg *et al.*, 1986).

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for lactose follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

<u>Oral</u>

Many of the findings from the oral studies on lactose are due to high dietary levels used in the studies, which results in a significant proportion reaching the cecum and colon where it is readily fermented by the intestinal microflora. Consequently, there is increased production of volatile fatty acids and lactic acid, and a lowering of the pH and increased osmotic pressure. These changes facilitate calcium absorption.

Non-neoplastic adverse effects were noted in rats given 20% in their diet for 130 weeks (Sinkeldam *et al.*, 1992a; De Groot *et al.*, 1995). The LOAEL from these studies are 1,000 mg/kg-day. Since only one dose level was used in these studies, a NOAEL was not identified. The LOAEL of 1,000 mg/kg-day will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 10
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 1,000/(10 x 10 x 10 x 1 x 1) = 1,000/1,000 = <u>1.0 mg/kg-day</u>

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (1 x 70 x 0.1)/2 = <u>3.5 mg/L</u>

B. Cancer

Increased adrenal medulla pheochromocytomas and Leydig cell tumors were noted rats given lactose in their diet for 130 weeks (Sinkeldam *et al.*, 1992a). The adrenal medulla pheochromocytomas tumors from high dietary administration of low digestible carbohydrates (includes lactose) are thought to be secondary to increased calcium absorption from the intestine. This appears to be rat-specific; altered calcium

homeostasis does not appear to occur in humans ingesting carbohydrates such as lactose (Lynch *et al.*, 1996). Thus, the adrenal medulla pheochromocytomas are unlikely to be relevant to human. Increased Leydig cell tumors in male rats are also of questionable relevance to humans. Thus a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Lactose does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Lactose is expected to be of low toxicity concern to aquatic organisms based on QSAR modeling results.

B. Aquatic Toxicity

Acute Studies

No aquatic toxicity studies were found on lactose.

Using ECOSAR, the 96-hour LC_{50} in fish was estimated to be 93,396 mg/L; the 48-hour LC_{50} in *Daphnia* and the 96-hour EC_{50} in green algae exceed the estimated water solubility of 111,000 mg/L (U.S. EPA, 2017).

Chronic Studies

No studies are available.

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for lactose follow the methodology discussed in DEWHA (2009).

PNEC water

No experimental results are available for lactose. Acute $E(L)C_{50}$ estimates using the QSAR model ECOSAR are: fish (93,396 mg/L), *Daphnia* (>111,000 mg/L), and algae (>111,000 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported $E(L)C_{50}$ value of 93,396 mg/L for fish. The $PNEC_{water}$ is 93 mg/L.

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 59.6 mg/kg sediment wet weight.

The calculations are as follows:

$$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$$
$$= (0.82/1280) \times 1000 \times 93$$
$$= 59.6$$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$$K_{sed\text{-}water} = 0.8 + [0.2 \times Kp_{sed})/1000 \times BD_{solid}]$$
$$= 0.8 + [0.2 \times 0.04/1000 \times 2400]$$
$$= 0.82$$

Where:
Kp_{sed} = solid-water partition coefficient (L/kg).
BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$$Kp_{sed} = K_{oc} \times f_{oc}$$
$$= 1 \times 0.04$$
$$= 0.04$$

Where:
K_{oc} = organic carbon normalized distribution coefficient (L/kg). The K_{oc} for lactose calculated from EPISUITE™ using lthe MCI is 1.0 L/kg .
F_{oc} = fraction of organic carbon in sediment = 0.04 [default].

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is 1.24 mg/kg soil dry weight.

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
$= (0.02/1500) \times 1000 \times 93$
$= 1.24$

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
$= 1 \times 0.02$
$= 0.02$

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for lactose calculated from EPISUITE™ using the MCI is 1.0 L/kg .
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

No biodegradation data are available on lactose. Lactose is a disaccharide found in milk and consists of D-galactose and D-glucose sugars. it is expected to be readily biodegradable; therefore, it does not meet the screening criteria for persistence.

Lactose is a disaccharide that has an estimated log K_{ow} of -5. It is water-soluble and is rapidly metabolized by enzymes. It is not expected to bioaccumulate.

The estimated acute $E(L)C_{50}$ value in fish is >1 mg/L. Thus it does not meet the screening criteria for toxicity.

The overall conclusion is that lactose is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Not classified.

B. Labelling

No signal word.

C. Pictogram

None.

X. SAFETY AND HANDLING

Eye Contact
Immediately flush eyes with plenty of water.

Skin Contact
Wash with soap and water.

Inhalation
If inhaled, remove from area to fresh air. If not breathing, give artificial respiration. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Ingestion
Do not induce vomiting. Rinse mouth with water and then drink a small amount of water. Get medical attention. Never give anything by mouth to an unconscious person.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
Combustible dust. May form dust explosion hazard in air. May emit toxic fumes under fire conditions.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus and chemical-protective clothing.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions

Use appropriate protective equipment. Avoid creating and breathing dust.

Environmental Precautions

No special precautions needed.

Steps to be Taken if Material is Released or Spilled

Scoop and remove.

D. STORAGE AND HANDLING

General Handling

Avoid creating or inhaling dust. Take precautionary measures against static charge.

Storage

Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
Workplace Australia has not established an occupational standard for lactose.

Engineering Controls

Use in a well-ventilated area. Avoid creating dust. Take precautionary measures against static charge.

Personal Protection Equipment

Respiratory Protection: Respiratory protection is not required.

Hand Protection: Use gloves.

Skin Protection: Body protection must be chosen depending on activity and possible exposure.

Eye Protection: Safety glasses with side-shields.

Other Precautions: Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible.

F. TRANSPORT INFORMATION

Lactose is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods Code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

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HYDROCARBONS, C12-C15, N-ALKANES, ISOALKANES, CYCLICS, <2% AROMATICS

This dossier on hydrocarbons, C12-C15, n-alkanes, isoalkanes, cyclics, <2% aromatics (C12-C15 aliphatic hydrocarbons (<2% aromatics)) does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of C12-C15 aliphatic hydrocarbons (<2% aromatics) in its use in drilling muds and hydraulic fracturing fluids. The information presented in this dossier was obtained primarily from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name: Hydrocarbons, C12-C15, n-alkanes, isoalkanes, cyclics, <2% aromatics

CAS RN: 64742-47-8 [CAS No. 869062-45-3; EC No. 920-107-4]

Historically, hydrocarbons, C12-C15, n-alkanes, isoalkanes, cyclics, <2%aromatics was included within the CAS RN 64742-47-8 for distillates, (petroleum), hydrotreated, light. This CAS RN is broadly defined as "A complex combination of hydrocarbons obtained by treating a petroleum fraction with hydrogen in the presence of a catalyst. It consists of hydrocarbons having carbon number predominantly in the range of C9 to C16 and boiling in the range of approximately 150^{o}C to 290^{o}C (302^{o} to 554^{o}F)." This CAS RN can include hydrocarbon streams and solvents that can vary widely in their compositions, processing, and classifications. The EU Hydrocarbon Solvents Producers Association (HSPA), for the purposes of REACH registrations, established more precise definitions for hydrocarbon solvents and established a new substance identification and naming convention.[1] Hydrocarbons, C12-C15, n-alkanes, isoalkanes, cyclics, < 2% aromatics would have the CAS RN 869062-45-3 and EC. No. 920-107-4 and would be within the HSPA category for C9-C14 Aliphatics ($\leq$2% aromatics).

Molecular formula: Not available (UVCB substance)

Molecular weight: Not available (UVCB substance)

Synonyms: Hydrocarbons, C12-C15, n-alkanes, isoalkanes, cyclics, <2% aromatics; distillates, petroleum, hydrotreated, light; C12-C15 aliphatic hydrocarbons (<2% aromatics)

SMILES: Not available (UVCB substance)

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of C12-C15 Aliphatic Hydrocarbons (<2% Aromatics)

[1] https://www.reachcentrum.eu/Consortia%20Documents/P-I163/Other/20110401160024-HSPA_CAS_April__2011.pdf.

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Colorless to faint yellow with a slight odor.	2	ECHA
Melting point	-30°C	2	ECHA
Boiling point	233 to 266°C	2	ECHA
Density	0.79 to 0.85 g/cm^3 @ 15°C	2	ECHA
Vapor pressure	0.003 kPa @ 20°C (calculated)	2	ECHA
Partition coefficient (log K_{ow})	Not determined (UVCB substance)	-	-
Water solubility	Not determined (UVCB substance)	-	-
Flash point	102°C	2	ECHA
Auto flammability	>200°C	2	ECHA
Viscosity	3.56 mm^2/s @ 20°C	2	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

There are no biodegradation data on C11-C15 aliphatic hydrocarbons (<2% aromatics). However, a hydrocarbons, C11-14, n-alkanes, isoalkanes, cyclics (<2% aromatics) hydrocarbon fluid was shown to be readily biodegradable. The C12-C15 aliphatic hydrocarbons (<2% aromatics) are expected to highly absorb to sediment and soil. The C12-C15 aliphatic hydrocarbons (<2% aromatics) is expected to have constituents with the potential to bioaccumulate.

B. Biodegradation

No biodegradation data are available on C12-C15 aliphatic hydrocarbons (<2% aromatics).

In an OECD 301F test, degradation of hydrocarbons, C11-14, n-alkanes, isoalkanes, cyclics (<2% aromatics) hydrocarbon fluid was 69% after 28 days (ECHA) [Kl. score = 1]. The results indicate that this substance is readily biodegradable even though it did not meet the 10-day window because the criterion does not apply to multi-component substance when assessing their ready biodegradability (ECHA) [Kl. score = 1].

D. Environmental Distribution

C12-C15 aliphatic hydrocarbons (<2% aromatics) and C9-C14 aliphatic hydrocarbons (≤2% aromatics) are UVCB substances. The standard tests to determine the K_{oc} are for single substances and not for UVCB substances. Therefore, a K_{oc} value for C12-C15 aliphatic hydrocarbons (<2% aromatics) was not determined.

The calculate K_{oc} values for linear aliphatic hydrocarbons dodecane (C12) and tetradecane (C14) are 110,000 and 759,000 L/kg, respectively, using SPARC v4.2 program in the Concawe Library of Petrorisk (ECHA). These values suggest that C12-C15 aliphatic hydrocarbons (<2% aromatics) will highly absorb to sediment and soil.

E. Bioaccumulation

C12-C15 aliphatic hydrocarbons (<2% aromatics) and C9-C14 aliphatic hydrocarbons (≤2% aromatics) are UVCB substances. The calculated BCF values for linear aliphatic hydrocarbons undecane (C11), dodecane (C12), and tetradecane (C14) are 337.8, 790.9, and 962.9 L/kg, respectively using the BCFWIN V2.16 model within EPISuite 3.12. The predicted BCFs for hydrocarbons are considered to be generally overly conservative because biotransformation is not quantitatively taken into account. For these linear aliphatic hydrocarbons, the values indicate that they are not expected to bioaccumulate. However, both C12-C15 aliphatic hydrocarbons (<2% aromatics) and C9-C14 aliphatic hydrocarbons (≤2% aromatics) contain branched and cyclic aliphatic hydrocarbons that are expected to have a greater potential to bioaccumulate.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

The acute toxicity of C9-C14 aliphatic hydrocarbons (≤2% aromatics) is low by the oral, dermal, and inhalation route. It is, however, an aspiration hazard. C9-C14 aliphatic hydrocarbons (≤2% aromatics) are neither skin nor eye irritants or a dermal sensitizer. Repeated inhalation exposure of rats to a C9-C14 aliphatic (≤2% aromatic) hydrocarbon fluid showed no target organ effects; oral exposures to very high doses of these hydrocarbons showed irritation to the gastrointestinal tract and effects in the liver that likely represent an adaptive response to the metabolism of the hydrocarbons and not a toxic response. C9-C14 aliphatic hydrocarbons (≤2% aromatics) are not genotoxic; nor do they exhibit and evidence of reproductive or developmental toxicity in rats.

B. Acute Toxicity

The oral LD_{50} in rats for C9-C14 aliphatic, ≤2% aromatic hydrocarbon fluids is >5,000 mg/kg (ECHA) [Kl. score = 2.

The 4-hour inhalation LC_{50} in rats for C9-C14 aliphatic, ≤2% aromatic hydrocarbon fluids is > 4,951 mg/m^4 (ECHA) [Kl. scores =1 and 2].

The dermal LD_{50} in rats for C9-C14 aliphatic, ≤2% aromatic hydrocarbon fluids is >5,000 mg/kg (ECHA) [Kl. score = 2].

C. Irritation

C9-C14 aliphatic, ≤2% aromatic hydrocarbon fluids are neither skin nor eye irritants (ECHA) [Kl. scores = 1 and 2].

D. Sensitization

C9-C14 aliphatics, <2% aromatic hydrocarbon fluids were not skin sensitizers when tested in guinea pig maximization tests (ECHA) [Kl. score = 2].

A C9-C14 aliphatic, <2% aromatic hydrocarbon fluid showed no indication of skin sensitization in a human repeated insult patch test (ECHA).

E. Repeated Dose Toxicity

Oral

Male and female rats were dosed by oral gavage with 0, 500, 2,500 or 5,000 mg/kg with a C9-C14 aliphatic, <2% aromatic hydrocarbon fluid 7 days/week for 13 weeks. Additional groups of animals were dosed with 0 or 5,000 mg/kg for 13 weeks, followed by a 4-week recovery period. There were dose-related changes in the hematology and serum chemistry parameters which were consistent with changes seen in the liver. Hepatocellular hypertrophy (liver cell enlargement) were seen in both males and females in all dose groups and were reversible. The liver effects were not considered to be an indication of toxicity but an adaptive response due to the metabolism of the hydrocarbons. There were also mucosal thickening and other signs of irritation to the stomach and anus, which appeared to be the direct result of high-dose intubation of a locally irritating material. All treatment-related effects were reversible within the 4-week recovery period. The NOAEL for systemic effects in this study is considered to be 5,000 mg/kg-day (ECHA) [Kl. score = 1].

Inhalation

Male and female rats were exposed by inhalation to 0, 2,600, 5,200, or 10,400 mg/m^3 of a C9-C14 aliphatic (<2% aromatic) hydrocarbon fluid, 6 hours/day, five days/week for 13 weeks. There was no mortality or effects in either the hematology or the serum chemistry parameters. The male rats at all dose levels had increased liver and kidney weights; male heart weights were also increased at 10,400 mg/m^3; and kidney weights were increased in the 10,400 mg/m^3 group. Kidney effects indicative of alpha-2u-globulin nephropathy was observed at all dose levels. There were no other effects that were considered to be treatment-related. The alpha-2u-nephropathy in the male rats was not considered to be relevant to humans; for the organ weight changes other than the male kidneys, there were no corresponding histopathologic changes. The NOAEL for this study is 10,400 mg/m^3, the highest exposure concentration tested (ECHA) [Kl. score = 1].

Dermal

No studies are available.

F. Genotoxicity

In Vitro Studies

The key *in vitro* genotoxicity studies on C9-C14 aliphatic hydrocarbons (≤2% aromatics) are presented in Table 2.

Table 2: *In vitro* Genotoxicity Studies on C9-C14 Aliphatic Hydrocarbons (≤2% Aromatics)

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* and *E. coli* strains)	-	-	1	ECHA
Mammalian cell gene mutation (Chinese hamster V 79 cells)	-	-	2	ECHA
Chromosomal aberration (human lymphocytes)	-	-	1	ECHA

*+, positive; -, negative

In Vivo Studies

In two separate studies involving two different C9-C14 aliphatic (<2% aromatic) hydrocarbon fluids, male and female CD-1 mice were given a single oral gavage dose at concentrations of 0, 1,250, 2,500, or 5,000 mg/kg. The frequency of micronucleated polychromatic erythrocytes was not significantly increased in the treated mice compared to that in the controls (ECHA) [Kl. score = 1].

In two separate dominant lethal studies involving two different C9-C14 aliphatic (<2% aromatic) hydrocarbon fluids, male rats were exposed for 6 hours/day for five consecutive days to exposure concentrations of 0, 300, or 900 ppm. There was no evidence of a mutagenic response in the treated rats (ECHA) [Kl. score = 2].

G. Carcinogenicity

No carcinogenicity studies are available on the C9-C14 aliphatic (<2% aromatic) hydrocarbon fluids.

H. Reproductive Toxicity

A C9-C14 aliphatic (<2% aromatic) hydrocarbon fluid was tested in a combined repeated dose toxicity study with a reproductive/developmental toxicity screening test (OECD 422). Male and female SD rats were given oral gavage doses of 0, 25, 150, or 1,000 mg/kg-day. There was no

indication of reproductive toxicity at any dose level. The NOAEL for reproductive toxicity is 1,000 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 1].

A C9-C14 aliphatic (<2% aromatic) hydrocarbon fluid was tested in a reproductive/developmental toxicity screening test (OECD 421). Male and female SD rats given oral gavage doses of 0, 100, 300, or 1,000 mg/kg-day. There was no indication of reproductive toxicity or any effects on the endocrine system at any dose level. The NOAEL for reproductive toxicity is 1,000 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 1].

I. Developmental Toxicity

A C9-C14 aliphatic (<2% aromatic) hydrocarbon fluid was tested in a rat pre-natal developmental toxicity study. Pregnant female rats were exposed by inhalation to 0, 300 or 900 ppm for 6 hours/day during gestation days 6 to 15. There was no evidence of maternal or developmental toxicity at either exposure level. The NOAEL for this study is 900 ppm (ECHA) [Kl. score = 1].

Another C9-C14 aliphatic (<2% aromatic) hydrocarbon fluid was tested in a rat pre-natal developmental toxicity study. Pregnant female rats were exposed by inhalation to 0, 300 or 900 ppm for 6 hours/day during gestation days 6 to 15. There was no evidence of maternal or developmental toxicity at either exposure level. The NOAEL for this study is 900 ppm (ECHA) [Kl. score = 1].

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for C12-C15 aliphatic hydrocarbons (<2% aromatics) follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

A 13-week oral gavage study was conducted on a C9-C14 aliphatic (<2% aromatic) hydrocarbon fluid in rats. There were no adverse effects at 5,000 mg/kg-day, the highest dose tested. The NOAEL of 5,000 mg/kg-day will be used to derive the oral reference dose and the drinking water guidance value for C12-C15 aliphatic hydrocarbons (<2% aromatics).

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 3

UF_D (database uncertainty) = 1

Oral RfD = 5,000/(10 x 10 x 1 x 3 x 1) = 5,000/300 = 17 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (17 x 70 x 0.1)/2 = 60 mg/L

B. Cancer

No carcinogenicity studies are available on C9-C14 aliphatic (<2% aromatic) hydrocarbon fluids. Thus, a cancer reference value was not derived for C12-C15 aliphatic hydrocarbons (<2% aromatics).

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

C12-C15 aliphatic hydrocarbons (<2% aromatics) do not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

C12-C15 aliphatic hydrocarbons (<2% aromatics) has a low acute toxicity concern to aquatic life.

B. Aquatic Toxicity

Acute Studies

There are no aquatic toxicity data on C12-C15 aliphatic hydrocarbons (<2% aromatics). Table 3 lists the results of acute aquatic toxicity studies conducted on a C11-C14 aliphatic hydrocarbon fluid (<2% aromatics).

Table 3: Acute Aquatic Toxicity Studies on C11-C14 Aliphatic Hydrocarbon Fluid (<2% Aromatics)*

Test Substance	Test Species	Endpoint	Results (mg/L) [WAF]	Kl. score
C11-C14, n-alkanes, isoalkanes, cyclics (<2% aromatics)	*Oncorhynchus mykiss*	96-h LL_{50}	>1,000	1
C11-C14, n-alkanes, isoalkanes, cyclics (<2% aromatics)	*Daphnia magna*	48-h LL_{50}	>1,000	1
C11-C14, n-alkanes, isoalkanes, cyclics (<2% aromatics)	*Pseudokirchnerella subcapitata*	72-h LL_{50} 72-hr NOELR	>1,000	1

*All studies used the water accommodated fractions (WAFs) of the test substance.

Chronic Studies

The value for NOELRs were estimated by QSAR model – Petrotox. This model combines a partitioning model used to calculate the aqueous concentration of hydrocarbon components with the Target Lipid Model used to calculate acute and chronic toxicity of non-polar narcotic chemicals. Petrotox computes toxicity based on the summation of the aqueous-phase concentrations of hydrocarbon block(s) that represent a hydrocarbon substance and membrane-water partition coefficients that describe the partitioning of the hydrocarbons between the water and organisms.

The 28-day NOELR (No-Observed-Effect-Loading-Rate) for hydrocarbons, C12-15, aliphatic hydrocarbons (<2% aromatics) in freshwater fish is estimated to be >1,000 mg/L based on growth (ECHA) [Kl. score = 2].

The 28-day NOELR (No-Observed-Effect-Loading-Rate) for hydrocarbons, C12-15, aliphatic hydrocarbons (<2% aromatics) in freshwater invertebrates is estimated to be >1,000 mg/L based on reproduction (ECHA) [Kl. score = 2].

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for C12-C15 aliphatic hydrocarbons (<2% aromatics) follow the methodology:

PNEC water
Using the QSAR model PETRORISK v7.04, the estimated $PNEC_{water}$ value for C11-15-iso- is 0.001 mg/L (CONCAWE) [Kl. score = 2].

PNEC sediment
Using the QSAR model PETRORISK, v7.04 the estimated $PNEC_{sediment}$ value for C11-15-iso- range from 42 to 260 mg/kg soil wet weight (CONCAWE), depending on the composition of the hydrocarbon classes (n- or iso-paraffins and type of cyclic paraffins) (CONCAWE) [Kl. score = 2].

PNEC soil
Using the QSAR model PETRORISK v7.04, the estimated $PNEC_{sediment}$ value for C11-15-iso- is 17 to 100 mg/kg soil wet weight (CONCAWE), depending on the composition of the hydrocarbon classes (n- or iso-paraffins and type of cyclic paraffins) (CONCAWE) [Kl. score = 2].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Hydrocarbons, C11-14, n-alkanes, isoalkanes, cyclics (<2% aromatics) hydrocarbon fluid was readily biodegradable. Thus, C12-C15 aliphatic hydrocarbons (<2% aromatics) is not expected to meet the screening criteria for persistence.

C12-C15 aliphatic hydrocarbons (<2% aromatics) is an UVCB substance that contains constituents that have the potential to bioaccumulate. Thus, C12-C15 aliphatic hydrocarbons (<2% aromatics) meets the screening criteria for bioaccumulation.

Hydrocarbons, C11-14, n-alkanes, isoalkanes, cyclics (<2% aromatics) hydrocarbon fluid did not exhibit acute toxicity to fish, invertebrates, or algae at WAF up to 1,000 mg/L. Thus, C12-C15 aliphatic hydrocarbons (<2% aromatics) is not expected to meet the screening criteria for toxicity.

The overall conclusion is that C12-C15 aliphatic hydrocarbons (<2% aromatics) is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Aspiration Toxicity Category 1

B. Labelling

Danger

C. Pictogram



X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
Immediately flush open eyes with plenty of water for at least 15 minutes. Remove contacts, if present and easy to do. If irritation occurs, get medical attention.

Skin Contact
Wash the contaminated area of with soap and water. Remove and isolate contaminated clothing. Launder contaminated clothing before reuse.

Inhalation
Move person to fresh air. If respiratory irritation, dizziness, nausea, or unconsciousness occurs, seek immediate medical assistance. Give artificial respiration if victim is not breathing.

Ingestion
Do not induce vomiting. Get medical attention immediately.

Notes to Physician
If ingested, material may be aspirated into the lungs and may cause chemical pneumonitis. Treat appropriately.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Use water spray or fog, foam, dry chemical or carbon dioxide. Do not use straight streams of water.

Specific Exposure Hazards
May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: carbon monoxide, carbon oxides.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus and chemical-protective clothing.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Isolate area. Keep unnecessary and unprotected personnel from entering the area. Use personal protective clothing. Ensure adequate ventilation. Wear respiratory protection if ventilation is inadequate. Do not breath mist, vapors, or spray Avoid contact with skin, eye, and clothing.

Environmental Precautions
Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled
Pick up with non-combustible absorbent material and transfer to a container for chemical waste. For large amounts: dike spillage and pump off product into container for chemical waste. Dispose of contaminated material as prescribed.

D. STORAGE AND HANDLING

General Handling
Avoid breathing vapor or aerosol. Keep away from open flames, hot surfaces and sources of ignition. Provide sufficient ventilation in work area.

Storage
Keep container tightly closed and in a dry, well-ventilated place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards

Workplace Australia has not established an occupational exposure standard for C12-C15 aliphatic hydrocarbons (<2% aromatics).

Engineering Controls
Use adequate ventilation to control air-borne concentrations.

Personal Protection Equipment

Respiratory Protection:
If workers are exposed to concentrations at a level that is not adequate to protect work health, they must use appropriate, certified respirators. The following type of respirator should be considered for this material: particulate, dust or mists. For high airborne concentrations, use an approved supplied-air respirator, operated in positive pressure mode.

Hand Protection:
Use gloves chemically resistant to this material. Consult the SDS for appropriate glove barrier materials.

Skin Protection:

Use protective clothing chemically resistant to this material. Selection of specific items such as face shield, boots, apron, or full body suit will depend on the task.

Eye protection*:*
Use chemical goggles.

Other Precautions:
Wash hands, forearms, and face thoroughly after handling chemical products, before eating, smoking, and using the lavatory and at the end of the working period. Appropriate techniques should be used to remove potentially contaminated clothing. Wash contaminated clothing before reusing. Ensure that eyewash stations and safety showers are close to the workstation location.

F. TRANSPORT INFORMATION

C12-C15 aliphatic hydrocarbons (<2% aromatics) is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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METHANOL

This dossier on methanol does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of methanol in its use in drilling muds and hydraulic fracturing fluids. The information presented in this dossier was obtained primarily from the OECD-SIDS documents on methanol (OECD, 2004a, b), and the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch et al., 1997).

I. SUBSTANCE IDENTIFICATION

Chemical Name (IUPAC): Methanol

CAS RN: 67-56-1

Molecular formula: CH_4O

Molecular weight: 32.04

Synonyms: Methyl alcohol, carbinol, wood spirits, wood alcohol, methylol, wood, columbian spirits, colonial spirit, columbian spirit, methyl hydroxide, monohydroxymethane, pyroxylic spirit, wood naphtha.

SMILES: CO

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Physico-Chemical Properties of Methanol

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Colourless liquid	2	ECHA
Melting Point	-97.8°C	2	ECHA
Boiling Point	64.7°C	2	ECHA
Density	0.79 g/cm^3	2	ECHA
Vapour Pressure	169.27 hPa	2	ECHA
Partition Coefficient (log Pow)	-0.77	2	ECHA
Water Solubility	>1,000 g/L [miscible]	2	ECHA
Flash Point	9.7°C	2	ECHA
Auto flammability	455°C @ 1013 hPa	2	ECHA
Viscosity	0.544 – 0.59 mPa s (dynamic)	2	ECHA
Henry's Law Constant	0.461 Pa m^3/mol	2	ECHA

Methanol is a highly flammable liquid.

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Methanol is readily bioavailable. It has a low adsorptive capacity to soils and is unlikely bioaccumulate.

B. Biodegradation

Methanol is readily biodegradable. In a closed bottle test using seawater, there was 84% and 95% degradation after 10 and 20 days, respectively (Price et al., 1974; ECHA). [Kl. score = 2]

In a soil test using [^{14}C]-methanol, there was 53.4% degradation under aerobic conditions after 5 days, as measured by CO_2 evolution; and 46.3% degradation under anaerobic conditions after 5 days, as measured by CO_2 evolution (Scheunert et al., 1987; ECHA). [Kl. score = 2]

C. Environmental Distribution

Adsorption/desorption

The adsorption of methanol was investigated in three different soil types at 6°C (Lokke, 1984; ECHA). There was slight adsorption with the sandy soils tested (percentage organic matter of 0.09% and 0.1% in the samples) and with the clay soil (percentage organic matter was 0.22%). Methanol solutions of concentrations of 0.1, 1.0, 9, and 90 mg/L were used in one-hour exposure adsorption studies; the K_{oc} values were between 0.13 and 0.61 for all soil types and at all concentrations.

D. Bioaccumulation

The BCF of methanol in *Cyprinus carpio* was determined to be 1.0 (Gluth et al. 1985); in *Leuciscus idus*, the BCF was <10 (Hansch and Leo, 1985; Freitag et al. 1985).

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Methanol has a low order of acute toxicity (as measured by lethality) by the oral, dermal, and inhalation routes of exposure, as measured by lethality. Sublethal doses, however, have been shown to produce central nervous system (CNS) effects and ocular injury that may result in blindness. This effect has been seen in primates but not in rodents, and is considered to be due to the differences in blood levels of the metabolites. Acute toxicity in humans is characterized in a well-defined pattern, that includes CNS effects, ocular symptoms, and acidosis. Methanol is not irritating to the skin, but it is slightly irritating to the eyes. Repeated exposures by the oral and inhalation routes have not resulted in any systemic toxicity to rodents. Methanol was not carcinogenic to rats or mice in chronic inhalation studies. Increased tumours from methanol in drinking water were reported by Soffritti et al. (2002); however, there are methodological problems with this study and questions have been raised about the validity of the results. Methanol is generally inactive in a variety of *in vitro* and *in vivo* genotoxicity studies. Conflicting results have been obtained concerning the effect of methanol on testicular hormones in rats; nevertheless, methanol does not appear to a male reproductive toxicant. The primate data indicates that methanol is unlikely to be a reproductive hazard in females. Methanol causes developmental effects at very high exposure levels in both rats (≥ 10,000 ppm) and mice (≥ 2000 ppm). There is also some evidence that it is a developmental neurotoxicant in rodents, but not in primates.

B. Toxicokinetics and Metabolism

Several reviews on the metabolism and pharmacokinetics of methanol are available (Kavet and Nauss, 1990; Liesivuori and Savolainen, 1991; Tephly, 1991; IPCS, 1997; OECD, 2004a, b). Methanol is first oxidized to formaldehyde. This initial metabolic step involves different enzymes in rats than in primates and humans, although the rates are similar. A catalase–peroxidase system is primarily responsible for the initial step in rats, whereas alcohol dehydrogenase plays a major role in humans

and monkeys. Methanol oxidation can also occur via hepatic microsomal oxidation involving the cytochrome P450 system.

Formaldehyde is converted to formic acid, which is converted to formate and a hydrogen ion. Conversion to formic acid is a two-step process, the second step is irreversible. In the first reaction, formaldehyde combines with reduced glutathione (GSH) to form S-formylglutathione. This is mediated by an NAD-dependent formaldehyde dehydrogenase. In the second reaction, thiolase catalyzes the hydrolysis of S-formylglutathione to form formic acid and GSH. A folate-dependent pathway in the liver is responsible for formate metabolism in both rats and primates. Formate first forms a complex with tetrahydrofolate (THF) that is sequentially converted to 10-formyl-THF (by formyl-THF synthetase) and then to CO2 (by formyl-THF dehydrogenase). THF is derived from folic acid in the diet and is also regenerated in the folate pathway. Although the folate pathway metabolizes formate in both rats and monkeys, rats use the pathway more efficiently.

The dermal uptake rate of liquid methanol applied to the forearm of human volunteers was 11.5 mg/cm^2/hr (Dutkiewicz et al., 1980). The dermal flux for methanol in human skin (epidermis) *in vitro* is 8.29 mg/cm^2/hr (Schueplein and Blank, 1971). When 12 human volunteers immersed one hand into a vessel containing neat methanol for up to 16 min, the maximum methanol concentration in blood was reached 1.9 $\pm$ 1.0 hr after exposure. Delivery rates from the skin into blood lagged exposure by 0.5 hours, and methanol continued to enter the blood for 4 hours following exposure. The average derived dermal absorption rate absorption rate was 8.1 $\pm$ 3.7 mg/cm^2/hr. The authors calculated that the maximum concentration of methanol in blood following immersion of one hand in methanol for approximately 20 min is comparable to that reached following inhalation exposures to 200 ppm methanol (Batterman and Franzblau, 1997).

C. Acute Toxicity

The acute oral LD_{50} for rats range from 6,200 to 13,000 mg/kg (Kimura et al., 1971; Welch and Slocum, 1943; Deichman and Mergard, 1948; Smyth et al., 1941). The acute dermal LD_{50} for rabbits was reported to be 20 mL/kg (Rowe and McCollister 1982). The inhalation 4- and 6-hour LC_{50} values in rats are 128.2 and 87.5 mg/L, respectively (BASF, 1980a, b). Sublethal doses, however, produce CNS effects and ocular injury that may result in blindness. This effect has been seen in primates, but not in rodents, and has been attributed to the differences in blood levels of the metabolite, formic acid.

Methanol is metabolized to formate, which is considered to be the ultimate toxicant in acute methanol intoxication in humans. Acute methanol toxicity in humans is characterized by CNS depression, followed by acidosis and ocular injury. Generally, transient CNS effects appear above methanol levels of 200 mg/L and serious ocular symptoms appear above 500 mg/L (OECD, 2004). This blood concentration can transiently be achieved in an adult person (70 kg) by ingestion of 0.4 ml methanol/kg (approximately 0.32 mg/kg). The minimal acute methanol dose to humans that can result in death is considered to be 300 to 1,000 mg/kg by ingestion, and fatalities have occurred in untreated patients with initial methanol blood levels in the range of 1500-2000 mg/L (OECD, 2004). However, such high blood methanol levels able to cause death are not likely to be achieved through inhalation exposure.

D. Irritation

Methanol is not irritating to the skin of rabbits (BASF, 1975), but it is slightly irritating to the eyes of rabbits (BASF, 1975).

E. Sensitization

Methanol was not considered a skin sensitiser to guinea pigs (BASF, 1979).

F. Repeated Dose Toxicity

Oral

Male and female Sprague–Dawley rats were dosed by oral gavage with 0, 100, 500, or 2,500 mg/kg of methanol for 90 days. There were no differences in body weight gain and food consumption between treated and control animals. Brain weights were decreased in both sexes in the 2,500 mg/kg dose group. Elevated serum glutamic pyruvate transaminase and alkaline phosphatase were noted in the 2,500 mg/kg dose group, but there were no adverse treatment-related effects in the gross pathology and histopathological evaluation. The NOAEL is 500 mg-kg-day (USEPA, 1986).

Sprague-Dawley rats were given in their drinking water 0, 500, 5,000 or 20,000 ppm methanol for 104 weeks, and then the animals were maintained until natural death. The study was conducted by the Ramazzini Foundation which uses their own testing guideline for carcinogenicity studies and not an internationally accepted guideline. Treatment with methanol did not decrease survival. However, there was considerable early mortality; by 18 months, 30% of the male controls had died. In females, there were no differences in survival between controls and treated groups. There was still more early mortality in the females than expected, but it was less pronounced that the males. There was no obvious effect of methanol exposure on water consumption. The 20,000 ppm males and females weighed more than the controls (up to 14% and 7%, respectively) throughout the study. The 5,000 ppm females also weighed more (4%) than the controls at 24 months, but not at earlier time points. There were no body weight differences between the remaining treatment groups and the controls. The calculated methanol doses based on water intake were: 0, 55, 542, and 1,840 mg/kg-day for males; and 0, 67, 630, and 2,250 mg/kg-day for females. Nearly all rats in all dose groups had some pathology in the lung. The finding of lung pathology was consistent regardless of the age at death (not an old age response). The lung pathology included inflammation, dysplasia, or tumours). Lung pathology was present in 70-100% of the first 10% of deaths in each group, including controls (70, 80, 80, 100% in males; and 90, 90, 100, 100% in females at 0, 500, 5,000, and 20,000 ppm). The degree of inflammation in the lungs is difficult to assess because no other lung information was recorded for the rats when a neoplasm in the lung was recorded (Soffritti et al., 2002; Cruzan, 2009; USEPA, 2013a). [Kl. score = 3]

Inhalation

Cynomolgus monkeys or Sprague–Dawley rats were exposed by inhalation to 0, 500, 2,000, or 5,000 ppm (0, 660, 2,620, or 6,552 mg/m3) methanol for 6 h/day, 5 days/ week for 4 weeks. There was no mortality and no clinical signs of toxicity among the monkeys, but there a few signs of eye and nose irritation in the rats. No differences were seen between treated and control groups in body weight gain and organ weights, with the exception being decreased absolute adrenal weight in the 5,000 ppm female monkeys and increased relative spleen weights in the 2,000 ppm female rats. These changes were not considered by the authors to be of biological significance. There were no treatment-related effects on the ophthalmoscopy, gross pathology or histopathology. The NOAEL for this study is 5,000 ppm (6,552 mg/m^3) (Andrews et al., 1987). [Kl. score = 4]

Groups of four male rats were exposed by inhalation to 0, 200, 2000, or 10,000 ppm (o, 262, 2,621, or 13,104 mg/m3) methanol for 6 hours/day, 5 days/week for 1, 2, 4, or 6 weeks. Additional groups of animals were exposed for 6 weeks followed by a 6-week recovery period. Evaluation of a number of parameters including lung weights, surfactant levels, and enzyme activities did not reveal any adverse effects on the lung. No histopathological examinations were performed (White et al. 1983). [Kl. score = 2]

Male and female F344 rats were exposed by inhalation to 0, 10, 100, or 1,000 ppm methanol 19.5 hours/day, 7 days/week for 104 weeks. The average methanol doses were: 0, 3.7, 37, and 369 mg/kg-day in males; and 0, 5.9, 60, and 599 mg/kg-day for females. There were no treatment-related clinical

signs and no effect on survival or food consumption. Lower body weights were seen in the 1,000 ppm females beginning around day 259, but after day 574, there was no difference from controls. Body weights in males were similar across all groups. There were no treatment-related effects on urinalysis, hematology, or clinical biochemistry. Nor was there any treatment-related effects on organ weights or gross lesions. Histopathologic examination showed no statistically significant differences between treated and control animals (NEDO, 1985a). [Kl. score = 2]

Male and female B6C3F1 mice were exposed by inhalation to 0, 10, 100, or 1,000 ppm methanol 19.5 hours/day, 7 days/week for 78 weeks. The average methanol doses were: 0, 9.8, 95, and 947 mg/kg-day in males; and 0, 8.1, 106, and 1,071 mg/kg-day for females. There were no treatment-related clinical signs and no effect on survival or body weight. Food consumption was decreased slightly between months 7 and 12 in the 1,000 ppm females. Urinalysis, hematology, and clinical biochemistry were similar across all groups. No differences were seen in organ weights, gross lesions, or histopathology between treated and control mice. (NEDO, 1985b). [Kl. score = 2]

Dermal

No studies were identified.

G. Genotoxicity

In Vitro Studies

Methanol was not mutagenic to *Salmonella* strains TA97, TA98, TA100, TA1535, TA1537, and TA1538 in *in vitro* bacterial mutation assays with or without metabolic activation (De Flora et al., 1984a, b; Florin et al., 1980; Gocke et al.,1981). Equivocal results were obtained with *Salmonella* strain TA102 in the presence of metabolic activation (De Flora et al. 1984b). Methanol was not mutagenic in a DNA-repair test using various strains of *Escherichia coli* WP2 (De Flora et al. 1984a) and in a forward mutation assay using *Schizosaccharomyces pombe* (Abbondandolo et al. 1980).

Methanol did not induce micronuclei in Chinese hamster lung V79 cells in vitro (Lasne et al., 1984). Methanol was mutagenic in the mouse lymphoma assay in the presence of metabolic activation (McGregor et al., 1985), but it was not mutagenic in a Basc test or in a Drosophila, sex-linked, recessive lethal mutation assay (Gocke et al., 1981). Treatment of primary cultures of Syrian golden hamster embryo cells with methanol did not lead to cell transformation (Heidelberger et al., 1983).

In Vivo Studies

Male C57BL/6J mice were exposed by inhalation 0, 800 or 4,000 ppm methanol, 6 hours/day for five days. There were no increased frequencies of micronuclei in blood cells; sister chromatid exchanges, chromosomal aberrations, or micronuclei in lung cells; or synaptosomal complex damage in spermatocytes (Campbell et al., 1991).

Normal or folate-deficient mice were given four daily intraperitoneal injections of up to 2,500 mg/kg of methanol. There was no increase in micronucleated erythrocytes in the treated mice compared to the controls (O'Loughlin et al., 1992).

Male and female NMRI mice were given a single intraperitoneal injection of 0, 1,920, 3,200, or 4,480 mg/kg methanol. There was no increase in micronuclei was observed in the bone marrow at any dose level (Gocke et al., 1981).

H. Carcinogenicity

The carcinogenicity studies conducted on methanol were reviewed by Cruzan (2009) and by the USEPA (2013).

Oral

Male and female SD rats were given in their drinking water 0, 500, 5,000, or 20,000 ppm methanol for 104 weeks. This study was conducted by the Ramazzini Foundation, which uses a unique methodology and not the standardized international testing guidelines. There was excessive early mortality, and lung pathology (inflammation, dysplasia, or tumours) was present in 87 to 94% of those dying anytime during the study. An increase in lympho-immunoblastic lymphomas was reported (Soffritti et al., 2002; Cruzan, 2009; USEPA, 2013). [Kl. score = 3]

Inhalation

Male and female F344 rats were exposed by inhalation to 0, 10, 100, or 1,000 ppm methanol 19.5 hours/day, 7 days/week for 104 weeks. The average methanol doses were: 0, 3.7, 37, and 369 mg/kg-day in males; and 0, 5.9, 60, and 599 mg/kg-day for females. There was no increase in tumours in the methanol-exposed rats and mice (NEDO, 1985a). [Kl. score = 2]

Male and female B6C3F1 mice were exposed by inhalation to 0, 10, 100, or 1,000 ppm methanol 19.5 hours/day, 7 days/week for 78 weeks. The average methanol doses were: 0, 9.8, 95, and 947 mg/kg-day in males; and 0, 8.1, 106, and 1,071 mg/kg-day for females. There was no increase in tumours in the methanol-exposed mice (NEDO, 1985b). [Kl. score = 2]

I. Reproductive Toxicity

The reproductive and developmental toxicity studies were reviewed by the NTP Centre for Evaluation of Risks to Human Reproduction (NTP-CERHR, 2003). Conflicting results have been obtained concerning the effect of methanol on testicular hormones in rats; nevertheless, methanol does not appear to a male reproductive toxicant. The primate data indicates that methanol is unlikely to be a reproductive hazard in females. Methanol causes developmental effects at very high exposure levels in both rats (≥ 10,000 ppm) and mice (≥ 2000 ppm); there is also some evidence that it is a developmental neurotoxicant in rodents, but not in primates.

NICNAS concluded in their human health Tier II assessment for methanol: "Based on the data available, [methanol] is not considered to have reproductive or developmental toxicity in humans."

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for methanol follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

A 90-day oral gavage rat study showed elevated serum enzymes and decreased brain weights in the 2,500 mg/kg-day dose group with a NOAEL of 500 mg/kg-day (USEPA, 1986). The NOAEL of 500 mg/kg-day will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 10
UF_D (database uncertainty) = 1

Oral RfD = 500/(10 x 10 x 1 x 10 x 1) = 500/1000 = 0.2 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD: Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2 L (ADWG, 2011)

Drinking water guidance value = (0.5 x 70 x 0.1)/2 = 1.8 mg/L

B. Cancer

Methanol was not carcinogenic to rats or mice in chronic inhalation studies. Increased tumours from methanol in drinking water were reported by Soffritti et al. (2002); however, there are methodological problems with this study and questions have been raised about the validity of the results. No cancer reference value was derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Methanol is a highly flammable liquid.

It does not exhibit the following physico-chemical properties:

- Explosivity
- Oxidising potential.

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Methanol exhibits a low toxicity concern for aquatic organisms, terrestrial invertebrates, and plants.

B. Aquatic Toxicity

Acute Studies

Table 2 lists the results of acute aquatic toxicity studies conducted on methanol.

Table 2: Acute Aquatic Toxicity Studies on Methanol

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Bluegill	96-hr LC_{50}	15,400	1	Poirer et al. 1986
Salmo gairdneri	96-hr LC_{50}	20,100	1	Call et al., 1983
Pimphales promelas	96-hr LC_{50}	28,100	1	Call et al., 1983
Daphnia magna	96-hr EC_{50}	18,260	2	Dorn et al., 2012; ECHA
Daphnia magna	48-hr EC_{50}	>10,000	2	Kuehn et al., 1989
Selenastrum capricornutum	96-hr EC_{50}	~22,000	2	Cho et al., 2008; ECHA
Chlorella pyrenoidosa	10-14 d EC_{50}	28,400	2	Stratton and Smith, 1988

Chronic Studies

No adequate chronic studies were identified.

C. Terrestrial Toxicity

The terrestrial toxicity studies on methanol are listed below in Table 3.

Table 3: Terrestrial Toxicity Studies on Methanol

Test Species (Method)	Endpoint	Results (mg/kg soil dw)	Klimisch score	Reference
Earthworm *Eisenia fetida* (OECD 222)	35-d EC_{50} 63-d EC_{50}	17,199 26,646	2	ECHA
Folsomia candida (OECD 232)	28-d EC_{25} 28-d NOEC* (reproduction)	2,842 1,000	1	ECHA
Hordeum vulgare (OECD 208)	14-d EC_{50} 14-d NOEC* (seedling emergence)	15,492 12,000	1	ECHA
	14-d EC_{25} 14-d NOEC* (shoot dry mass)	2,538 1,555		
	14-d EC_{25} 14-d NOEC* (root dry mass)	2,823 2,592		
	14-d EC_{25} 14-d NOEC* (shoot length)	4,885 2,592		
	14-d EC_{25} 14-d NOEC* (root length)	5,752 4,320		

* Since only EC_{25} values were available from the test results, NOECs were derived graphically from the representing treatment means.

D. Calculation of PNEC

The PNEC calculations for methanol follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (15,400 mg/L), *Daphnia* (>10,000 mg/L), and algae (22,000 mg/L). There are no well-conducted long-term studies on methanol. Therefore, an assessment of 1,000 has been applied to the lowest reported effect concentration of 10,000 mg/L for *Daphnia*. The $PNEC_{water}$ is 10 mg/L.

PNEC sediment

There are no adequate toxicity studies on sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 6.3 mg/kg wet weight.

The calculations are as follows:

$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$
$= (0.81/1280) \times 1000 \times 10$
$= 6.3$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$K_{sed\text{-}water} = 0.8 + [0.2 \times Kp_{sed}/1000 \times BD_{soilid}]$
$= 0.8 + [0.2 \times 0.02/1000 \times 2400]$
$= 0.81$

Where:
Kp = solid-water partition coefficient (L/kg).
BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$Kp_{sed} = K_{oc} \times f_{oc}$
$= 0.61 \times 0.04$
$= 0.02$

Where:
K_{oc} = organic carbon normalized distribution coefficient (L/kg). The K_{oc} for methanol is 0.61.
F_{oc} = fraction of organic carbon suspended sediment = 0.04 [default].

PNEC soil

Experimental results from chronic studies are available for three trophic levels. The lowest NOEC is 1,000 mg/kg soil dry weight for the arthropod *Folsomia candida*. On the basis that the data consists of long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported long-term NOEC of 1,000 mg/kg soil dry weight. The $PNEC_{soil}$ is 100 mg/kg soil dry weight.

VIII. PBT ASSESSMENT

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009, ECHA, 2008).

Methanol is readily biodegradable and thus it does not meet the screening criteria for persistence.

Based on an experimental BCF of <10 in fish, methanol does not meet the criteria for bioaccumulation.

There are no adequate chronic toxicity studies on methanol. The acute E(L)C_{50} values of methanol in fish, invertebrates and algae is >1 mg/L; thus, it does not meet the screening criteria for toxicity.

The overall conclusion is that methanol is not a PBT substance.

IX. CLASSIFICATION AND LABELLING

A. Classification

Flammable Liquid Category 2
Acute Toxicity Category 3 [Oral]
Acute Toxicity Category 3 [dermal]
Acute Toxicity Category 3 [inhalation]
STOT SE Category 1 [optic nerve, central nervous system]

In the EU, there are concentration limits for the STOT SE classification of methanol. This may or may not apply to GHS classifications for Australian SDS.

Concentration range (%):	
>10	STOT SE Category 1
>3 and <10	STOT SE Category 2

B. Labelling

Danger

C. Pictograms



The health hazard pictogram is omitted if the STOT SE classification for methanol does not apply. (i.e., concentration of methanol is below the concentration limits).

X. SAFETY AND HANDLING

Methanol is used in the drilling mud product ALDACIDE® G ANTIMICROBIAL at a concentration of 0.1% to 1%. The safety and handling of methanol at this concentration in ALDACIDE® G

ANTIMICROBIAL will be provided in the dossier on glutaraldehyde, the major constituent of ALDACIDE® G ANTIMICROBIAL.

Occupational Exposure Standards

The workplace exposure standard for methanol in Australia is 200 ppm (262 mg/m^3 as an 8-hr TWA and 250 ppm (328 mg/m^3) as a 15-min STEL. There is also a skin notation indicating that absorption through the skin may be a significant source of exposure.

A. Transport Information

Methanol is used drilling mud product ALDACIDE® G ANTIMICROBIAL at a concentration of 0.1 to 1%. The transportation information for ALDACIDE® G ANTIMICROBIAL will be provided in the dossier on glutaraldehyde, the major constituent of ALDACIDE® G ANTIMICROBIAL.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

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XIV. ACRONYMS AND GLOSSARY

°C	degrees Celsius
ADWG	Australian Drinking Water Guidelines
BMD	benchmark dose
CERHR	Centre for Evaluation of Risks to Human Reproduction
CNS	central nervous system
DEWHA	Department of the Environment, Water, Heritage and the Arts
ECHA	European Chemicals Agency
EU	European Union
FOB	functional observation battery
GHS	Globally Harmonised System of Classification and Labelling of Chemicals
HHRA	enHealth Human Risk Assessment
IRIS	Integrated Risk Information System
IUPAC	International Union of Pure and Applied Chemistry
kg/m^3	kilograms per cubic metre
LOAEL	lowest observed adverse effect level
$mg/cm^2/hr$	milligrams per square centimetre per hour
mg/kg	milligrams per kilogram
mg/L	milligrams per litre
mg/m^3	milligrams per cubic metre
NICNAS	The National Industrial Chemicals Notification and Assessment Scheme
NOAEL	no observed adverse effect level
NOEC	no observed effective concentration
NPT	National Toxicology Program
OECD	Organisation for Economic Co-operation and Development
PBT	Persistent, Bioaccumulative and Toxic
ppm	parts per million
RfD	oral Reference dose
SIDS	Screening Information Data Set
SMILES	simplified molecular-input line-entry system
STOT SE	Specific Target Organ Toxicity - Single Exposure
THF	tetrahydrofolate
TLV	threshold limit value
USEPA	United States Environmental Protection Agency

MONOETHANOLAMINE BORATE

This dossier on monoethanolamine borate does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of monoethanolamine borate in its use in drilling muds and hydraulic fracturing fluids. The majority of information presented in this dossier was obtained from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name: Monoethanolamine borate

CAS RN: 26038-87-9 (EC No. 701-025-6)

Molecular formula: $C_2H_7NO.xBH_3O_3$ [UVCB substance]

Synonyms: Monoethanolamine borate; orthoboric acid, compound with 2-aminoethanol; boric acid (H_3BO_3), reaction products with ethanolamine; MEA polyborate

In this dossier, data on CAS No. 68512-53-8 (Boric acid, reaction products with monoethanolamine [MEA] and triethanolamine [TEA]) has been used to read-across to monoethanolamine borate.

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Monoethanolamine Borate

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Liquid	2	ECHA
Density	$\leq$1.245 g/cm^3 @ 20°C	2	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Monoethanolamine borate is readily biodegradable. It will not adsorb significantly to suspended solids and sediments in water and would be highly mobile in soil. No information is available on the potential for monoethanolamine borate to bioaccumulate.

B. Biodegradation

Monoethanolamine borate 1:1 is readily biodegradable. In a modified Sturm test (OECD 301B), degradation was 73% after 28 days; the 10-day window was met (ECHA). [Kl. score = 1]

Monoethanolamine borate 1:3 is readily biodegradable. In a modified Sturm test (OECD 301B), degradation was 75% after 28 days; the 10-day window was met (ECHA).

D. Environmental Distribution

Adsorption/desorption

The log K_{oc} was determined for monoethanolamine borate 1:1 and monoethanolamine borate 1:3 on soil and on sewage sludge using high performance liquid chromatography (HPLC). Both the monoethanolamine and the polyborate part of both substances did not significantly adsorb to soil. The experimental log K_{oc} was determined to be approximately 1.26 [K_{oc} = 18.2 L/kg] (ECHA). [Kl. score = 1]

E. Bioaccumulation

No bioconcentration studies are available. No information is available on the octanol-water partition coefficient for monoethanolamine borate.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Limited toxicity data are available for monoethanolamine borate. Data on CAS No. 68512-53-8 (boric acid reaction product with MEA and TEA) has been used to read-across to monoethanolamine borate. Monoethanolamine borate exhibits low acute toxicity by the oral and dermal routes. Monoethanolamine borate is not irritating to the skin and eyes, and has a low potential for skin sensitization. Repeated oral exposures of CAS No. 68512-53-8 to rats showed no adverse effects. Monoethanolamine borate is not genotoxic. No carcinogenicity, reproductive or developmental toxicity studies have been conducted on monoethanolamine borate or CAS No. 68512-53-8.

B. Acute Toxicity

The acute oral LD_{50} in rats is >2,000 mg/kg (ECHA) [Kl. score = 1].

No acute inhalation studies are available on monoethanolamine borate.

There are no dermal toxicity studies on monoethanolamine borate. The acute dermal LD_{50} of CAS 68512-53-8 (boric acid reaction product with MEA and TEA) in rats is >2,000 mg/kg (ECHA). [Kl. score = 1]

C. Irritation

Application of 0.5 g monoethanolamine borate to the skin of rabbits for 4 hours under semi-occlusive conditions was essentially non-irritating. The mean of the 24, 48, and 72 hour scores were approximately 0.1 for erythema and 0.00 for edema (ECHA) [Kl. score = 1).

Monoethanolamine borate 1:1 and monoethanolamine borate 1:3 were tested for eye irritancy using the Bovine Corneal Opacity and Permeability test (BCOP test). Minimal to no ocular irritation was observed in both studies (ECHA) [Kl. scores = 1].

D. Sensitization

There are no skin sensitization studies on monoethanolamine borate. CAS No. 68512-53-8 (boric acid reaction product with MEA and TEA) was not a skin sensitizer to guinea pigs using the Buehler method (ECHA) [Kl. score = 2).

E. Repeated Dose Toxicity

Oral

No studies are available on monoethanolamine borate.

Male and female SD rats were dosed daily by oral gavage with 0, 62.5, 250 or 1,000 mg/kg CAS No. 68512-53-8 (boric acid reaction product with MEA and TEA) for 28 days. There were no deaths during the study. Clinical signs, body weights, feed consumption, and neurobehavior (FOB, motor activity) were unaffected by treatment. Hematology parameters, clinical chemistry, and urinalysis were within normal range for treated and control animals. There were no treatment-related effects on organ weights, and gross necropsy findings and histopathologic examination showed no effects attributed to treatment. The NOAEL for this study is 1,000 mg/kg-day (ECHA) [Kl. score = 1].

Inhalation

No studies are available.

Dermal

No studies are available.

F. Genotoxicity

The results of in vitro genotoxicity studies on monoethanolamine borate and structurally similar substance CAS No. 68512-53-8 (boric acid reaction product with MEA and TEA) are shown in Table 2.

In Vitro Studies

Table 2: *In vitro* Genotoxicity Studies on Monoethanolamine Borate and CAS No. 68512-53-8 (Boric Acid Reaction Product with MEA and TEA)

Test System	Test Substance	Results*		Klimisch Score	Reference
		-S9	+S9		
Bacterial reverse mutation (S. typhimurium strains)	CAS No. 68512-53-8**	-	-	1	ECHA
Mammalian cell gene mutation (CHL V79 cells)	CAS No. 68512-53-8**	-	-	1	ECHA
Chromosomal aberration (Human lymphocytes)	Monoethanolamine borate 1:1	-	-	1	ECHA
Chromosomal aberration (human lymphocytes)	Monoethanolamine borate 1:3	-	-	1	ECHA

*+, positive; -, negative
** Boric acid reaction product with MEA and TEA.

In Vivo Studies

No studies are available.

G. Carcinogenicity

No studies are available.

H. Reproductive Toxicity

No studies are available.

I. Developmental Toxicity

No studies are available.

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for monoethanolamine borate follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

The were no adverse effects seen in rats given oral gavage doses of CAS No. 68512-53-8 (boric acid, reaction products with MEA and TEA) for 28 days (ECHA). The NOAEL for this study is 1,000 mg/kg-day, the highest dose tested. The NOAEL from this study will be used for determining the oral Reference dose (RfD) and the drinking water guidance value for monoethanolamine borate.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 10
UF_D (database uncertainty) = 1

Oral RfD = 1,000/(10 x 10 x 1 x 10 x 1) = 1,000/1,000 = 1.0 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,

Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (1.0 x 70 x 0.1)/2 = 3.5 mg/L

B. Cancer

No studies have been conducted on monoethanolamine borate. Therefore, a cancer reference value has not been derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Monoethanolamine borate does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Monoethanolamine borate has moderate acute toxicity concern to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies conducted on monoethanolamine borate.

Table 3: Acute Aquatic Toxicity Studies on Monoethanolamine Borate

Test Species	Test Substance	Endpoint	Results (mg/L)	Klimisch score	Reference
Danio rario	Monoethanol-amine borate	96-h LC_{50}	>100	1	ECHA

	1:1				
Carp	Monoethanol-amine borate 1:3	96-h LC_{50}	617	1	ECHA
Daphnia magna	Monoethanol-amine borate 1:3	48-h EC_{50}	496	1	ECHA
Daphnia magna	Monoethanol-amine borate 1:1	48-h EC_{50}	423	1	ECHA
Pseudokirchneriella subcapitata	Monoethanol-amine borate 1:3	72-h EC_{50} NOEC	67 (growth rate) 72 (biomass) 18 (growth rate)	1	ECHA
Pseudokirchneriella subcapitata	Monoethanol-amine borate 1:1	72-h EC_{50}	26 (growth rate) 13 (biomass) 3.2 (growth rate)	1	ECHA

Chronic Studies

No studies are available.

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for monoethanolamine borate follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (617 mg/L), *Daphnia* (423 mg/L), and algae (26 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported $E(L)C_{50}$ value of 26 mg/L for algae. The $PNEC_{water}$ is 0.026 mg/L.

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 0.02 mg/kg sediment wet weight.

The calculations are as follows:

$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$
$= (1.15/1280) \times 1000 \times 0.026$
$= 0.02$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$K_{sed\text{-}water} = 0.8 + [0.2 \times Kp_{sed})/1000 \times BD_{solid}]$
$= 0.8 + [0.2 \times 0.73/1000 \times 2400]$
$= 1.15$

Where:
Kp_{sed} = solid-water partition coefficient (L/kg).
BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$Kp_{sed} = K_{oc} \times f_{oc}$
$= 18.2 \times 0.04$
$= 0.73$

Where:
K_{oc} = organic carbon normalized distribution coefficient (L/kg). The experimental K_{oc} for monoethanolamine borate is 18.2 L/kg.
F_{oc} = fraction of organic carbon in sediment = 0.04 [default].

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is 0.006 mg/kg soil dry weight.

The calculations are as follows:

$PNEC_{soil}$ = (Kp_{soil}/BD_{soil}) x 1000 x $PNEC_{water}$
= (0.36/1500) x 1000 x 0.026
= 0.006

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

Kp_{soil} = K_{oc} x f_{oc}
= 18.2 x 0.02
= 0.36

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The experimental K_{oc} for monoethanolamine borate is 18.2 L/kg.
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Monoethanolamine borate is readily biodegradable; thus it does not meet the screening criteria for persistence.

No bioconcentration studies have been conducted on monoethanolamine borate. It is a UVCB substance and a log K_{ow} has not been determined. Thus the bioaccumulation potential for monoethanolamine borate is not known.

No chronic aquatic toxicity studies are available for monoethanolamine borate. The acute E(L)C_{50} values in fish, invertebrates and algae are >1 mg/L. Thus monoethanolamine borate does not meet the criteria for toxicity.

The overall conclusion is that monoethanolamine borate is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

[Acute Aquatic Toxicity Category 3]

B. Labelling

No signal word.

C. Pictogram

None

X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
Immediately flush open eyes with plenty of water for at least 15 minutes. Remove contacts, if present and easy to do. If effects occur, get medical attention immediately, preferably a physician for an ophthalmologic examination.

Skin Contact
Remove contaminated clothing. Wash thoroughly with soap and water. Seek medical attention if irritation persists.

Inhalation
If inhaled, remove from area to fresh air. Give artificial respiration if victim is not breathing. Get medical attention.

Ingestion
Rinse mouth with water and then drink a small amount of water. Get medical attention. Never give anything by mouth to an unconscious person.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: nitrogen oxides, carbon monoxide, carbon dioxide.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus and chemical-protective clothing.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Use appropriate protective equipment. Handle in accordance with good industrial hygiene and safety practice. Avoid contact with skin, eyes, and clothing.

Environmental Precautions
Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled
For large amounts: dike spillage and pump off product. For residues: pick up with suitable absorbent material. Dispose of contaminated material as prescribed.

D. STORAGE AND HANDLING

General Handling
Ensure adequate ventilation, especially in confined areas. Avoid breathing vapors.

Storage
Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
Workplace Australia has not established an occupational exposure standard for monoethanolamine borate.

Engineering Controls
Good general ventilation should be used.

Personal Protection Equipment

Respiratory Protection:
Use respiratory protection in case of vapor or aerosol release.

Hand Protection:
Chemical resistant protective gloves.

Skin *Protection*:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Safety glasses with side-shields.

Other Precautions:

Handle in accordance with good industrial hygiene and safety practice. Wearing of closed work clothing is recommended. Ensure that eyewash stations and safety showers are close to the workstation location.

F. TRANSPORT INFORMATION

Monoethanolamine borate is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

Department of the Environment, Water, Heritage and the Arts [DEWHA] (2009). Environmental risk assessment guidance manual for industrial chemicals, Department of the Environment, Water, Heritage and the Arts, Commonwealth of Australia.

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances

enHealth Human Risk Assessment [HHRA] (2012). Environmental Health Risk Assessment, Guidelines for Assessing Human Health Risks from Environmental Hazards. Office of Health Protection of the Australian Government Department of Health.

European Chemicals Agency [ECHA] (2008). Guidance on Information Requirements and Chemical Safety Assessment, Chapter R11: PBT Assessment, European Chemicals Agency, Helsinki, Finland.

Klimisch, H.J., Andreae, M., and Tillmann, U. (1997). A systematic approach for evaluating the quality of experimental and toxicological and ecotoxicological data. Regul. Toxicol. Pharmacol. 25:1-5.

SILICON DIOXIDE

This dossier on silicon dioxide does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of silicon dioxide in its use in drilling muds and hydraulic fracturing fluids. The majority of information presented in this dossier was obtained from the OECD-SIDS documents on synthetic amorphous silica and silicates (OECD 2004a,b), and the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC): Silicon dioxide

CAS RN: 112926-00-8

Molecular formula: $nSiO_2$

Molecular weight: 60.08

Synonyms: Silicon dioxide; synthetic amorphous silica; silica gel; precipitated silica, crystalline-free

SMILES: O=[Si]=O

Silicon dioxide is the IUPAC name for synthetic amorphous silica (SAS) [CAS No. 7631-86-9]; it can be produced by a "wet process" or by a "thermal or fumed process." Silica gel and precipitated silica, crystalline-free (CAS No. 112926-00-8) is a SAS prepared by the "wet process." Silica, amorphous, fumed, crystalline-free (CAS No. 112945-52-5) is a SAS prepared by flame hydrolysis.

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Silicon Dioxide

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Powder, granules, pellets	2	ECHA
Melting Point	1,713°C	2	ECHA

Boiling Point	2.2 g/cm^3	2	ECHA
Water Solubility	76 – 128 mg/L* (slightly soluble)	1	ECHA

*Based on dissolved SiO_2.

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Silicon oxides are the most abundant compounds in the earth's crust mass. Silicon dioxide (CAS No. 112926-00-8) released into the environment is expected to combine indistinguishably with the soil layer or sediment due to their chemical similarity with inorganic soil matter (OECD, 2004a).

Biodegradation is not applicable to silicon dioxide (CAS No. 112926-00-8). The bioavailable form of silicon dioxide (CAS No. 112926-00-8) is the dissolved form which exists exclusively monosilicic [$Si(OH)_4$] acid under environmental pH (OECD, 2004a). Although the water-soluble fraction of silicon dioxide (CAS No. 112926-00-8) acts as weak acid, pH changes are not likely to occur in the environment due to low aquatic releases and sufficient natural buffer capacities (OECD, 2004a).

Bioaccumulation of silicon dioxide (CAS No. 112926-00-8) is generally unlikely to occur. However, dissolved silica can be actively assimilated by some marine and terrestrial organisms as normal natural processes mainly related to structural function.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

The oral bioavailability of silicon dioxide in animals and humans is low. Absorbed silicon dioxide is rapidly eliminated and there is no accumulation in the body. The bioavailablity of silicon dioxide by the inhalation route is low. While there is deposition in the lungs following inhalation exposure to silicon dioxide, it is rapidly eliminated. The acute toxicity of silicon dioxide is low by the oral, inhalation, and dermal routes. Silicon dioxide is not irritating to the skin and eyes. Repeated oral exposures to rodents showed no adverse effects. Repeated inhalation exposure to high respirable levels of silicon dioxide resulted in an inflammatory response in the respiratory tract and lungs, which was reversible following cessation of exposure. Silicon dioxide is not genotoxic. Although the study was of poor quality, there was no evidence of adverse effects on reproduction in rats given silicon dioxide in the diet. Animal studies showed no adverse effects on fetal development from oral exposure to silicon dioxide.

B. Toxicokinetics/Metabolism

The oral bioavailability of silicon dioxide in animals and humans is low. Absorbed silicon dioxide is rapidly eliminated and there is no accumulation in the body. The bioavailablity of silicon dioxide by the inhalation route is low. While there is deposition in the lungs following inhalation exposure to silicon dioxide, it is rapidly eliminated (OECD, 2004a,b).

C. Acute Toxicity

The oral LD_{50} of silicon dioxide (CAS No. 112926-00-8) in rats from two different studies is >5,000 mg/kg (ECHA) [Kl. scores = 1].

The 4-hour inhalation LC_{50} in rats for an aerosol of silicon dioxide (CAS No. 112926-00-8) is >0.69 mg/L, which was the maximum technically attainable concentration. The mass median aerodynamic diameter (MMAD) was approximately 0.6 μm, and approximately 65% of the mass was <6 μm (ECHA) [Kl. score = 2].

The 4-hour inhalation LC_{50} in rats for an aerosol of silicon dioxide (CAS No. 112945-52-5) is >2.08 mg/L. The mass median aerodynamic diameter (MMAD) was approximately 0.76 μm, and approximately 98-99.4% of the mass was <10 μm (ECHA) [Kl. score = 2].

The 4-hour inhalation LC_{50} in rats for an aerosol of silicon dioxide (CAS No. 112945-52-5) from a nose-only exposure is >0.14 mg/L, which was the maximum technically attainable concentration. The mass median aerodynamic diameter (MMAD) was 3.2 μm, and 47-50% of the mass was <6 μm (ECHA) [Kl. score = 2].

The dermal LD_{50} in rabbits is >5,000 mg/kg (no deaths) (ECHA) [Kl. score = 2].

D. Irritation

Application of 0.5 g silicon dioxide (CAS No. 112926-00-8) to the skin of rabbits for 4 hours under occlusive conditions was not irritating. (ECHA) [Kl. score = 1].

Instillation of 0.1 g silicon dioxide (CAS No. 112926-00-8) to the eyes of rabbits was minimally irritating (ECHA) [Kl. score = 1].

E. Sensitization

No studies are available.

F. Repeated Dose Toxicity

Oral

Male and female Wistar rats were given diets containing silicon dioxide (CAS No. 112926-00-8) for 90 days. The dietary concentrations as silica concentrations were 0, 0.4-0.7, 1.7-1.9, or 6.5-7.0% silica; this equates to 0, 300-330, 1,200-1,400, or 4,000-4,500 mg/kg CAS No. 112926-00-8. There were no treatment-related effects. The NOAEL is 4,000 to 4,500 mg/kg-day (ECHA). [Kl. score = 1]

Male and female CD rats were given diets containing silicon dioxide (CAS No. 112926-00-8) for 6 months. The estimated daily intakes were 0, 2,170, and 7,950 mg/kg-day for males, and 0, 2,420, and 8,980 mg/kg-day for females. There were no treatment-related effects. The NOAEL is 7,950 and 8,980 mg/kg-day for males and females, respectively (ECHA). [Kl. score = 1]

Male and female Fischer 344 rats were fed a diet containing a synthetic amorphous silica (CAS No. not stated) for 102 weeks. The dose levels were 0, 12,500, 25,000, and 50,000 ppm. There were no treatment-related effects on body weight gain, feed consumption, survival, or hematology parameters. Liver weights were lower (up to 15%) in the $\geq$25,000 ppm females from 12 to 24 months; a dose-related trend was not apparent. The NOAEL is 50,000 ppm. Using 0.05 as the fraction of body weight that rats consume per day as food (U.S. EPA), the NOAEL corresponds to 2,500 mg/kg-day (Takizawa *et al.*, 1988) [Kl. score = 2].

Male and female $B6C3F_1$ mice were fed a diet containing a synthetic amorphous silica (CAS No. not stated) for 93 weeks. The dose levels were 0, 12,500, 25,000, and 50,000 ppm. There were no treatment-related effects on survival or clinical signs. Body weight gain was lower in the 5% group from week 15 to week 50 for the males and from 30 to 50 for the females. Mean body weights for 5% group animals for the remainder of the study were similar to controls. The NOAEL is 50,000 ppm in the diet. Using 0.13 as the fraction of body weight that mice consume per day as food (U.S. EPA), the NOAELs corresponds to 6,500 mg/kg-day (Takizawa et al., 1988). [Kl. score = 2]

Inhalation

Male and female Wistar rats were exposed by inhalation to 0, 1, 6, or 30 mg/m^3 silicon dioxide (CAS No. 112945-52-5) 6 hours/day, 5 days/week for 13 weeks. There were no deaths during the study. Respiration rates were increased in a concentration-dependent manner. Body weight and body weight gain were unaffected in females, but were lower in the males with the 30 mg/m^3 groups significantly affected throughout the study. At $\geq$6 mg/m^3, there were hematological changes, increased lung weights, and histopathologic changes in the lungs (including collagen increase and sporadic focal fibrosis). At 1 mg/m^3, there was a slight, but fully reversible, pulmonary response indicative of an inflammatory reaction. The NOAEC for this study is 1.3 mg/m^3 (ECHA) [Kl. score = 1].

Dermal

No adequate studies are available.

G. Genotoxicity

In Vitro Studies

The results of *in vitro* genotoxicity studies on silicon dioxide are presented below in Table 2.

Table 2: *In vitro* Genotoxicity Studies on Silicon Dioxide

Test System	Test substance	Results*		Klimisch Score	Reference
		-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* strains)	CAS No. 112926-00-8	-	-	2	Prival *et al.* (1991)
Bacterial reverse mutation (*E. coli* strains)	CAS No. 112926-00-8	-	-	2	Prival *et al.* (1991)
Bacterial reverse mutation (*S. typhimurium* strains)	CAS No. 112945-52-5	-	-	1	ECHA
Mammalian cell gene mutation (CHO cells)	CAS No. 112945-52-5	-	-	1	ECHA
Chromosomal aberration (Human embryonic lung cells, WI-38)	CAS No. 112926-00-8	NA	-	2	ECHA
Chromosomal aberration (CHO cells)	CAS No. 112945-52-5	-	-	1	ECHA
Unscheduled DNA synthesis (primary rat hepatocytes)	CAS No. 112945-52-5	NA	-	1	ECHA

*+, positive; -, negative; NA, not applicable.

In Vivo Studies

Male F344 rats were exposed by inhalation to 0 or 50 mg/m^3 silicon dioxide (CAS No. 112945-52-5) 6 hours/day, 5 days/week for 13 weeks. When tested in a HPRT assay,

there was no increase in mutation frequency in the alveolar Type II cells from exposed rats compared to controls (ECHA) [Kl. score = 2].

Male SD rats were given by oral gavage either a single dose of 0, 1,4, 14, or 140 mg/kg silicon dioxide (CAS No. 112926-00-8), or five consecutive daily doses of 0, 500, or 5,000 mg/kg silicon dioxide (CAS No. 112926-00-8). Chromosomal aberrations were not significantly increased in the treated animals compared to controls (ECHA) [Kl. score = 2].

In a dominant lethal mutation assay, male SD rats were given by oral gavage either a single dose of 0, 1,4, 14, or 140 mg/kg silicon dioxide (CAS No. 112926-00-8), or five consecutive daily doses of 0, 500, or 5,000 mg/kg silicon dioxide (CAS No. 112926-00-8). There was no indication of a mutagenic effect by silicon dioxide (CAS No. 112926-00-8) (ECHA) [Kl. score = 2].

H. Carcinogenicity

Oral

Male and female Fischer 344 rats were fed a diet containing a synthetic amorphous silica (CAS No. not stated) for 102 weeks. The dose levels were 0, 12,500, 25,000, and 50,000 ppm. The incidence of tumors was similar between treated and control animals. The number of animals used in this study was small (Takizawa *et al.*, 1988). [Kl. score = 2]

Male and female $B6C3F_1$ mice were fed a diet containing a synthetic amorphous silica (CAS No. not stated) for 93 weeks. The incidence of tumors was similar between treated and control animals (Takizawa *et al.*, 1988). [Kl. score = 2].

I. Reproductive Toxicity

A one-generation reproductive toxicity study has been conducted on silicon dioxide (CAS No. 112945-52-5). Male and female Wistar rats were given diets containing 0 or 497 mg/kg-day (males) or 509 mg/kg-day (females). In the parental animals, there were no treatment-related effects on mortality, clinical symptoms, feed consumption, body weight gain, and measured hematology parameters. There was no reproductive or developmental toxicity (ECHA) [Kl. score = 3].

J. Developmental Toxicity

Pregnant female rats were given by oral gavage doses up to 1,350 mg/kg silicon dioxide (CAS No. 112926-00-8) on GD 6-15. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity is 1,350 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 2].

Pregnant female mice were given by oral gavage doses up to 1,340 mg/kg silicon dioxide (CAS No. 112926-00-8) on GD 6-15. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity is 1,340 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 2].

Pregnant female rabbits were given by oral gavage doses up to 1,600 mg/kg silicon dioxide (CAS No. 112926-00-8) on GD 6-18. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity is 1,600 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 2].

Pregnant female Syrian hamsters were given by oral gavage up to 1,600 mg/kg silicon dioxide (CAS No. 112926-00-8) on GD 6-10. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity is 1,600 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 2].

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for silicon dioxide (CAS No. 112945-00-8) follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

There were no adverse effects seen in rats or mice fed a diet containing up to 50,000 ppm silicon dioxide (CAS No. not stated) for 102 and 93 weeks, respectively (Takizawa *et al.*, 1988). The NOAELs for rats and mice were 2,500 and 6,500 mg/kg-day, respectively. The lowest NOAEL of 2,500 mg/kg-day will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 2,500/(10 x 10 x 1 x 1 x 1) = 2,500/100 = 25 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (25 x 70 x 0.1)/2 = 88 mg/L

B. Cancer

Silicon dioxide was not carcinogenic to rats or mice in chronic dietary studies. Hence, a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Silicon dioxide does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Silicon dioxide has a low acute toxicity concern to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies conducted on silicon dioxide.

Table 3: Acute Aquatic Toxicity Studies on Silicon Dioxide

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Danio rerio	96-h LL_0	10,000*	1	ECHA
Danio rerio	96-h LL_0	10,000	1	ECHA
Daphnia magna	48-h EL_{50}	>1,000**	2	ECHA
Daphnia magna	24-h EL_{50}	>10,000	2	ECHA

*Silica, amorphous, fumed, crystalline-free (CAS No. 112945-52-5)
**Mortality may have occurred may have occurred from physical effects of unfiltered medium.

Chronic Studies

No studies are available.

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for silicon dioxide follow the methodology discussed in DEWHA (2009).

PNEC water

Silicon dioxide is a solid in powder form, which is slightly soluble in water. Acute aquatic toxicity studies on fish and *Daphnia* using excess loadings of silicon dioxide showed no acute toxicity (Table 3). Physical effects of silicon dioxide on *Daphnia* were seen in tests using unfiltered test medium (OECD, 2004a,b; ECHA). Because of the physico-chemical properties of silicon dioxide, the $PNEC_{water}$ was not determined.

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. The $PNEC_{sed}$ cannot be derived using the equilibrium partitioning method.

PNEC soil

There are no toxicity data for terrestrial or soil organisms. The $PNEC_{soil}$ cannot be derived using the equilibrium partitioning method.

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Silicon dioxide (CAS No. 111945-00-8) released into the environment is expected to combine indistinguishably with the soil layer or sediment due to their chemical similarity with inorganic soil matter. Biodegradation is not applicable to silicon dioxide (CAS No. 112926-00-8). For the purposes of this PBT assessment, the persistent criteria is not considered applicable to silicon dioxide (CAS No. 112926-00-8).

Silicon dioxide (CAS No. 112926-00-8)is an inorganic substance that is a slightly soluble powder. Bioaccumulation of silicon dioxide (CAS No. 112926-00-8) is generally unlikely to occur, given its low bioavailability. However, dissolved silica can be actively assimilated by some marine and terrestrial organisms as normal natural processes mainly related to structural function. For the purposes of this PBT assessment, silicon dioxide (CAS No. 112926-00-8) does not meet the criteria for bioaccumulation.

The acute toxicity of the water-soluble fraction of silicon dioxide (CAS No. 112926-00-8) is >1 mg/L. Thus, it does not meet the criteria for toxicity.

The overall conclusion is that silicon dioxide (CAS No. 112926-00-8) is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

No classified.

B. Labelling

No signal word.

C. Pictogram

None.

X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. If symptoms persist, seek medical advice.

Skin Contact
Wash thoroughly with soap and water.

Inhalation
If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Ingestion
Rinse mouth with water and then drink plenty of water. Never give anything by mouth to an unconscious person. If symptoms develop, seek medical advice.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
No data are available.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Use appropriate protective equipment.

Environmental Precautions
Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled

Scoop up and remove.

D. STORAGE AND HANDLING

General Handling
No special measures necessary provided product is used correctly.

Other Handling Precautions
Avoid eye and skin contact. Avoid creating or inhaling dust.

Storage
Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
The workplace exposure standard for silica gel (silicon dioxide, CAS No. 112926-00-8) in Australia is 10 mg/m^3 as an 8-hour TWA.

Engineering Controls
Good general ventilation should be used.

Personal Protection Equipment

Respiratory Protection:
Use respiratory protection if airborne dust levels are expected to exceed the occupational exposure guidance value.

Hand Protection:
Use gloves.

Skin *Protection*:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Safety glasses with side-shields.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible.

F. TRANSPORT INFORMATION

Silicon dioxide is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

Department of the Environment, Water, Heritage and the Arts [DEWHA] (2009). Environmental risk assessment guidance manual for industrial chemicals, Department of the Environment, Water, Heritage and the Arts, Commonwealth of Australia.

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enHealth Human Risk Assessment [HHRA] (2012). Environmental Health Risk Assessment, Guidelines for Assessing Human Health Risks from Environmental Hazards. Office of Health Protection of the Australian Government Department of Health.

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OECD (2004a). Screening Information Dataset (SIDS) Initial Assessment Report for Synthetic Amorphous Silica and Silicates: Silicon Dioxide (CAS No. 7631-86-9, 112945-52-5, 112926-00-8; Silicic Acid, Aluminum Sodium Salt (CAS No. 1344-00-9); Silicic Acid, Calcium Salt (CAS No. 1344-95-2), UNEP Publications.

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Prival, M.J., Simmon, V.F., and Mortelmans, K.E. (1991). Bacterial mutagenicity testing of 49 food ingredients gives very few positive results. Mutat. Res. 260: 321-329.

Takizawa, Y., Hirasawa, F., Noritomi, E., Aida, M., Tsunoda, H., and Uesugi, S. (1988). Oral ingestion of syloid to mice and rats and its chronic toxicity and carcinogenicity. Acta Medica et Biologica 36: 27-56.

SODIUM BISULFITE

This dossier on sodium bisulfite does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of sodium bisulfite in water treatment systems. The information presented in this dossier was obtained mainly from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC): Sodium hydrogen sulfite

CAS RN: 7631-90-5

Molecular formula: $NaHSO_3$

Molecular weight: 104.1

Synonyms: Sodium bisulfite; sodium hydrogen sulfite; sodium hydrogensulfite; monosodium sulfite; sodium sulfhydrate; hydrogen sodium sulfite; sulfurous acid, monosodium salt

SMILES: OS(=O)[O].[Na]

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Physico-chemical Properties of Sodium Bisulfite

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	White, crystalline, solid	-	HSDB
Melting Point	Decomposes	-	HSDB
Density	1.348 g/cm^3	1	ECHA
Vapor Pressure	Not applicable	-	-
Partition Coefficient (log K_{ow})	Not applicable	-	-
Water Solubility	Very soluble	2	ECHA

Sodium bisulfite is a weak acid with a pK_a of 6.97. Its conjugate base is the sulfite ion (SO_3^{2-}).

$NaHSO_3 \leftrightarrow Na^+ + HSO_3^-$

$HSO_3^- \leftrightarrow H^+ + SO_3^{2-}$

At neutral pH, a mixture of 50% sulfite (SO_3^{2-}) and 50% bisulfite (HSO_3^{2-}) is present.

In surface waters, sulfite is oxidized to sulfate either catalytically by air oxygen or by microbial action (OECD, 2008). The presence of cations like iron, copper or manganese in the environment accelerates the oxidation rate significantly.

Dissociation of sodium bisulfite in aqueous solutions can also liberate sulfur dioxide (SO_2), which is a gas.

III. ENVIRONMENTAL FATE PROPERTIES

At environmental pHs, sodium bisulfite dissociates in water to form sodium (Na^+) ions, bisulfite ions (HSO_3^-), sulfite (SO_2^{3-}) ions, and sulfur dioxide (SO_2) which is a gas.

Sodium bisulfite is not expected to bioaccumulate in the environment because of its dissociation to ionic species and a gas. Furthermore, sulfite will oxidize to sulfate, which is ubiquitous in the environment.

Sodium bisulfite and its dissociated species are expected to have a low potential to adsorb to soil and sediment.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Limited toxicity data are available on sodium bisulfite; therefore, structural analogues have been used to read-across to sodium bisulfite. Sodium sulfite has low acute toxicity by the oral, inhalation, and dermal routes. Sodium sulfite is minimally irritating to the skin and slightly irritating to the eyes. Sodium sulfite is not a skin sensitizer. No systemic toxicity was seen in rats when given sodium metabisulfite in their diet over a lifetime. There were, however, indications of stomach lesions as a result of localized irritation from the ingestion of sodium metabisulfite. Sodium bisulfite is not expected to be genotoxic. No reproductive or developmental toxicity was observed in any of the animal studies on sodium bisulfite or its structural analogues.

B. Acute Toxicity

No acute toxicity studies are available for sodium bisulfite.

The oral LD_{50} value in rats for sodium sulfite is 2,610 mg/kg (ECHA) [Kl. score = 2]. The oral LD_{50} values in rats for sodium metabisulfite are 1,420 mg/kg (males), 1,630 mg/kg (females), and 1,540 mg/kg (combined sexes) (ECHA) [Kl. score = 2].

The 4-hour inhalation LC_{50} in rats for sodium sulfite is >5.5 mg/L (ECHA). [Kl. score = 2]

The dermal LD_{50} in rats for sodium sulfite is >2,000 mg/kg (ECHA). [Kl. score = 2]

C. Irritation

No studies are available on sodium bisulfite.

Application of 0.5 mL of sodium sulfite to the skin of rabbits for 4 hours under occlusive conditions was minimally irritating. The mean of the 24, 48, and 72 scores were: 0.5 for erythema and 0.0 for edema (ECHA). [Kl. score = 2]

Instillation of 0.1 mL of sodium sulfite (with 0.5% cobalt sulfate) into the eyes of rabbits produced slight irritation. The mean of the 24, 48, and 72 hour scores are as follows: 0.5 for conjunctival redness; 0.5 for conjunctival chemosis; 0.0 for corneal lesions; and 0.0 for iridial lesions (ECHA). [Kl. score = 2]

D. Sensitization

No studies are available on sodium bisulfite.

Sodium bisulfite was not considered a skin sensitizer in a mouse local lymph node assay (ECHA). [K. score = 1]

E. Repeated Dose Toxicity

Oral

No studies are available on sodium bisulfite.

A study is available on sodium metabisulfite. Sodium metabisulfite dissociates in water to form sodium (Na^+) ions, disulfite ($S_2O_5^{2-}$) ions, and sulfur dioxide (SO_2). The disulfite ions can form bisulfite (HSO_3^-) and sulfite ions (SO_2^{3-}); at neutral pH, a mixture of 50% sulfite (SO_3^{2-}) and 50% bisulfite (HSO_3^{2-}) is present.

Male and female Wistar rats were fed in their diet 0, 0.125, 0.25, 0.5, 1.0, or 2.0% sodium metabisulfite for up to two years and over three generations. The diet was enriched with thiamine to prevent thiamine deficiency as a result of sulfite-induced destruction of this vitamin. During storage up to the time of consumption, the losses of sulfite from the feed containing sodium metabisulfite at levels of 0.125, 0.25, 0.5, 1.0, and 2.0% averaged 22, 14,12, 8, and 4.5%, respectively, while the decrease in thiamine was 2.7, 1.7, 8.3, 14.5, and 15.4%, respectively. Addition of thiamine to the diet prevented thiamine deficiency in rats at all dose levels based on measurements of thiamine levels in the urine and liver. The general condition of the rats was good during the first 72 weeks in the F_0 generation, as well as the other two generations. After 72 weeks, there was a rapid increase in mortality in all groups. Survival in the treated groups were generally higher than the controls, except for the 2% F_1 males; no deaths occurred in the 2% F_2 females. A marginal reduction in body weight gain was observed in the 2% dose group (both sexes) in the F_1 and F_2 generations. Feed consumption was similar between treated and control groups. There were no changes in hematology and clinical chemistry parameters and urinalysis that were considered toxicologically significant. The $\geq$1% dietary groups had occult blood in their feces. Relative kidney weights were increased in the 2% F_2 females, but there were no pathological changes noted in the kidneys from this group. Hyperplastic changes in the fore- and glandular stomachs were noted in the $\geq$1% groups in all three generations. Some slight alterations were also noted in stomachs of the 0.5% F_2 rats. The NOAEL for systemic toxicity is 1.91% in the diet. This was estimated to be 955 mg/kg-day based on a rat body weight of 400 g and a daily feed intake of 20 g. The histopathologic effects on the stomach and the occult blood in feces are considered to be the result of localized irritation (a site-of-contact effect) from the ingestion of sodium metabisulfite (Til et al., 1972; ECHA). [Kl. score = 2]

Inhalation

No studies on sodium bisulfite were located.

Dermal

No studies on sodium bisulfite were located.

G. Genotoxicity

In Vitro Studies

No *in vitro* genotoxicity studies were located for sodium bisulfite. Table 2 presents the findings from *in vitro* genotoxicity studies conducted on structural analogues of sodium bisulfite.

Table 2: *In Vitro* Genotoxicity Studies on Structural Analogues to Sodium Bisulfite

Test System	Test Substance	Results*		Klimisch Score	Reference
		-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* strains)	Sodium metabisulfite	-	-	2	ECHA
Bacterial reverse mutation (*S. typhimurium* strains)	Potassium metabisulfite	-	-	2	ECHA
Bacterial reverse mutation (*S. typhimurium* strains)	Potassium metabisulfite	-	-	2	ECHA
Bacterial reverse mutation (*S. typhimurium* and *E. coli* strains)	Sodium metabisulfite	-	-	2	ECHA
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	Sodium metabisulfite	-	-	2	ECHA
Chromosomal aberration (human lymphocytes)	Sodium metabisulfite	-	-	1	ECHA

*+, positive; -, negative

In Vivo Studies

Sodium bisulfite did not show a mutagenic response in a rat dominant lethal assay when given in feed at doses of 0, 4.5, 15, or 45 mg/kg-day (ECHA). [Kl. score = 2]

Sodium sulfite was not genotoxic in a bone marrow micronucleus test in rats. Male NMRI rats were given a single subcutaneous injection of 0, 250, 500, or 1,000 mg/kg sodium sulfite (ECHA). [Kl. score = 1]

H. Carcinogenicity

No studies are available on sodium bisulfite.

Male and female Wistar rats were fed in their diet 0, 0.125, 0.25, 0.5, 1.0, or 2.0% sodium metabisulfite for up to two years and over three generations. There was no

increased incidence of tumors in the treated groups compared to the controls (Til et al., 1972). [Kl. score = 2]

Male and female ICR/JCL mice were given in their drinking water 0, 1, or 2% potassium metabisulfite for two years. There was no increased incidence of tumors in the treated groups compared to the controls (Tanaka et al., 1979). [Kl. score = 2]

No inhalation or dermal carcinogenicity studies were located.

I. Reproductive Toxicity

No studies are available on sodium bisulfite.

Male and female Wistar rats were fed in their diet 0, 0.125, 0.25, 0.5, 1.0, or 2.0% sodium metabisulfite for up to two years and over three generations. The diet was enriched with thiamine to prevent thiamine deficiency as a result of sulfite-induced destruction of this vitamin. During storage up to the time of consumption, the losses of sulfite from the feed containing sodium metabisulfite at levels of 0.125, 0.25, 0.5, 1.0, and 2.0% averaged 22, 14,12, 8, and 4.5%, respectively, while the decrease in thiamine was 2.7, 1.7, 8.3, 14.5, and 15.4%, respectively. Addition of thiamine to the diet prevented thiamine deficiency in rats at all dose levels based on measurements of thiamine levels in the urine and liver. The effects other than reproductive and developmental toxicity are discussed above in the Repeated Dose Toxicity section. There were no treatment-related effects on female fertility, the number of young per litter, or birth weight or mortality of the offspring. The number of F_{2a} pups was significantly reduced in the $\geq$0.5% groups during the first breeding cycle, but there was no dose-response and the reduction did not occur during the second breeding cycle. Slight growth retardation was observed in the F_1 and F_2 generation rats both before and after weaning. The NOAEL for reproductive toxicity is 1.91% in the diet. This was estimated to be 955 mg/kg-day based on a rat body weight of 400 g and a daily feed intake of 20 g (Til et al., 1972; ECHA). [Kl. score = 2]

Male and female rats were given sodum metabisulfite in their drinking water for up to 2.5 years and in three successive generations. The doses were 375 and 750 ppm as sulfur dioxide (SO_2). There was no evidence of systemic toxicity in either dose group. The number of offspring of either the F_1 and F_2 generation and the proportion surviving to the end of lactation were similar between treated and control groups. The NOAEL for reproductive toxicity is 750 ppm (as SO_2) in drinking water. Assuming an average rat body weight of 400 g and a daily water intake of 28 mL, 750 ppm (as SO_2) corresponds to 53 mg/kg-day sodium metabisulfite (Lockett and Natoff, 1960; ECHA). [Kl. score = 2]

J. Developmental Toxicity

Pregnant female Wistar rats were dosed by oral gavage with up to 110 mg/kg-day sodium bisulfite during GD 6-15. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity for this study is 110 mg/kg-day (ECHA). [Kl. score = 2]

Pregnant female CD-1 mice were dosed by oral gavage with up to 150 mg/kg-day sodium bisulfite during GD 6-15. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity for this study is 150 mg/kg-day (ECHA). [Kl. score = 2]

Pregnant female Dutch-belted were dosed by oral gavage with up to 100 mg/kg-day sodium bisulfite during GD 6-18. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity for this study is 100 mg/kg-day (ECHA). [Kl. score = 2]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for sodium metabisulfite follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

No repeated dose toxicity studies have been conducted on sodium bisulfite. In a study conducted on sodium metabisulfite, there was no evidence of systemic toxicity in rats fed up to 2% for two years (Til et al., 1972). The NOAEL for this study is 2% or 955 mg/kg-day.

Using the molecular weights of sodium metabisulfite (190.1 g/mol) and sodium bisulfite (104.1 g/mol), the NOAEL of 955 mg/kg-day for sodium metabisulfite is converted to 523 mg/kg-day for sodium bisulfite. The NOAEL of 523 mg/kg-day will be used for determining the oral reference dose (RfD) and the drinking water guidance value for sodium bisulfite.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10

UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 523/(10 x 10 x 1 x 1 x 1) = 523/100 = 5 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (5 x 70 x 0.1)/2 = 18 mg/L

The Australian drinking water guidance value for sodium is 180 mg/L based on aesthetics (ADWG, 2011).

B. Cancer

There are no carcinogenicity studies on sodium bisulfite. No carcinogenic effects were reported for sodium metabisulfite in rat and mouse chronic studies. Thus, a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Sodium bisulfite does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

No aquatic toxicity studies have been conducted on sodium bisulfite. Other inorganic sulfite compounds show low to moderate toxicity concern to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

No acute aquatic studies are available on sodium bisulfite; however, studies are available on other inorganic sulfite compounds. The studies on these inorganic sulfite compounds can used to read-across to sodium bisulfite since sulfite ions are formed in water upon dissociation of sodium bisulfite. Table 3 lists the results of acute aquatic toxicity studies on the structural analogues of sodium bisulfite.

Table 2: Acute Aquatic Toxicity Studies on the Structural Analogues of Sodium Bisulfite

Test Species	Test Substance	Endpoint	Results (mg/L)	Klimisch score	Reference
Leuciscus idus	Potassium sulfite	96-hr LC_{50}	316	2	ECHA
Salmo gairdneri	Sodium pyrosulfite	96-hr LC_{50}	147-215 (177.8*)	2	ECHA
Brachydanio rerio	Potassium metabisulfite	96-hr LC_{50}	464-1,000 (681.2*)	1	ECHA
Daphnia magna	Sodium disulfite	48-hr EC_{50}	88.8	2	ECHA
S. subspicatus	Sodium disulfite	96-hr EC_{50} 72-hr EC_{10}	43.9 33.3	2	ECHA

*Geometric mean.

Chronic Studies

No chronic studies are available on sodium bisulfite; however, studies are available on sodium sulfite. Table 4 lists the results of chronic aquatic toxicity studies conducted on sodium sulfite.

Table 4: Chronic Aquatic Toxicity Studies on Sodium Sulfite (CAS No. 7757-83-7)

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Danio rerio	34-d NOEC	>316	1	ECHA
Daphnia magna	21-d NOEC	>10	2	ECHA

B. Terrestrial Toxicity

No studies were located.

C. Calculation of PNEC

The PNEC calculations for sodium bisulfite follow the methodology discussed in DEWHA (2009).

PNEC water

No studies have been conducted on sodium bisulfite; however, the results from studies conducted on other inorganic sulphite compounds can be used to read-across to sodium bisulfite. Hence, experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (177.8 mg/L for sodium pyrosulfite), invertebrates (88.8 mg/L for sodium sulfite), and algae (43.9 mg/L for sodium disulfite).

Results from chronic studies on sodium sulfite are also available for all three trophic levels, with the lowest NOEC being 10 mg/L for invertebrates. Using the molecular weights of sodium sulfite (126 g/mol) and sodium bisulfite (104.1 g/mol, the NOEC of 10 mg/L for sodium sulfite is converted to 8.3 mg/L. On the basis that the data consist of short-term and long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported NOEC of 8.3 mg/L for invertebrates. The $PNEC_{water}$ is 0.8 mg/L.

PNEC sediment

No experimental toxicity data on sediment organisms are available. Sodium bisulfite dissociates completely in water with its environmental distribution is dominated by its high water solubility. K_{ow} and K_{oc} parameters do not readily apply to inorganics, such as sodium bisulfite. Thus, the equilibrium partitioning method cannot be used to calculate

the $PNEC_{sed}$. Based on its properties, no adsorption of sodium bisulfite to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

PNEC soil

No experimental toxicity data on soil organisms are available. Sodium bisulfite dissociates completely in water with its environmental distribution is dominated by its high water solubility. K_{ow} and K_{oc} parameters do not readily apply to inorganics, such as sodium bisulfite. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on its properties, no adsorption of sodium bisulfite to soil is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Sodium bisulfite is an inorganic compound that dissociates completely to ionic species and sulfur dioxide gas. Biodegradation is not applicable to these compounds. For the purposes of this PBT assessment, the persistent criterion is not considered applicable to sodium bisulfite or its dissociated compounds.

Sodium bisulfite is not expected to bioaccumulate because its dissociated species are inorganic ions and a gas.

There are no aquatic toxicity data on sodium bisulfite. The lowest NOEC from chronic aquatic toxicity studies on sodium sulfite, a structural analogue of sodium bisulfite, is >0.1 mg/L. Thus, sodium bisulfite is not expected to meet the criteria for toxicity.

The overall conclusion is that sodium bisulfite is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Aquatic Acute Category 3

B. Labelling

No signal word.

C. Pictogram

None

X. SAFETY AND HANDLING [for a solution of sodium bisulfite]

A. FIRST AID

Eye Contact
In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. If symptoms persist, seek medical advice.

Skin Contact
Wash thoroughly with soap and water.

Inhalation
If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Ingestion
Rinse mouth with water and then drink plenty of water. Never give anything by mouth to an unconscious person. If symptoms develop, seek medical advice.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
When contacted by water, sodium bisulfite releases sulfur dioxide (SO_2), a poisonous gas. In the case of fire, the following may be liberated: Sulfur oxides and sulfur dioxide.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Use appropriate protective equipment.

Environmental Precautions
Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled
Pick up with absorbent material. Dispose of contaminated material as prescribed.

D. STORAGE AND HANDLING

General Handling
No special measures necessary provided product is used correctly.

Other Handling Precautions
Avoid eye and skin contact.

Storage
Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards

The workplace exposure standard for sodium bisulfite in Australia is 5 mg/m^3 as an 8-hr TWA.

Engineering Controls
None

Personal Protection Equipment

Respiratory Protection:
Respiratory protection is not required.

Hand Protection:
Chemical resistant protective gloves.

Skin *Protection*:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Safety glasses with side-shields.

Other Precautions:

Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible.

F. TRANSPORT INFORMATION

Sodium bisulfite is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

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SODIUM CARBONATE

This dossier on sodium carbonate does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of sodium carbonate in its use in drilling muds and hydraulic fracturing fluids. The information presented in this dossier was obtained primarily from the OECD-SIDS documents on sodium carbonate (OECD, 2002a, b) and the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch et al., 1997).

I. SUBSTANCE IDENTIFICATION

Chemical Name (IUPAC): disodium carbonate

CAS RN: 497-19-8

Molecular formula: $CH_2O_3.2Na$

Molecular weight: 106

Synonyms: sodium carbonate; disodium carbonate; carbonic acid, disodium salt; bisodium carbonate; soda ash, calcined soda

SMILES: C(=O)([O-])[O-].[Na+].[Na+]

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-Chemical Properties of Sodium Carbonate

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Solid; white powder	1	ECHA
Melting Point	851°C	2	ECHA
Boiling Point	No data	-	-
Density	>2.52 and <2.53 (20°C)	1	ECHA
Vapour Pressure	No data	-	-
Partition Coefficient (log K_{ow})	Not applicable	-	-
Water Solubility	404 g/L* [soluble]	2	ECHA
pH	ca 11.5**	2	ECHA
Flammability	No	1	ECHA

*GLP-compliant study. The water solubility was overestimated, possibly due to the high temperature (during dissolution) or due to gel formation.

**pH value from water solubility test.

Aqueous solutions are strongly alkaline. At 25°C, the pH of 1, 5 and 10 wt% sodium carbonate solutions are 11.37, 11.58, and 11.70, respectively (Eggeman, 2001).

III. ENVIRONMENTAL FATE PROPERTIES

Due to its high water solubility and low vapour pressure, sodium carbonate will be found predominantly in the aquatic environment where it dissociates completely to sodium (Na^+) and carbonate (CO_3^{2-}) ions. Both ions are ubiquitous in the environment (UNEP, 1995).

Addition of sodium carbonate to an aquatic ecosystem will result in an increase in alkalinity and a tendency to increase the pH. The carbonate ions will react with water, forming bicarbonate (HCO_3^-) and hydroxide (OH^-) ions until an equilibrium is reached. A re-equilibration takes place when carbonate (CO_3^{2-}) is dissolved in water according to the following equations:

$HCO_3^- \leftrightarrow CO_3^{2-} + H^+$ pKa=10.33

$CO_2 + H_2O \leftrightarrow HCO_3^- + H^+$ pKa = 6.35

Only a small fraction of the dissolved CO_2 is present as H_2CO_3 (carbonic acid), the major part is present as CO_2. The amount of CO_2 in water is in equilibrium with the partial pressure of CO_2 in the atmosphere. The CO_2/ HCO_3^-/ CO_3^{2-} equilibria are the major buffer of the pH of freshwater.

Based on the above equations, CO_2 is the predominant species at a pH smaller than 6.35, while HCO_3^- is the predominant species at a pH in the range of 6.35-10.33 and CO_3^{2-} is the predominant species at a pH higher than 10.33.

A release of sodium carbonate into the aquatic environment from the use of sodium carbonate could potentially increase the sodium concentration and the pH in the aquatic environment. Table 2 shows the concentration of sodium carbonate needed to increase the pH to values of 9.0, 10.0, and 11.0.

Table 2: Sodium Carbonate Concentration (mg/L) Needed to Increase pH (DeGroot et al., 2002; taken from OECD, 2002b).

Buffer capacity*	Final pH**		
	9.0	10.0	11.0
0 mg/L HCO_3^- (distilled water)	11.1 (0.6)	16 (6.1)	603 (61)
20 mg/L HCO_3^- (10^{th} percentile of 77 rivers)	2.7 (21)	32 (26)	766 (81)
106 mg/L HCO_3^- (mean value of 77 rivers)	9.7 (107)	102 (112)	1467 (167)
195 mg/L HCO_3^- (90^{th} percentile of 77 rivers)	17 (196)	175 (201)	2192 (256)

*The initial pH of a bicarbonate solution with a concentration of 20-195 mg/L is 8.3 (calculated).

**The final concentration of bicarbonate is given in parentheses.

Na^+ and CO_3^{2-} ions will not adsorb on particulate matter or surfaces and will not accumulate in living tissues (OECD 2002b).

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

There are limited toxicity data on sodium carbonate. It has a low order of acute toxicity by the oral, dermal, and inhalation routes. It is not a skin irritant, but it is an eye irritant. Sodium carbonate is not expected to be systemically available in the body from oral exposure due to its dissociation in bodily fluids and the neutralisation of the carbonate ion in the stomach. No developmental toxicity was seen in studies with rats, mice, or rabbits.

B. Toxicokinetics and Metabolism

Sodium carbonate will dissociate in bodily fluids into sodium (Na^+) and carbonate (CO_3^{2-}) ions. The oral uptake of sodium carbonate would lead to neutralisation of carbonate in the stomach by the gastric acids which would lead to bicarbonate and/or carbon dioxide (CO_2) formation. It is unlikely that an oral uptake of sodium carbonate would disrupt the acid-base balance of the body because CO_2 formation in the stomach would alleviate the high amounts of carbonate that would be present in the stomach from an acute exposure. The equation that describes this reaction is:

$HCO_3^- + H^+ \leftrightarrow \square H_2CO_3 \leftrightarrow CO_2 + H_2O$

C. Acute Toxicity

An acute oral LD_{50} of sodium carbonate monohydrate in rats is 2,800 mg/kg, and the acute dermal LD_{50} in rabbits is >2,000 mg/kg (OECD, 2002a,b; ECHA). [Kl. scores = 1]

An acute inhalation toxicity study was conducted on an aerosol of sodium combustion products, which contain predominantly sodium carbonate. The 2-hour inhalation LC_{50} values for this aerosol to guinea pigs, mice and rats were 800, 1,200 and 2,300 mg/m^3, respectively. The median aerodynamic diameter of the aerosol was 0.77 $\pm$ 2.1µm (OECD, 2002a, b; ECHA). [Kl. score = 1]

D. Irritation

As reviewed in the OECD-SIDS documents (OECD, 2002a,b), skin irritation studies in laboratory animals and human volunteers with sodium carbonate either as a 50% solution or as a solid showed slight to no skin irritation.

Sodium carbonate is an eye irritant (OECD, 2002a,b; ECHA). A dose of 0.1 ml sodium carbonate monohydrate was irritating to the eyes of rabbits and, in another study, 0.1 ml of sodium carbonate (anhydrous) was highly irritating to rabbit eyes. However, 0.1 g sodium carbonate (anhydrous) was found not to be an eye irritant. [Kl scores of 1, 2, 1, respectively]

E. Sensitisation

No studies were identified.

F. Repeated Dose Toxicity

No studies were identified by the oral, inhalation or dermal routes.

G. Genotoxicity

In Vitro Studies

Sodium carbonate did not induce primary DNA damage in an *E. coli* chromotest (Olivier and Marzin, 1987; OECD, 2002a, b). [Kl. score = 3]

In Vivo Studies

No studies were identified.

H. Carcinogenicity

No studies were identified.

I. Reproductive Toxicity

No studies were identified.

J. Developmental Toxicity

Pregnant rats were dosed by oral gavage with 0, 2.45, 11.4, 52.9 or 245 mg/kg sodium carbonate on gestational days 6 to 15. No maternal or developmental toxicity was observed. The NOAEL for maternal and developmental toxicity is 245 mg/kg-day, the highest dose tested (OECD, 2002a, b). [Kl. score = 2]

Pregnant mice were given doses of sodium carbonate (3.4 to 340 mg/kg) by oral gavage on gestational days 6 to 15. No maternal or developmental toxicity was observed. The NOAEL for maternal and developmental toxicity is 340 mg/kg-day, the highest dose tested (OECD, 2002a, b). [Kl. score = 2]

Pregnant rabbits were dosed by oral gavage with 0, 1.79, 8.31, or 179 mg/kg sodium carbonate on gestational days 6 to 15. No maternal or developmental toxicity was observed. The NOAEL for maternal and developmental toxicity is 179 mg/kg-day, the highest dose tested (OECD, 2002a, b). [Kl. score = 2]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

There are no repeated dose toxicity studies conducted on sodium carbonate by any route of exposure. Developmental toxicity studies conducted by the oral route in three animal species showed no developmental effects at the highest doses tested. Sodium carbonate dissociates to sodium and carbonate ions in bodily fluids, and significant amount of these ions are already ingested in foods. Furthermore, both ions are present in the body and are highly regulated by homeostatic mechanisms.

Sodium carbonate is used in many countries (e.g., U.S. and EU) as a food additive. It is regarded as a Generally Recognized as Safe (GRAS) substance in food with no limitation other than current good manufacturing practice (OECD, 2002a, b).

Therefore, a toxicological reference value was not derived for sodium carbonate.

The Australian drinking water guideline values for sodium (180 ppm, aesthetic) and pH may be applicable (ADWG, 2011).

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Sodium carbonate does not exhibit the following physico-chemical properties:

- Flammability
- Explosivity
- Oxidising potential.

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Sodium carbonate is of low toxicity concern to aquatic and terrestrial organisms.

B. Aquatic Toxicity

Acute Studies

The results of the aquatic toxicity studies conducted on sodium carbonate are presented in Table 3.

Table 3: Aquatic Toxicity Studies on Sodium Carbonate (OECD, 2002a,b)

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Bluegill sunfish	96-h LC_{50}	300	2	OECD, 2002a, b
Mosquitofish	96-h LC_{50}	740	2	OECD, 2002a, b
Bluefill sunfish	24-h LC_{50}	385	4	OECD, 2002a, b
Molly	50-h LC_{50}	297	4	OECD, 2002a, b
Ceriodaphnia dubia	48-h EC_{50}	200 - 227	2	OECD, 2002a, b

There are other studies conducted on invertebrates, but the results of these studies were not included in Table 3 because of the low reliability of the data (OECD, 2002a, b). No studies on algae were identified (OECD, 2002a, b).

C. Terrestrial Toxicity

No studies were identified.

D. Calculation of PNEC

The OECD-SIDS SIAR on sodium carbonate states the following regarding the aquatic toxicity studies on sodium carbonate (OECD, 2002b):

> "In general, the available toxicity studies with sodium carbonate were not conducted according to current standard guidelines. In many cases pH, buffer capacity and/or medium composition were not discussed in the publications, although this is essential information for toxicity tests with sodium carbonate. In general, mortality of the test organisms was found at concentrations higher than 100 mg/l but for *Amphipoda*, salmon and trout lethal effects were already observed at 67-80 mg/l although these studies had a low reliability. The main factor explaining the acute aquatic toxicity of sodium carbonate is most likely the increase of the pH."

> "Because the natural pH, bicarbonate and also the sodium concentration (and their fluctuations in time) varies significantly between aquatic ecosystems, it is not considered useful to derive a generic PNEC or $PNEC_{added}$."

Based on the information above, PNEC values for freshwater, sediment, and soil were not derived for sodium carbonate.

VIII. PBT ASSESSMENT

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Sodium carbonate is an organic salt that dissociates completely to sodium and carbonate ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both sodium and

carbonate ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria are not considered applicable to this inorganic salt.

Sodium and carbonate ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, sodium carbonate is not expected to bioaccumulate.

No chronic aquatic toxicity data exist on sodium carbonate; however, the acute $EC(L)_{50}$s are >1 mg/L in fish, invertebrates and algae. Therefor, sodium carbonate does not meet the screening criteria for toxicity.

The overall conclusion is that sodium carbonate is not a PBT substance.

IX. CLASSIFICATION AND LABELLING

A. Classification

Eye Irritant Category 2

B. Labelling

Warning

C. Pictograms



X. SAFETY AND HANDLING

A. First Aid

Eye Contact

Immediately flush eyes with plenty of water for at least 15 minutes. Remove contacts, if present and easy to do. If symptoms persist, seek medical attention.

Skin Contact

Wash with soap and water.

Inhalation

If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Ingestion

Do not induce vomiting. Rinse mouth with water. Never give anything by mouth to an unconscious person. If symptoms persist, get medical attention.

B. Firefighting Information

Extinguishing Media

Water fog, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards

Decomposition in fire may produce toxic gases.

Special Protective Equipment for Fire fighters

Full protective clothing and approved self-contained breathing apparatus.

C. Accidental Release Measures

Personal Precautions

Use appropriate protective equipment. Avoid creating and breathing dust.

Environmental Precautions

Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled

Scoop up and remove.

D. Storage and Handling

General Handling

Avoid contact with eyes and skin. Avoid creating or inhaling dust.

Storage

Store away from acids. Store in a cool, dry location.

E. Exposure Controls/Personal Protection

Occupational Exposure Standards

Workplace Australia has not established an occupational exposure limit for sodium carbonate.

Engineering Controls

Use in a well ventilated area. Localised ventilation should be used to control dust levels.

Personal Protection Equipment

Respiratory Protection: In case of insufficient ventilation, wear suitable respiratory equipment. Dust/mist respirator.

Hand Protection: Chemical resistant protective gloves.

Skin Protection: Body protection must be chosen depending on activity and possible exposure

Eye protection: Safety glasses with side-shields.

Other Precautions: Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible.

F. Transport Information

Sodium Carbonate is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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XIV. ACRONYMS AND GLOSSARY

C	Centigrade
ECHA	European Chemicals Agency
EU	European Union
GD	gestational day
GHS	Globally Harmonised System of Classification and Labelling of Chemicals
GRAS	Generally Recognized as Safe
IUPAC	International Union of Pure and Applied Chemistry
kg	kilogram
kPa	kilopascal
L	litre
LOAEL	lowest observed adverse effect level
m	metre
mg/m3	milligrams per cubic meter
mm	millimetre
µg	microgram
mg	milligram
mL	millilitre
NOAEL	no observed adverse effect level
OECD	Organisation for Economic Co-operation and Development
Kl	Klimisch scoring system
Pow	octanol/water partition coefficient
PNEC	Predicted No Effect Concentration
ppm	parts per million

REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RfD	Reference Dose
SDS	Safety Data Sheet
SIDS	Screening Information Data Set
SMILES	simplified molecular-input line-entry system

SODIUM HYDROXIDE

This dossier on sodium hydroxide does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of sodium hydroxide in its use in drilling muds and hydraulic fracturing fluids. The information presented in this dossier was obtained from the OECD-SIDS documents on sodium hydroxide (OECD, 2002a, b) and the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch et al., 1997).

I. SUBSTANCE IDENTIFICATION

Chemical Name (IUPAC): Sodium hydroxide

CAS RN: 1310-73-2

Molecular formula: HNaO

Molecular weight: 40 g/mol

Synonyms: Caustic soda, soda lye, NaOH

SMILES: O[Na]

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Physico-Chemical Properties of Sodium Hydroxide

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Solid	2	Lide, 2009; ECHA
Melting Point	318°C (solid, 100%); 52°C (60% solution)	2	ECHA
Boiling Point	1,388°C @ 101.325 kPa	2	Lide, 2009; ECHA
Density	2.13 g/cm^2, 20°C (100%) 1.43 g/cm^2, 20°C (40%)	2	Lide, 2009; ECHA
Vapour Pressure	1 Pa @ 513°C	2	Lide, 2009; ECHA
Partition Coefficient (log Kow)	Not applicable	-	-
Water Solubility	Very soluble	2	Lide, 2009; ECHA
Dissociation Constant (pKa)	14.8 @ 25°C	2	Lide, 2009; ECHA
pH of 5% NaOH solution	14	2	O'Neil, 2006

Sodium hydroxide (NaOH) is a strong alkaline substance that dissociates completely in water to sodium (Na^+) and hydroxyl (OH^-) ions.

III. ENVIRONMENTAL FATE PROPERTIES

Due to its high water solubility and low vapour pressure, sodium hydroxide will be found predominantly in the aquatic environment where it dissociates completely to sodium (Na^+) and hydroxyl (OH^-) ions. Both ions are ubiquitous in the environment (UNEP, 1995).

The addition of sodium hydroxide to an aquatic ecosystem may increase the pH depending on the buffer capacity of the receiving water. In general, the buffer capacity is regulated by the equilibria between CO_2, HCO_3^- and CO_3^{2-}:

$CO_2 + H_2O \leftrightarrow HCO_3^- + H^+$ ($pKa_1 = 6.35$)
$HCO_3^- \leftrightarrow CO_3^{2-} + H^+$ ($pKa_2 = 10.33$)

A release of sodium hydroxide into the aquatic environment from the use of NaOH could potentially increase the sodium concentration and the pH in the aquatic environment. Table 2 shows the concentration of sodium hydroxide needed to increase the pH to values of 9.0, 10.0, 11.0, and 12.0.

Table 2: Sodium Hydroxide Concentration (mg/L) Needed to Increase pH (DeGroot et al., 2002; taken from OECD, 2002b).

Buffer capacity*	Final pH			
	9.0	10.0	11.0	12.0
0 mg/L HCO_3 (distilled water)	0.4	4.0	40	400
20 mg/L HCO_3 (10^{th} percentile of 77 rivers)	1.0	8.2	51	413
106 mg/L HCO_3^- (mean value of 77 rivers)	3.5	26	97	468
195 mg/L HCO_3^- (90^{th} percentile of 77 rivers)	6.1	45	145	525

*The initial pH of a bicarbonate solution with a concentration of 20-195 mg/L was 8.25 to 8.35.

Na^+ and OH^- ions will not adsorb on the particulate matter or surfaces and will not accumulate in living tissues (OECD, 2002b).

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Limited toxicity data exist for sodium hydroxide (NaOH). Depending on the concentration, solutions of NaOH are corrosive, irritating, or non-irritating. These solutions cause direct effects to the skin, eyes, respiratory tract, and gastrointestinal tract. Vapors from aqueous solutions of KOH can cause respiratory irritation. NaOH is not a skin sensitiser. There are no repeated dose, reproductive, and developmental toxicity studies on potassium hydroxide.

B. Toxicokinetics/Metabolism

Sodium hydroxide dissociates completely in aqueous solutions to sodium (Na^+) and hydroxyl (OH^-) ions. Sodium is an essential nutrient involved in fluid and electrolyte balance and is required for normal cellular function (Ganong, 1995). Sodium is the major extracellular cation in the body; the total body content is tightly regulated (Ganong, 1995).

C. Acute Toxicity

There are no oral toxicity guideline studies on sodium hydroxide. An oral LD_{50} of a 1 to 10% solution of NaOH in rabbits was reported to be 325 mg/kg (expressed as 100% NaOH) (OECD, 2002a,b). Mortality was also observed when a 1% NaOH solution was dosed, but in this case, the applied volume was relatively high (24 mL per kg body weight) (OECD, 2002a,b).

Acute toxicity studies were not identified for the inhalation and dermal route.

D. Irritation

Animal studies have shown that an 8% NaOH solution is corrosive to the skin. In humans, 0.5 to 4% NaOH concentrations produced skin irritation; and, based on the results of two different human patch tests, a NaOH solution that is slightly less than 0.5% would be non-irritating to human skin (OECD, 2002a,b).

Results from animal eye irritation studies indicate that a 0.2-1.0% NaOH solution would be non-irritating, while 1.2 or >2% NaOH solutions would be corrosive (OECD, 2002a,b).

E. Sensitisation

Male volunteers were exposed on the skin of their back to solutions of 0.063 to 1.0% NaOH in the induction phase of a human patch test. After 7 days the volunteers were challenged to a concentration of 0.125% NaOH. The irritant response correlated well with the concentration of NaOH, but an increased response was not observed when the previously patch tested sites were re-challenged. Based on this study, sodium hydroxide is not a skin sensitiser (OECD, 2002a, b; ECHA). [Kl. score = 2]

F. Repeated Dose Toxicity

No studies were identified for the oral and dermal route. An inhalation study was conducted in rats exposed to aerosols of solutions of NaOH ranging from 5% to 40%. Exposures were twice weekly (hours/day and total exposure days unspecified). All animals in the 40% solution group died within a month mostly from bronchopneumonia. At the lower concentrations, respiratory tract lesions were observed; an NOAEL was not identified (NIOSH, 1975).

G. Genotoxicity

In Vitro Studies

Several *in vitro* studies have been conducted on NaOH (OECD, 2002a, b; ECHA). Although these studies reported negative results, they are considered unreliable (Kl. score = 3) due to methodological or reporting deficiencies.

In Vivo Studies

Several *in vivo* studies have been conducted on NaOH (OECD, 2002a,b; ECHA). Although these studies reported negative results, they are considered unreliable (Kl. score = 3) due to methodological or reporting deficiencies.

H. Carcinogenicity

No studies were identified.

I. Reproductive Toxicity

No valid studies were identified regarding toxicity to reproduction in animals after oral, dermal or inhalation exposure to NaOH.

J. Developmental Toxicity

No valid studies were identified regarding developmental toxicity in animals after oral, dermal or inhalation exposure to NaOH (OECD, 2002a, b; ECHA).

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

Oral and dermal repeated dose, reproductive, and developmental toxicity studies have not been conducted on NaOH. A repeated dose toxicity study was conducted by the inhalation route, but the methodology and documentation preclude its use for deriving a toxicological reference value. These toxicity studies would have questionable usefulness because of the corrosive/irritating nature of NaOH, which would limit the amount absorbed. NaOH dissociates to sodium and hydroxyl ions in bodily fluids, and a significant amount of these ions are already ingested in foods. Furthermore, both ions are present in the body and are highly regulated by homeostatic mechanisms. Thus, a toxicological reference value was not derived for NaOH.

The Australian drinking water guideline values for sodium (180 ppm, aesthetic) and pH may be applicable (ADWG, 2011).

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Sodium hydroxide does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidising potential.

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Aquatic Toxicity

The OECD-SIDS SIAR on NaOH states the following regarding the aquatic toxicity studies on NaOH (OECD, 2002b):

> "At concentrations reported in publications and study reports, the toxicity has been assumed to be due to hydroxide only, because at these effect concentrations the concentration of sodium is too low to explain the effects. However, it should be realised that the results of toxicity tests with NaOH depend on the buffer capacity of the test medium. In a highly buffered test medium, the hydroxyl ion will be neutralised, and the observed toxicity will be low, while in a poorly buffered test medium the pH will increase rapidly and therefore the observed toxicity will be relatively high. Besides the direct effects (pH change) NaOH could also have indirect effects. The pH change could influence the speciation of other chemicals and therefore increase and/or decrease the toxicity, e.g.; NH_3 is more toxic than NH_4^+."

There are no guideline studies on NaOH; the studies summarised below have Klimisch scores of 3 or 4.

Acute Fish

The 24-hour LC_{50} to *Carassius auratus* (goldfish) is 160 mg/L. At 100 mg/L, which was equivalent to a pH of 9.8, no mortality was observed. The 48-hour LC_{50} to *Leuciscus idus melanotus*, is 189 mg/L. The 96-hour LC_{50} of *Gambusia affinis* (mosquitofish) is 125 mg/L. At 84 mg/L, no effects on the fish were observed. The pH was 9 at 100 mg/L.

Acute Invertebrate

The 48-hour LC_{50} is 40 mg/L for *Ceriodaphnia cf. dubia*. The toxicity threshold concentration of NaOH for *Daphnia magna* was reported to range from 40 to 240 mg/L.

Acute Algae

No studies were identified.

B. Terrestrial Toxicity

No studies were identified.

C. Calculation of PNEC

The OECD-SIDS SIAR on NaOH states the following regarding the aquatic toxicity studies on NaOH (OECD, 2002b):

> "In many cases pH, buffer capacity and/or medium composition were not discussed in the publications, although this is essential information for toxicity tests with NaOH. This is the most important reason why most of the studies, mentioned above were considered invalid. Although valid acute ecotoxicity tests and chronic ecotoxicity tests with NaOH are not available, there is no need for additional testing with NaOH. A significant number of acute toxicity tests are available, and the results of the tests are more or less consistent. Altogether they give a sufficient indication of acute toxicity levels of sodium hydroxide."
>
> "Furthermore, acute toxicity data cannot be used to derive a PNEC or a PNEC added for sodium hydroxide. Aquatic ecosystems are characterised by an alkalinity/pH, and the organisms of the ecosystem are adapted to these specific natural conditions. Based on the natural alkalinity of waters, organisms will have different optimum pH conditions, ranging from poorly buffered waters with a pH of 6 or less to very hard waters with pH values up to 9. A lot of information is available about the relationship between pH and ecosystem structure and also natural variations in pH of aquatic ecosystems have been quantified and reported extensively in ecological publications and handbooks."
>
> "Normally a PNEC or a PNEC added has to be derived from the available ecotoxicity data. A PNEC added is a PNEC which is based on added concentrations of a chemical (added risk approach). Based on the available data it is not considered useful to derive a PNEC or a PNEC added for NaOH because:
> - The natural pH of aquatic ecosystems can vary significantly between aquatic ecosystems,
> - Also, the sensitivity of the aquatic ecosystems to a change of the pH can vary significantly between aquatic ecosystems and
> - The change in pH due to an anthropogenic NaOH addition is influenced significantly by the buffer capacity of the receiving water."
>
> "Although a PNEC or a PNEC added was not calculated for NaOH, there is a need to assess the environmental effect of a NaOH (alkaline) discharge. Based on the pH and buffer capacity of effluent and receiving water and the dilution factor of the effluent, the pH of the receiving water after the discharge can be calculated. Of course, the pH change can also be measured very easily via a laboratory experiment or by conducting field measurements. The change in pH should be compared with the natural variation in pH of the receiving water and based on this comparison it should be assessed if the pH change is acceptable."

Based on the information above, PNEC values for freshwater, sediment, and soil were not derived for sodium hydroxide.

VIII. PBT ASSESSMENT

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Sodium hydroxide is an inorganic salt that dissociates completely to sodium and hydroxide ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both sodium and hydroxide ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria are not considered applicable to this inorganic salt.

Sodium and hydroxide ions are essential to all living organisms, and their intracellular, and extracellular concentrations are actively regulated. Thus, sodium hydroxide is not expected to bioaccumulate.

No chronic toxicity data exist on sodium hydroxide; however, the acute $E(L)C_{50}$ values are >1 mg/L in fish, invertebrates and algae. Thus, sodium hydroxide does not meet the screening criteria for toxicity.

The overall conclusion is that sodium hydroxide is not a PBT substance.

IX. CLASSIFICATION AND LABELLING

A. Classification

Metal Corrosive Category 1
Skin Corrosive, Category 1A
Eye Damage, Category 1

EU Concentration Limits:

≥5%: Skin Corrosive 1A

≥2 to <5%: Skin Corrosive 1B

≥0.5%to <2%: Skin Irritant Category 2

≥0.5% to <2%: Eye Irritant Category 2

In addition to the hazard statements corresponding the GHS classification for corrosive, the following non-GHS hazard statement is to be added to the SDS: AUH071: Corrosive to the Respiratory Tract.

B. Labelling

Danger

C. Pictograms



X. SAFETY AND HANDLING

A. First Aid

Eye Contact

Flush with plenty of fresh water for 15 minutes holding eyelids open, lifting eyelids occasionally to ensure complete removal of the product. Remove contacts, if present and easy to do. DO NOT allow rubbing of eyes or keeping eyes closed. Seek medical attention.

Skin Contact

Rinse with soap and plenty of water for several minutes. Remove contaminated clothing. Seek medical attention immediately.

Inhalation

Remove person to fresh air. Apply artificial respiration if not breathing. Seek medical attention.

Ingestion

Rinse mouth with water (only if the person is conscious), but do not administer fluids. Do NOT induce vomiting. Seek medical attention immediately.

B. Fire Fighting Information

Extinguishing Media

Carbon dioxide, water spray, foam, dry chemical.

Specific Exposure Hazards

Containers may explode when heated. May form explosive mixtures with strong acids. Hazardous combustion products may include the following materials: halogenated compounds, metal oxides/oxides, sodium monoxide.

Special Protective Equipment for Firefighters

Full protective clothing and approved self-contained breathing apparatus required for firefighting personnel.

C. Accidental Release Measures

Personal Precautions

Use appropriate protective equipment and avoid direct contact. Do not touch damaged containers or spilt material unless wearing appropriate protective clothing. Ventilate the area before entry.

Environmental Precautions

Prevent spills from entering storm drains or sewers and contact with soil.

Steps to be Taken if Material is Released or Spilt

Use an absorbent material to recover as much product as possible, then, rinse the affected area with water to dilute the residue. Disposal of leftover product and used containers should be carried out in accordance with all local, state and federal regulations.

D. Storage and Handling

General Handling

Wear appropriate personal protective equipment. Avoid contact with eyes, skin or clothing. Avoid breathing mist, vapours or spray. Use only with adequate ventilation. Wash hands after use. Launder contaminated clothing.

Storage

Store away from acids. Keep container closed when not in use. Store in a cool well-ventilated area.

E. Exposure Controls / Personal Protection

Occupational Exposure Standards

The workplace exposure standard for sodium hydroxide in Australia is 2 mg/m^3 as a peak limitation, with a sensitisation notation. A peak limitation is defined by Safe Work Australia as a maximum or peak airborne concentration of a substance determined over the shortest analytically practicable period of time which does not exceed 15 minutes.

Engineering Controls

Good general ventilation should be used. If applicable, use process enclosures, local exhaust ventilation, or other engineering controls to maintain airborne levels below recommended exposure limits.

Personal Protection Equipment

Respiratory Protection: Use a mask or approved air-purifying respirator with appropriate cartridge or canister in spray applications or in confined spaces.

Hand Protection: Wear impervious gloves to prevent skin contact and absorption of this material. Rubber or Neoprene gloves may afford adequate skin protection.

Skin Protection: Wear appropriate clothes (i.e., coveralls). Use non-slip footwear.

Eye protection: Wear eye protection in situations where splash or thick mists are possible.

Other Precautions: Avoid contact with skin, eyes and clothing. When using, do not eat or drink. Wash hands thoroughly with soap and water before eating or drinking. Remove contaminated clothing and launder before reuse.

F. Transport Information

For sodium hydroxide solutions of >5%:
Australian Dangerous Goods
UN1824, Corrosive liquid, (Sodium hydroxide solution)
Class 8
Packing Group: II

Lower concentrations of sodium hydroxide may require a different packing group or may not require any hazard code if the concentration of NaOH is low enough not to be considered a corrosive material.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

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XIV. ACRONYMS AND GLOSSARY

°C	degrees Celsius
ADWG	Australian Drinking Water Guidelines
DEWHA	Department of the Environment, Water, Heritage and the Arts
ECHA	European Chemicals Agency
EU	European Union
GHS	Globally Harmonised System of Classification and Labelling of Chemicals
HHRA	enHealth Human Risk Assessment
IUPAC	International Union of Pure and Applied Chemistry
LOAEL	lowest observed adverse effect level
mg/kg	milligrams per kilogram
mg/L	milligrammes per litre
mg/m^3	milligrammes per cubic metre
NOAEL	no observed adverse effect level
NOEC	no observed effective concentration
OECD	Organisation for Economic Co-operation and Development
PBT	Persistent, Bioaccumulative and Toxic
ppm	parts per million
RfD	oral Reference Dose
SDS	Safety Data Sheet
SIDS	Screening Information Data Set
SMILES	simplified molecular-input line-entry system

SODIUM PERSULFATE

This dossier on sodium persulfate does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of sodium persulfate in its use in drilling muds and hydraulic fracturing fluids. Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBSTANCE IDENTIFICATION

Chemical Name (IUPAC): Disodium [(sulfonatoperoxy)sulfonyl]oxidanide

CAS RN: 7775-27-1

Molecular formula: $O_8S_2.2Na$

Molecular weight: 238.1

Synonyms: Sodium persulfate; disodium persulfate; sodium peroxodisulfate; disodium [(sulfonatoperoxy)sulfonyl]oxidanide

SMILES: [O-]S(=O)(=O)OOS(=O)(=O)[O-].[Na+].[Na+]

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Sodium Persulfate

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	White, crystalline, odorless solid	1	ECHA
Melting Point	Decomposes at 180°C before melting point is reached.	1	ECHA
Density	1.68 g/cm^3	1	ECHA
Vapor Pressure	Negligible	2	ECHA
Partition Coefficient (log K_{ow})	Not applicable	-	-
Water Solubility	Very soluble	2	ECHA
Oxidizing Properties	Strong oxidizer	4	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

Sodium persulfate dissociates in aqueous media to the sodium cation (Na^+) and persulfate anion ($S_2O_8^{2-}$) (OECD 2005a; ECHA). The persulfate anion will readily hydrolyze (decompose) into sulfate ions.

The rates of hydrolysis are expected to be similar for sodium persulfate, potassium persulfate, and ammonium persulfate. The rates of decomposition (hydrolysis) was measured at 50°C at various pHs. The half-lives increased from 20 hours at pH 1 to 210 hours at pH 10 (Koltoff and Miller, 1951).

Biodegradation is not applicable to inorganic compounds. Sodium persulfate is not expected to bioaccumulate; it will dissociate (and decompose) to ions that are ubiquitous in the environment. Sodium persulfate is not expected to absorb to soil or sediment because of its dissociation properties, instability (hydrolysis), and high-water solubility.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Sodium persulfate exhibits moderate acute toxicity by the oral route, and low acute toxicity by the inhalation and dermal routes. In humans, sodium persulfate has the potential for skin irritation; it is also a skin sensitizer to guinea pigs and humans. Human exposure to persulfates (including sodium persulfate) have been linked to a variety of skin and respiratory complaints indicative of sensitization. The complaints consist of immediate and delayed contact hypersensitivity, contact urticarial, rhinitis, bronchitis, and asthma. Repeated oral exposure to sodium persulfate resulted in irritation to the gastrointestinal tract; and respiratory irritation was seen in rats repeatedly exposed by inhalation to ammonium persulfate. Sodium persulfate is not genotoxic. A dermal carcinogenicity study showed no carcinogenic effects in mice. In a screening study, there was no reproductive or developmental toxicity in rats given oral gavage doses of ammonium persulfate.

B. Acute Toxicity

The oral LD_{50} in male rats is 895 mg/kg (ECHA) [Kl. score = 2].

The 4-hour inhalation LC_{50} of sodium persulfate dust is >5.1 mg/L. The mass median aerodynamic diameter (MMAD) ranged from 4.28 to 5.35 μm. The fraction of particles ≤1 μm in MMAD ranged from 0 to 5.6%. The fraction of particles ≤10 μm in MMAD ranged from 76.5 to 81.2% (ECHA) [Kl. score = 1].

The dermal LD_{50} in rabbits is >2,000 mg/kg (ECHA) [Kl. score = 1].

C. Irritation

Application of 0.5 mL of sodium persulfate (aqueous solution) to the skin of rabbits for 4 hours under occlusive conditions was not irritating (ECHA) [Kl. score = 1]. In another study, application of sodium persulfate to the skin of rabbits was not irritating (ECHA) [Kl. score = 2].

Instillation of sodium persulfate into the eyes of rabbits was slightly irritating. Slight conjunctival effects were noted in five of six animals; all observed effects were completely reversible within 24 hours (ECHA) [Kl. score = 2].

Studies in humans indicate that persulfates have the potential for skin irritation (NICNAS, 2001). Calnan and Schuster (1963) reported skin irritation in a human patch test with 5% ammonium persulfate. Jordan (1998) reported that a mixture with 17.5% persulfates (ammonium, potassium, and sodium) induced skin irritation in human subjects from patches applied under occlusive conditions.

D. Sensitization

Sodium persulfate was a skin sensitizer when tested in a guinea pig maximization test. The concentration of sodium persulfate used in the induction and challenge phases was 0.1% in physiological saline (ECHA) [Kl. score = 1]. Sodium persulfate was not a skin sensitizer to guinea pigs in a Buehler test (dermal application only). The concentration of sodium persulfate used for the induction and challenge phase was 0.3 g (ECHA) [Kl. score = 1].

Sodium persulfate was considered a strong skin sensitizer in a mouse local lymph node assay (ECHA) [Kl. score = 1].

Human exposure to persulfates have been linked to a variety of skin and respiratory complaints indicative of sensitization. The complaints consist of immediate and delayed contact hypersensitivity, contact urticarial, rhinitis, bronchitis, and asthma (NICNAS, 2001).

E. Repeated Dose Toxicity

Oral

Male and female CR strain rats were fed in their diet 0, 300, 1,000 or 3,000 ppm sodium persulfate for 90-days. On day 48 of the study, the dietary concentration of the group receiving 1,000 ppm was increased to 5,000 ppm for the remainder of the study. Body

weights was decreased in the two highest dose groups during the last six weeks of treatment. There were no treatment-related effects on urinalysis, clinical chemistry or hematology parameters. Histopathological findings were limited to the 3,000 ppm group only and consisted of necrosis and atrophy of the gastrointestinal tract epithelial lining. The absence of the gastrointestinal lesions in the group receiving 1,000 ppm for 8 weeks, followed by 5000 ppm for 5 weeks, indicates that the lesions are related both to concentration in diet (dose) and length of exposure. A clear NOAEL for this study is 300 ppm, which is estimated to be 22 mg/kg-day. Another NOAEL may be the 1,000 ppm dietary group for an 8-week exposure period. (ECHA; OECD, 2005a,b). [Kl. score = 2]

Inhalation

No studies are available on sodium persulfate.

Male and female SD rats were exposed (whole-body) by inhalation to 0, 5, 10.3, or 25 mg/m^3 ammonium persulfate dust, 6 hours/day, 5 days/week for 13 weeks. Additional groups of animals were exposed for 13 weeks, followed by either a 4- or 13-week recovery period. The MMAD was 2.5, 2.7, and 2.5 μm for the 5, 10, and 25 mg/m^3 groups, respectively. No deaths occurred during the study that were considered to be exposure-related. The 25 mg/m^3 animals showed increased respiration rates, as well as a few of the 25 mg/m^3 animals. This clinical sign disappeared during the first few weeks of the recovery period. Body weights of the 25 mg/m^3 animals were significantly lower during most of the exposure period; by the end of the recovery period the body weights were comparable to the controls. Lung weights were increased in the 25 mg/m^3 animals at the end of the 13-week exposure period, but were similar to controls after 6 weeks in the recovery period. Histopathologic changes indicative of irritation was seen in the trachea and bronchi/bronchioles in the 25 mg/m^3 animals; these lesions were not seen after 6 weeks in the recovery period. The NOAEL for this study is 10.3 mg/m^3 (ECHA). [Kl. score = 1]

Dermal

No studies are available.

F. Genotoxicity

In Vitro Studies

The *in vitro* genotoxicity studies on sodium persulfate are presented below in Table 2.

Table 2: *In vitro* Genotoxicity Studies on Sodium Persulfate

Test System	**Results***		**Klimisch Score**	**Reference**
	-S9	**+S9**		

Bacterial reverse mutation (*S. typhimurium* strains)	-	-	1	ECHA
Unscheduled DNA synthesis (rat hepatocytes)	NA	-	1	ECHA

*+, positive; -, negative; NA, not applicable

In vivo Studies

Sodium persulfate did not induce micronuclei in the bone marrow cells of male and female mice given a single intraperitoneal injection of 0, 85, 169, or 338 mg/kg sodium persulfate (ECHA) [Kl. score = 2].

G. Carcinogenicity

No studies are available on sodium persulfate.

A 51-week dermal study in female SENCAR mice exposed to 0.2 ml of a 200 mg/mL solution of ammonium persulfate showed that ammonium persulfate is neither a tumor promoter nor a complete carcinogen when applied to the skin (OECD, 2005a,b; ECHA). [Kl. score = 2]

H. Reproductive and Developmental Toxicity

No studies are available on sodium persulfate.

A reproductive and developmental toxicity screening study (OECD 421) has been conducted on ammonium persulfate. Male and female Crl:CD (SD)GS BR rats were fed in their diet 0, 40, 100, or 250 mg/kg ammonium persulfate. In the parental animals, there was no treatment-related mortality, clinical signs, body or organ weight changes, or effects seen in gross necropsy. There were no effects on reproductive performance, fertility, fetal anomalies, fetal viability, spermatogenesis, spermatogenic cycle. The NOAEL for reproductive and developmental toxicity and parental toxicity is 250 mg/kg-day, the highest dose tested (ECHA). [Kl. score = 1]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

Toxicological reference values were not derived. Sodium persulfate dissociates in water to sodium and persulfate ions. The persulfate ions will further hydrolyze to sulfate ions.

The Australian drinking water guideline value for sodium is 180 mg/L based on aesthetics (ADWG, 2011).

The Australian drinking water guideline value for sulfate is 500 mg/L based on health. Concentrations of >500 mg/L can have purgative effects. There is also an Australian drinking water guideline value for sulfate of 250 mg/L based on aesthetics; it is the taste threshold (ADWG, 2011).

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Sodium persulfate is an oxidizing solid.

Sodium persulfate does not exhibit the following physico-chemical properties:
- Explosivity
- Flammability

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Sodium persulfate has a low toxicity concern to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies on sodium persulfate.

Table 3: Acute Aquatic Toxicity Studies on Sodium Persulfate

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Oncorhynchus mykiss	96-h LC_{50}	163	1	ECHA
Daphnia magna	48-h EC_{50}	133	1	ECHA
Selenastrum capricornutum	72-h EC_{50}	116	1	ECHA

Chronic Studies

No data are available.

C. Terrestrial Toxicity

No data are available.

D. Calculation of PNEC

The PNEC calculations for sodium persulfate follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (163 mg/L), *Daphnia* (133 mg/L), and algae (116 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 116 mg/L for algae. The $PNEC_{water}$ is 0.12 mg/L.

PNEC sediment

No experimental toxicity data on sediment organisms are available. Sodium persulfate dissociates completely in water with its environmental distribution is dominated by its high water solubility. K_{ow} and K_{oc} parameters do not readily apply to inorganics, such as sodium persulfate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of sodium persulfate to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

PNEC soil

No experimental toxicity data on terrestrial organisms are available. The environmental distribution of sodium persulfate is dominated by its water solubility. Sorption of sodium persulfate should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. K_{oc} and K_{ow} parameters do not readily apply to inorganics, such as sodium persulfate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, sodium persulfate is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Sodium persulfate is an inorganic compound that dissociates completely to sodium and persulfate ions in aqueous solutions. Persulfate ions are further hydrolysed to sulphate ions. Biodegradation is not applicable to these compounds. For the purposes of this PBT assessment, the persistent criteria are not considered applicable to sodium persulfate or its dissociated compounds.

Sodium persulfate is an inorganic compound that dissociates completely in water to ionic compounds that are ubiquitous in the environment. Thus, sodium persulfate is not expected to bioaccumulate.

There are no chronic aquatic toxicity data on sodium persulfate. The acute $E(L)C_{50}$ values for fish, invertebrates, and algae are >1 mg/L. Thus, sodium persulfate does not meet the criteria for toxicity.

The overall conclusion is that sodium persulfate is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Oxidizing Solid Category 3
Acute Toxicity Category 4 [Oral]
Skin Irritant Category 2
Eye Irritant Category 2
Skin Sensitizer Category 1
Respiratory Sensitization Category 1
STOT SE Category 3 [Respiratory Irritation]

B. Labelling

Danger

C. Pictogram



X. SAFETY AND HANDLING

A. First Aid

Eye Contact
Immediately flush open eyes with plenty of water for at least 15 minutes. Remove contacts, if present and easy to do. Get medical attention.

Skin Contact
Wash thoroughly with soap and water.

Inhalation
If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Ingestion
Rinse mouth with water and then drink plenty of water. Get medical attention. Never give anything by mouth to an unconscious person.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: sulfur oxides.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus and chemical-protective clothing.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Use personal protective clothing. Avoid dust formation. Ensure adequate ventilation. Do not breathe dust. Wear respiratory protection if ventilation is inadequate. Avoid contact with skin, eye, and clothing.

Environmental Precautions
Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled
Scoop up and remove.

D. STORAGE AND HANDLING

General Handling
Good general ventilation should be used. Ventilation rates should be matched to conditions. If applicable, use process enclosures, local exhaust ventilation, or other engineering controls to maintain airborne levels below recommended exposure limits.

Other Handling Precautions
Avoid eye and skin contact. Avoid creating or inhaling dust.

Storage
Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place. Do not store with alkalis, acids, or reducing agents.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
The workplace exposure standard for sodium persulfate in Australia is 0.01 mg/m^3 as a peak exposure. A peak limitation is defined by Safe Work Australia as a maximum or peak airborne concentration of a substance determined over the shortest analytically practicable period of time which does not exceed 15 minutes.

Engineering Controls

Ensure adequate ventilation. Localized ventilation should be used to control dust levels below permissible exposure limits.

Personal Protection Equipment

Respiratory Protection:
Use respiratory protection when airborne concentrations are expected to be high.

Hand Protection:
Chemical resistant protective gloves.

Skin *Protection*:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Safety glasses with side-shields.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible. Remove and wash contaminated clothing before re-use. Contaminated work clothing should not be allowed out of the workplace.

F. TRANSPORT INFORMATION

UN1505 SODIUM PERSULPHATE
Class: 5.1
Packing Group: III

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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XIV. ACRONYMS AND GLOSSARY

°C	degrees Celsius
ADI	acceptable daily intake
ADWG	Australian Drinking Water Guidelines
BCF	bioconcentration factor
BMD	benchmark dose

BOD	biological oxygen demand
CAS	Chemical Abstracts Service
CERHR	Centre for Evaluation of Risks to Human Reproduction
CHO	Chinese Hamster Ovary
CNS	central nervous system
DEWHA	Department of the Environment, Water, Heritage and the Arts
ECHA	European Chemicals Agency
EU	European Union
FAO	Food and Agriculture Organization
FOB	functional observation battery
GD	gestational days
GHS	Globally Harmonised System of Classification and Labelling of Chemicals
HHRA	enHealth Human Risk Assessment
HRIPT	Human Repeated Insult Patch Test
IOM	Institute of Medicine
IRIS	Integrated Risk Information System
IUPAC	International Union of Pure and Applied Chemistry
JECFA	Joint FAO/WHO Expert Committee on Food Additives
LOAEL	lowest observed adverse effect level
MCI	molecular connectivity index
mg/kg	milligrams per kilogram
mg/L	milligrams per litre
mg/m^3	milligrams per cubic metre
MOA	mode-of-action
NICNAS	The National Industrial Chemicals Notification and Assessment Scheme
NIOSH	National Institute for Occupational Safety and Health
NOAEC	no observed adverse effect concentration
NOAEL	no observed adverse effect level
NOEC	no observed effective concentration
OECD	Organisation for Economic Cooperation and Development
PBPK	physiologically-based pharmacokinetic
PBT	Persistent, Bioaccumulative and Toxic
PND	postnatal day
PNEC	predicted no effect concentration
ppm	parts per million

QAC	quaternary ammonium compound
QSAR	quantitative structure activity relationship
RACB	Reproductive Assessment by Continuous Breeding
REACH	Registration, Evaluation, Authorisation and Restriction of Chemical Substances
RfD	Reference Dose (oral)
SCBA	self-contained breathing apparatus
SCE	sister chromatid exchange
SDS	Safety Data Sheet
SIAR	SIDS Initial Assessment Report
SIDS	Screening Information Data Set
SMILES	simplified molecular-input line-entry system
STEL	short-term exposure limit
ThOD	theoretical oxygen demand
TWA	time-weighted average
WHO	World Health Organization

SODIUM POLYACRYLATE

This dossier on sodium polyacrylate do not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of sodium polyacrylate in its use in drilling muds and hydraulic fracturing fluids. The majority of information presented in this dossier was obtained from the HERA document on polyacrylic acid homopolymers and their sodium salts (CAS 9003-04-7) (HERA, 2014). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch et al., 1997).

I. SUBSTANCE IDENTIFICATION

Chemical Name (IUPAC): 1-Propenoic acid, homopolymer, sodium salt

CAS RN: 9003-04-7

Molecular formula: $(C_3H_4O_2)x$-.x-Na

Molecular weight: Variable

Synonyms: 2-Propenoic acid, homopolymer, sodium salt; polyacrylic acid, sodium salt, sodium polyacrylate; acrylic acid, polymers, sodium salt; poly(acrylic acid), sodium salt; polyacrylate sodium salt

II. PHYSICO-CHEMICAL PROPERTIES

Sodium polyacrylates are polymers that range in molecular weight (MW) from 1,000 to 78,000 (HERA, 2014). The sodium polyacrylates mostly used in detergents have a typical molecular weight of approximately 4,500 (HERA, 2014). For sodium polyacrylate (MW 4,500), the melting point is >150^{o}C, where is decomposes; and the water solubility is >400 g/L (HERA, 2014).

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Sodium polyacrylates are not readily biodegradable. Due to their high molecular weights, sodium polyacrylates are not expected to bioaccumulate. In addition, these water-soluble polymers can form insoluble calcium salts in natural waters, suggesting that bioaccumulation is unlikely.

B. Abiotic Degradation

Abiotic degradation mechanisms, such as photolytic and hydrolytic processes, do not significantly influence the environmental fate of sodium polyacrylates (HERA, 2014).

C. Biodegradation

Sodium polyacrylates are not readily biodegradable, but are partly accessible to ultimate biodegradation particularly under long incubation conditions. Sodium polyacrylates with MW of <2,000 are partly biodegradable under the conditions of soil and sediment inoculation. Test results with activated sludge inoculum indicate different elimination degrees, apparently due to adsorption and precipitation processes. The removal degrees of different sodium polyacrylates show no clear relationship between elimination extent and molecular weight (HERA, 2014).

D. Bioaccumulation

No experimental studies are available on sodium polyacrylates. Estimated bioconcentration factors based on octanol-water coefficients are not appropriate since the molecular weights of these polymers are higher than the molecular weight range for the QSAR models. Due to their high molecular weights, sodium polyacrylates are not expected to bioaccumulate. In addition, these water-soluble polymers can form insoluble calcium salts in natural waters, suggesting that bioaccumulation is unlikely.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

The acute toxicity of sodium polyacrylates are very low by the oral and dermal routes. These polymers are not irritating to the skin and eyes; nor are they skin sensitizers. No systemic toxicity was observed in rats given high oral doses of a sodium polyacrylate for four weeks; pulmonary irritation was seen in rats that inhaled an aerosol or dust of a sodium polyacrylate for 13 weeks, but there was no systemic toxicity. No developmental toxicity was seen in rats when given high oral doses of sodium polyacrylates. Sodium polyacrylates are not genotoxic.

B. Acute Toxicity

Acute oral toxicity studies have been conducted in rats on sodium polyacrylates with molecular weights (MW) of 1,000 to 78,000. The oral LD_{50} values are >5,000 or >10,000 mg/kg (the highest doses tested), with the exception of one study on a 3,500 MW sodium polyacrylate, which was reported to be >1,000 mg/kg (the attainable limit dose of a 10% aqueous solution) (HERA, 2014). [Kl. scores = 2]

The dermal LD_{50} values in rabbits for sodium polyacrylates with MW of 1,000 or 4,500 are >5,000 mg/kg (HERA, 2014). [Kl. scores = 2]

No acute inhalation studies are available.

C. Irritation

The sodium polyacrylates with MW of 1,000 to 78,000 are not irritating to the skin or eyes (HERA, 2014). [Kl. scores = 2]

D. Sensitisation

Sodium polyacrylates with MW of 4,500 or 78,000 were not dermal sensitizers in the guinea pig maximization test (HERA, 2014). [Kl. scores = 2 and 4, respectively]

E. Repeated Dose Toxicity

Oral

Male rats were fed diets containing 0 or 2.5% sodium polyacrylate (MW 2,500) for four weeks. Body weight, body weight gain, and appearance of the animals were similar between treated and control animals. In the fourth week of the study, a small, but significant, decrease in total weight of bone minerals was detected and confirmed by radiographic and histological examination. There was a significant reduction in the concentration of magnesium in the bones and plasma of the treated animals. Calcium loss was slight and not statistically significant. Urinary excretion of sodium and phosphorus was markedly increased; calcium only slightly increased. The authors of the study

interpreted the finding as a metabolic imbalance rather than systemic toxicity. Sodium excretion could have been increased by the high intake of the sodium-neutralized test substance. The NOAEL for the study was considered to be 2.5% sodium polyacrylate in the diet, which was estimated to be 1,136 mg/kg-day (HERA, 2014). [Kl. score = 2]

Inhalation

Male and female rats were exposed by inhalation to 0, 0.2, 1.0, or 5.0 mg/m^3 sodium polyacrylate (MW 4,500) as an aerosol for 6 hours/day, 5 days/week for 13 weeks. Additional groups of animals were exposed for 13 weeks followed by a 91-day recovery period. There were no treatment-related effects on body weights, organ weights, feed and water consumption, clinical observations, and blood chemistry. In the histopathologic examination, the lungs of the mid- and high-dose animals showed signs of mild pulmonary irritation: increases in polymorphonuclear granulocytes or alveolar macrophages, pneumocyte hyperplasia, alveolar wall thickening and focal alveolitis. The lung effects were reversible and were not seen in the recovery group animals. The NOEC for systemic effects in this study was considered to be 5 mg/m^3, and the NOEC for localized irritation is 0.2 mg/m^3 (HERA, 2014). [Kl. score = 2]

Dermal

No studies are available.

F. Genotoxicity

In Vitro Studies

The results of the *in vitro* studies on sodium polyacrylates are presented below in Table 1. All of the studies show that sodium polyacrylates are not mutagenic or genotoxic.

Table 1: In Vitro Genotoxicity Studies on Sodium Polyacrylates (HERA, 2014)

Mean MW	Test System	Results*	Klimisch Score	Reference
2,000	Bacterial reverse mutation	-	2	HERA (2014)
2,000	Mouse lymphoma	-	2	HERA (2014)
2,000	Unscheduled DNA synthesis	-	2	HERA (2014)
4,500	Bacterial reverse mutation	-	2	HERA (2014)
4,500	Mouse lymphoma	-	2	HERA (2014)
4,500	Unscheduled DNA synthesis	-	2	HERA (2014)
4,500	Cytogenetic (CHO cells)	-	2	HERA (2014)
4,500	Bacterial reverse mutation	-	2	HERA (2014)
4,500	Mammalian cell gene mutation	-	2	HERA (2014)
4,500	Unscheduled DNA synthesis	-	2	HERA (2014)

*+, positive; -, negative

In Vivo Studies

There was no increase in micronuclei in polychromatic erythrocytes from the bone marrow of mice given a single oral gavage dose of 13,850 mg/kg sodium polyacrylate with a MW of 2,000 (HERA, 2014).

G. Carcinogenicity

No studies are available.

H. Reproductive Toxicity

No studies are available

I. Developmental Toxicity

Pregnant female rats were dosed by oral gavage with 0, 500, 1,000, or 3,000 mg/kg sodium polyacrylate (MW 4,500) on GD 6 to 15. At 3,000 mg/kg, the dams had soft or liquid stools during the treatment period. There was no maternal or developmental toxicity observed in this study. The NOAEL for maternal and developmental toxicity is 3,000 mg/kg-day (HERA, 2014). [Kl. score = 2]

Pregnant female rats were dosed by oral gavage with 0, 125, 375, or 1,125 mg/kg sodium polyacrylate (MW 90,000 as a 77.5% aq. solution) during GD 6 to 13. Some of the dams were sacrificed on GD 13 and the remaining on GD 19. One mid-dose dam and 6 high-dose dams died during the study; of these, three of the high-dose deaths were treatment-related and the remaining were considered the result of gavage errors. There was a transient decrease in feed consumption in the high-dose dams during GD 7-9, but not other indications of maternal toxicity. There was no developmental toxicity. The NOAELs for maternal and developmental toxicity are 375 and 1,125 mg/kg-day (HERA, 2014). [Kl. score = 2]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

NICNAS has assessed sodium polyacrylates in an IMAP Tier 1 assessment and considers it “a chemical identified as low concern to human health by application of expert validated rules”.[1]

The toxicological reference values developed for sodium polyacrylates follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

<u>Oral</u>

A 4-week dietary study showed no systemic toxicity in rats given 2.5% sodium polyacrylate (MW 2,500) in their feed. The estimated dose is 1,136 mg/kg-day. Two pre-natal developmental toxicity studies showed no effects at the highest dose tested: 3,000 and 1,125 mg/kg-day for sodium polyacrylates with MW of 4,500 and 90,000, respectively. The NOAEL of 1,136 mg/kg-day from the 4-week dietary study will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10

[1] https://www.nicnas.gov.au/chemical-information/imap-assessments/imap-assessments/tier-i-human-health-assessments#cas-A_9003-04-7

UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subacute to chronic) = 10
UF_D (database uncertainty) = 1

Oral RfD = 1,136 (10 x 10 x 1 x 10 x 1) = 1,136/1,000 = 1.0 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD:

Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (1 x 70 x 0.1)/2 = 3.5 mg/L

B. Cancer

No carcinogenicity studies have been conducted on sodium polyacrylates. Therefore, a cancer reference value was not derived.

VI. Human Health Hazard Assessment of Physico-Chemical Properties

Sodium polyacrylates do not exhibit the following physico-chemical properties:

- Flammability
- Explosivity
- Oxidising potential.

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Sodium polyacrylates are a low toxicity concern for aquatic organisms, terrestrial invertebrates, and plants.

B. Aquatic Toxicity

Acute Studies

Table 2 lists the results of acute aquatic toxicity studies on sodium polyacrylates.

Table 2: Acute Aquatic Toxicity Studies on Sodium Polyacrylates

Mean MW	Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
1,000	*Brachydanio rerio*	96-hr LC_{50}	>200	1	HERA, 2014

Mean MW	Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
1,000	*Salmo gairdneri*	96-hr LC_{50}	>1,000	1	HERA, 2014
1,200	*Leuciscus idus*	96-hr LC_{50}	>500	1	HERA, 2014
2,000	*Brachydanio rerio*	96-hr LC_{50}	>200	1	HERA, 2014
2,500	*Leuciscus idus*	96-hr LC_{50}	>500	1	HERA, 2014
4,500	*Lepomis macrochirus*	96-hr LC_{50}	>1,000	1	HERA, 2014
4,500	*Lepomis macrochirus*	96-hr LC_{50}	>1,000	1	HERA, 2014
8,000	*Leuciscus idus*	96-hr LC_{50}	>500	1	HERA, 2014
10,000	*Lepomis macrochirus*	96-hr LC_{50}	>1,000	1	HERA, 2014
15,000	*Leuciscus idus*	96-hr LC_{50}	>10,000	1	HERA, 2014
78,000	*Brachydanio rerio*	96-hr LC_{50}	>400	2	HERA, 2014
1,000	*Daphnia magna*	48-hr EC_{50}	>200	1	HERA, 2014
1,000	*Daphnia magna*	48-hr EC_{50}	>1,000	1	HERA, 2014
2,000	*Daphnia magna*	48-hr EC_{50}	>200	1	HERA, 2014
4,500	*Daphnia magna*	48-hr EC_{50}	>200	1	HERA, 2014
4,500	*Daphnia magna*	48-hr EC_{50}	>1,000	1	HERA, 2014
78,000	*Daphnia magna*	24-hr EC_{50}	276	2	HERA, 2014
8,000	*Selenastrum capricornutum*	72-hr EC_{50}	40	1	HERA, 2014
78,000	*Scenedesmus subspicatus*	96-hr EC_{50}	44	2	HERA, 2014

Chronic Studies

Table 3 lists the results of chronic aquatic toxicity studies on sodium polyacrylates.

Table 3: Chronic Aquatic Toxicity Studies on Sodium Polyacrylates (HERA, 2014)

Mean MW	Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
4,500	*Pimephales promelas*	32-d NOEC	56	2	HERA, 2014
4,500	*Brachydanio rerio*	28-d NOEC	>450	1	HERA, 2014
78,000	*Brachydanio rerio*	14-d NOEC	>400	2	HERA, 2014
4,500	*Daphnia magna*	21-d NOEC	450	1	HERA, 2014
4,500	*Daphnia magna*	21-d NOEC	58	1	HERA, 2014
4,500	*Daphnia magna*	21-d NOEC	12	2	HERA, 2014
78,000	*Daphnia magna*	21-d NOEC	100	2	HERA, 2014
4,500	*Scenedesmus subspicatus*	96-hr NOEC	180	2	HERA, 2014
78,000	*Scenedesmus subspicatus*	96-hr NOEC	32.8	2	HERA, 2014

There is considerable variability in the chronic aquatic toxicity results for *Daphnia magna* for sodium polyacrylates with the same molecular weight of 4,500. This was discussed in HERA (2014) and was explained by the solubility of sodium polyacrylates in water. In distilled water, the solubility of sodium polyacrylates with the molecular weight of 4,500 is >400 mg/L; however, under test conditions water solubility will decrease due to the presence of Ca^{++} and Mg^{++} (as measured by water hardness). In a study by BASF (reviewed in HERA, 2014), the water solubility of sodium polyacrylate (MW 4,500) was determined with radiolabelled compounds in a test system with a calcium concentration of 70 mg/L, which corresponds to the mean water hardness to the media used in an OECD TG 202 test. Under these conditions, the water solubility of sodium polyacrylate was 1.3 mg/L after 24 hours. So, one explanation for the variability of the chronic *Daphnia* studies may be due to differences in water hardness.

C. Toxicity to Sediment Organisms

The 96-hr EC_0 to *Chironomus riparius* (larvae) is >4,500 mg/kg sediment dry weight (HERA, 2014).

D. Terrestrial Toxicity

The results of terrestrial toxicity studies on sodium polyacrylate polymers are listed below.

Table 3: Terrestrial Toxicity Studies on Sodium Polyacrylates (HERA, 2014)

Mean MW	Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
4,500	*Eisenia foetida foetida*	14-d EC_0	1,000	1	HERA, 2014
78,000	*Eisenia foetida andrei*	14-d EC_0	1,000	2	HERA, 2014
78,000	*Brassica rapa*	21-d NOEC	1,000	2	HERA, 2014
4,500	Nitrogen transformation*	28-d EC_{10}	>2,500	1	HERA, 2014
4,500	Carbon transformation*	28-d EC_{10}	>2,500	1	HERA, 2014

*Soil organisms

E. Calculation of PNEC

The PNEC calculations for sodium polyacrylates follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute E(L)C_{50} values are available for fish (>200 mg/L), invertebrates (>200 mg/L), and plants (40 mg/L). Results from chronic studies are also available for all three trophic levels, with the lowest NOEC being 12 mg/L for invertebrates. On the basis that the data consists of short-term and long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported NOEC of 12 mg/L for invertebrates. The $PNEC_{water}$ is 1.2 mg/L.

PNEC sediment

Experimental results are available for one trophic level. There were no visual signs of toxicity to *Chironomus riparius* (larvae) at the highest concentration tested (>4,500 mg/kg sediment dry weight) (HERA) 2014). The EC_0 is considered to be above 4,500 mg/kg and an assessment factor cannot apply. Thus, the equilibrium partitioning method will be used to determine the $PNEC_{sed}$. The HERA (2014) risk assessment calculated a $PNEC_{sed}$ of 130 mg/kg sediment wet weight using the default of

0.05 as the weight fraction of organic carbon in sediment according to the EU Technical Guidance Document (TGD) (EU 2003).

PNEC soil

Experimental results are available for three trophic levels. An acute LC_{50} value is available for earthworms (1,000 mg/kg soil dry weight). A 21-day NOEC for *Brassica rapa* was reported to be 1,000 mg/kg soil dry weight. Results from two long-term studies are available for soil microorganisms, with the NOECs for nitrogen and carbon transformation being >2,500 mg/kg soil dry weight. On the basis that the data consists of short-term tests, as well as one long-term test from one trophic level, an assessment factor of 100 has been applied to the lowest reported long-term NOEC of >2,500 mg/kg soil dry weight. The $PNEC_{soil}$ is 25 mg/kg soil dry weight.

VIII. PBT ASSESSMENT

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009, ECHA, 2008).

The sodium polyacrylates are not readily biodegradable; thus they meet the screening criteria for persistence.

The sodium polyacrylates are expected to have high molecular weights and are not expected to be bioavailable. Thus these polymers do not meet the criteria for bioaccumulation.

Chronic NOECs for fish, daphnia and algae are available for sodium polyacrylates, and the NOEC values are >0.1 mg/L. Thus sodium polyacrylates do not meet the screening criteria for toxicity.

The overall conclusion is that sodium polyacrylates are not PBT substances.

IX. CLASSIFICATION AND LABELLING

A. Classification

Aquatic Acute Toxicity Category 3

B. Labelling

No signal word.

C. Pictograms

None.

X. SAFETY AND HANDLING

A. First Aid

Eye Contact

In case of contact, immediately flush eyes with plenty of water for at least 5 minutes. If symptoms persist, seek medical advice.

Skin Contact

Wash thoroughly with soap and water..

Inhalation

If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Ingestion

Rinse mouth with water and then drink plenty of water. Never give anything by mouth to an unconscious person. If symptoms develop, seek medical advice.

B. Firefighting Information

Extinguishing Media

Water fog, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards

Burning produces harmful and toxic fumes. Heat from fire may melt, decompose polymer, and generate flammable vapors. Combustion products may include: Carbon monoxide, carbon dioxide, and unburned hydrocarbons (smoke). Dust can accumulate static charges which can cause an incendiary electrical discharge. Fine dust dispersed in air in sufficient concentrations, and in the presence of an ignition source, is a potential dust explosion hazard.

Special Protective Equipment for Firefighters

Wear a self-contained breathing apparatus.

C. Accidental Release Measures

Personal Precautions

Use appropriate protective equipment. Potential combustible dust hazard. Avoid generating dust. Creates dangerous slipping hazard on any hard smooth surface.

Environmental Precautions

Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilt

Scoop up and remove.

D. Storage and Handling

General Handling

Avoid dust accumulation in enclosed space. Avoid generating dust; fine dust dispersed in air in sufficient concentrations, and in the presence of an ignition source is a potential dust explosion

hazard. Electrostatic charge may build up during handling. Equipment, container and metal containers should be grounded and bonded.

Storage

Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place. Use adequate ventilation to avoid excessive dust accumulation. Store away from excessive heat and away from strong oxidizing agents. Take measures to prevent the build up of electrostatic charge.

E. Exposure Controls/Personal Protection

Occupational Exposure Standards

Workplace Australia has not established an occupational exposure limit for sodium polyacrylates.

Engineering Controls

Use in a well ventilated area. Avoid creating dust. Take precautionary measures against static charge.

Personal Protection Equipment

Respiratory Protection: Not normally needed. But if significant exposures are possible then the following respirator is recommended: Dust/mist respirator.

Hand Protection: Normal work gloves.

Skin Protection: Normal work coveralls.

Eye protection: Wear safety glasses or goggles to protect against exposure.

Other Precautions: Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible.

F. Transport Information

Sodium polyacrylates are not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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Department of the Environment, Water, Heritage and the Arts (DEWHA). (2009). Environmental risk assessment guidance manual for industrial chemicals, Department of the Environment, Water, Heritage and the Arts, Commonwealth of Australia.

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European Chemicals Agency (ECHA). (2008). Guidance on Information Requirements and Chemical Safety Assessment, Chapter R11: PBT Assessment, European Chemicals Agency, Helsinki, Finland.

HERA (2014). Human & Environmental Risk Assessment (HERA) on ingredients of European household cleaning products. Polycarboxylates used in detergents (Part I): Polyacrylic acid homopolymers and their sodium salts (CAS 9003-04-7). (http://www.heraproject.com/files/HERA_P-AA_final_v3_23012014.pdf)

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XIV. ACRONYMS AND GLOSSARY

°C	degrees Celsius
ADWG	Australian Drinking Water Guidelines
DEWHA	Department of the Environment, Water, Heritage and the Arts
ECHA	European Chemicals Agency
EU	European Union
GHS	Globally Harmonised System of Classification and Labelling of Chemicals
HHRA	enHealth Human Risk Assessment
IUPAC	International Union of Pure and Applied Chemistry
LOAEL	lowest observed adverse effect level
mg/kg	milligrams per kilogram
mg/L	milligrams per litre
mg/m^3	milligrams per cubic metre
MW	molecular weight
NICNAS	The National Industrial Chemicals Notification and Assessment Scheme
NIOSH	National Institute for Occupational Safety and Health
NOAEL	no observed adverse effect level
NOEC	no observed effective concentration
OECD	Organisation for Economic Co-operation and Development
PBT	Persistent, Bioaccumulative and Toxic
ppm	parts per million
QSAR	quantitative structure–activity relationship
RfD	oral Reference dose

SDS	Safety Data Sheet
SMILES	simplified molecular-input line-entry system
TGD	Technical Guidance Document

SODIUM SULFATE

This dossier on sodium sulfate does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of sulfate in its use in drilling muds and hydraulic fracturing fluids. The majority of information presented in this dossier was obtained the OECD-SIDS documents on sodium sulfate (OECD, 2005a,b), and from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBSTANCE IDENTIFICATION

Chemical Name (IUPAC): Disodium sulfate

CAS RN: 7757-82-6

Molecular formula: Na_2SO_4

Molecular weight: 142.04

Synonyms: Sodium sulfate; disodium sulfate; sodium bisulfate; sulfuric acid, disodium salt

SMILES: [O-]S(=O)(=O)[O-].[Na+].[Na+]

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Sodium Sulfate

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	White crystalline solid,	2	ECHA
Melting Point	ca. 884°C	2	ECHA
Density	2.7 g/cm^3 @ 20°C	2	ECHA
Water Solubility	445.5 g/L @ 20°C	1	ECHA
Auto flammability	Not auto-flammable	1	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

Sodium sulfate dissociates in aqueous media to sodium (Na^+) and sulfate (SO_4^{2-}) ions in water.

Biodegradation is not applicable to inorganic compounds. Sodium sulfate is not expected to bioaccumulate; it will dissociate to ions that are ubiquitous in the environment. Sodium sulfate is not expected to absorb to soil or sediment because of its dissociation properties and high water solubility.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Sodium sulfate exhibits low acute toxicity by the oral and inhalation routes. It is not irritating to the skin and eyes; and it is not a skin sensitizer. In a reproductive and developmental toxicity screening study, there was no indication of any toxicity in rats given oral doses as high as 1,000 mg/kg-day. Sodium sulfate is not genotoxic.

B. Acute Toxicity

The oral LD_{50} in rats is >2,000 mg/kg (ECHA) [Kl. score = 1]. The 4-hour inhalation LC_{50} for an aerosol of sodium sulfate is >2.4 mg/L, which was the highest technically feasible aerosol concentration. The mas median aerodynamic diameters (MMAD) were 2.65 to 2.71 μm (ECHA) [Kl. score = 1]. There are no data on acute dermal toxicity.

Human data indicate a very low acute toxicity of sodium sulfate. High oral doses of sodium sulfate, from 300 mg/kg up to 20 grams for an adult, are well tolerated, except from (intentionally) causing severe diarrhea (OECD, 2005a,b).

C. Irritation

Application of 0.5 g sodium sulfate (in PEG 400) to the skin of rabbits for 4 hours was not irritating (ECHA) [Kl. score = 1].

Instillation of 90 mg sodium sulfate to the eyes of rabbits was not irritating (ECHA) [Kl. score = 1].

D. Sensitization

Sodium sulfate was not considered a skin sensitizer in a mouse local lymph node assay (ECHA). [Kl. score = 1]

E. Repeated Dose Toxicity

Oral

In a reproductive and developmental toxicity screening (OECD 421) study, male and female Wistar rats were dosed by oral gavage with 0, 100, 300, or 1,000 mg/kg sodium sulfate for a total of 4 weeks for males and 7 weeks for females. There was no evidence of toxicity at any dose level. The NOAEL for systemic toxicity is 1,000 mg/kg-day, the highest dose tested.

Inhalation

No studies are available.

Dermal

No studies are available.

F. Genotoxicity

In Vitro Studies

The *in vitro* genotoxicity studies on sodium sulfate are presented in Table 2.

Table 2: *In vitro* Genotoxicity Studies on Sodium Sulfate

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* and E. coli strains)	-	-	1	ECHA
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	-	-	1	ECHA
Chromosomal aberration (Chinese hamster lung fibroblasts)	-	-	1	ECHA

*+, positive; -, negative

In Vivo Studies

No studies are available.

G. Carcinogenicity

No valid studies are available.

H. Reproductive/Developmental Toxicity

A reproductive and developmental toxicity screening (OECD 421) study has been conducted on sodium sulfate. Male and female Wistar rats were dosed by oral gavage with 0, 100, 300, or 1,000 mg/kg sodium sulfate. There were no deaths during the study and no clinical signs. Body weights, body weight gain, and feed consumption were similar across all groups. There was no reproductive or developmental toxicity at any dose level. The NOAEL for systemic, reproductive, and developmental toxicity is 1,000 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 1].

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

Toxicological reference values were not derived. Sodium sulfate dissociates in water to sodium andsulfate ions.

The Australian drinking water guideline value for sodium is 180 mg/L based on aesthetics (ADWG, 2011).

The Australian drinking water guideline value for sulfate is 500 mg/L based on health. Concentrations of >500 mg/L can have purgative effects. There is also an Australian drinking water guideline value for sulfate of 250 mg/L based on aesthetics; it is the taste threshold (ADWG, 2011).

B. Cancer

There are no valid carcinogenicity studies on sodium sulfate. Thus, a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Sodium sulfate does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Sodium sulfate is of low acute concern to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies conducted on sodium sulfate.

Table 3: Acute Aquatic Toxicity Studies on Sodium Sulfate

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Pimephales promelas	96-h LC_{50}	7,960	2	Mount *et al.* (1997)
Daphnia magna	48-h EC_{50}	4,736*	2	Davies and Hall (2007)

* Standard test conditions: 100 mg $CaCO_3$/L and Ca:Mg ratio of 0.7.

Chronic Studies

The lowest 7-day NOEC from a *Ceriodapnia dubia* reproduction study, in which the test media contained varying degrees of water hardness, was 1,109 mg/L (Soucek, 2007).

C. Sediment Toxicity

The lowest 96-hour LC_{50} value to *Hyalella azteca* in series of studies involving different hardness of water was 757 mg/L (Soucek and Kennedy, 2005). In another study with *Hyalella Azteca*, the lowest 96-hour LC_{50} value (in water with the lowest hardness) was 841 mg/L (Davies and Hall, 2007). The lowest 96-hour LC_{50} value to *Chironomus tentans* in series of studies involving different hardness of water was 20,899 mg/L (Soucek and Kennedy, 2005).

D. Terrestrial Toxicity

No adequate studies were located.

E. Calculation of PNEC

The PNEC calculations for sodium sulfate follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for two trophic levels. Acute $E(L)C_{50}$ values are available for fish (7,960 mg/L) and *Daphnia* (4,736 mg/L). A chronic toxicity study has also been conducted on *Ceriodapnia dubia*, but this study is considered inadequate for deriving a PNEC value. On the basis that the data consists of short-term results from two trophic levels, an assessment factor of 1,000 has been applied to the lowest reported $E(L)C_{50}$ value of 4,736 mg/L for *Daphnia*. The $PNEC_{water}$ is 4.7 mg/L.

PNEC sediment

No reliable experimental toxicity data on sediment organisms are available. Sodium sulfate dissociates completely in water with its environmental distribution is dominated by its high water solubility. K_{ow} and K_{oc} parameters do not readily apply to inorganics, such as sodium sulfate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of sodium sulfate to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

PNEC soil

No reliable experimental toxicity data on terrestrial organisms are available. The environmental distribution of sodium sulfate is dominated by its water solubility. Sorption of sodium sulfate should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. K_{ow} and K_{oc} parameters do not readily apply to inorganics, such as sodium sulfate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, sodium sulfate is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Sodium sulfate is an organic salt that dissociates completely to sodium and sulfate ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both sodium and sulfate ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria is not considered applicable to sodium sulfate or its dissociated ions.

Sodium and sulfate ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus sodium sulfate is not expected to bioaccumulate.

The NOEC from a chronic toxicity study in *Ceriodaphnoa rerio* is >0.1 mg/L, and the acute E(L)C_{50} values for fish and *Daphnia* are >1 mg/L. Thus sodium sulfate does not meet the screening criteria for toxicity.

The overall conclusion is that sodium sulfate is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Not classified.

B. Labelling

No signal words.

C. Pictogram

None

X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact

Immediately flush eyes with plenty of water for at least 15 minutes. Remove contacts, if present and easy to do. If symptoms persist, seek medical attention.

Skin Contact

Wash with soap and water.

Inhalation

If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Ingestion

Do not induce vomiting. Rinse mouth with water and then drink a small amount of water. Get medical attention. Never give anything by mouth to an unconscious person.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: sodium and sulfur oxides.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus and chemical-protective clothing.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions

Use appropriate protective equipment. Avoid creating and breathing dust.

Environmental Precautions

Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled

Scoop and remove.

D. STORAGE AND HANDLING

General Handling

Avoid creating or inhaling dust.

Storage

Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
Workplace Australia has not established an occupational standard for sodium sulfate.

Engineering Controls

Use in a well-ventilated area.

Personal Protection Equipment

Respiratory Protection: Respiratory protection is not required.

Hand Protection: Chemical resistant protective gloves.

Skin Protection: Body protection must be chosen depending on activity and possible exposure.

Eye Protection: Safety glasses with side-shields.

Other Precautions: Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible.

F. TRANSPORT INFORMATION

Sodium sulfate is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods Code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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XIV. ACRONYMS AND GLOSSARY

°C	degrees Celsius
ADI	acceptable daily intake
ADWG	Australian Drinking Water Guidelines

BCF	bioconcentration factor
BMD	benchmark dose
BOD	biological oxygen demand
CAS	Chemical Abstracts Service
CERHR	Centre for Evaluation of Risks to Human Reproduction
CHO	Chinese Hamster Ovary
CNS	central nervous system
DEWHA	Department of the Environment, Water, Heritage and the Arts
ECHA	European Chemicals Agency
EU	European Union
FAO	Food and Agriculture Organization
FOB	functional observation battery
GD	gestational days
GHS	Globally Harmonised System of Classification and Labelling of Chemicals
HHRA	enHealth Human Risk Assessment
HRIPT	Human Repeated Insult Patch Test
IOM	Institute of Medicine
IRIS	Integrated Risk Information System
IUPAC	International Union of Pure and Applied Chemistry
JECFA	Joint FAO/WHO Expert Committee on Food Additives
LOAEL	lowest observed adverse effect level
MCI	molecular connectivity index
mg/kg	milligrams per kilogram
mg/L	milligrams per litre
mg/m^3	milligrams per cubic metre
MOA	mode-of-action
NICNAS	The National Industrial Chemicals Notification and Assessment Scheme
NIOSH	National Institute for Occupational Safety and Health
NOAEC	no observed adverse effect concentration
NOAEL	no observed adverse effect level
NOEC	no observed effective concentration
OECD	Organisation for Economic Cooperation and Development
PBPK	physiologically-based pharmacokinetic
PBT	Persistent, Bioaccumulative and Toxic
PND	postnatal day

PNEC	predicted no effect concentration
ppm	parts per million
QAC	quaternary ammonium compound
QSAR	quantitative structure activity relationship
RACB	Reproductive Assessment by Continuous Breeding
REACH	Registration, Evaluation, Authorisation and Restriction of Chemical Substances
RfD	Reference Dose (oral)
SCBA	self-contained breathing apparatus
SCE	sister chromatid exchange
SDS	Safety Data Sheet
SIAR	SIDS Initial Assessment Report
SIDS	Screening Information Data Set
SMILES	simplified molecular-input line-entry system
STEL	short-term exposure limit
ThOD	theoretical oxygen demand
TWA	time-weighted average
WHO	World Health Organization

TRIETHANOLAMINE

This dossier on triethanolamine does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of triethanolamine in its use in drilling muds and hydraulic fracturing fluids. The majority of information presented in this dossier was obtained from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC): 2-[bis(2-hydroxyethyl)amino]ethan-1-ol

CAS RN: 102-71-6

Molecular formula: $C_6H_{15}NO_3$ or $(CH_2OHCH_2)_3N$

Molecular weight: 149.19

Synonyms: Triethanolamine; 2,2',2"-nitrilotriethanol; 2,2',2"-nitrilotris[ethanol]; ethanol, 2,2',2"-nitrilotri- (8Cl); ethanol, 2,2',2"-nitrilotris- (9Cl); nitrilotriethanol; TEA; tris(beta-hydroxyethyl)amine; tris(2-hydroxyethyl)amine

SMILES: C(CO)N(CCO)CCO

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Triethanolamine

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Colorless to pale-yellow liquid with an amine-like odor.	2	ECHA
Melting Point	20.5°C	2	ECHA
Boiling Point	336.1°C	2	ECHA
Density	1.12 g/cm^3 @ 20°C	2	ECHA
Vapor Pressure	Negligible	2	ECHA
Partition Coefficient (log K_{ow})	-1.9 @ 25°C [Experimental]	2	ECHA

Water Solubility	>1,000 g/L @ 20°C	2	ECHA
Flash Point	179°C	2	ECHA
Auto flammability	324°C	2	ECHA
Viscosity	830.2 mm^2/s @ 20°C 181.5 mm^2/s @ 40°C	2	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Triethanolamine is readily biodegradable, and it has a low potential to bioaccumulate. Triethanolamine will not adsorb significantly to suspended solids and sediments in water and would be highly mobile in soil.

B. Biodegradation

Triethanolamine is readily biodegradable. In an OECD 301E test, there was 96% degradation after 19 days (ECHA). [Kl. score = 2]

Triethanolamine was completely degraded after incubation in municipal activated sludge for 1 or 5 days (West and Gonsior, 1996). The rate constants in all test batches for degradation and mineralization were reported to be >0.359. Thus, triethanolamine can be considered to be readily biodegradable. [Kl. score = 2]

C. Environmental Distribution

Adsorption/desorption

No experimental data are available for triethanolamine. Using KOCWIN in EPISUITE™ (EPA, 2017), the estimated K_{oc} value from log K_{ow} is 0.3046 L/kg. The estimated K_{oc} value from the molecular connectivity index (MCI) is 10 L/kg.

E. Bioaccumulation

Triethanolamine has been tested in a bioconcentration flow-through fish (OECD 305) test using *Cyprinus carpio*. The BCF was determined to be <0.4 and <3.9 at triethanolamine concentrations of 2.5 and 0.25 mg/L, respectively (ECHA). [Kl. score = 2]

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

The acute toxicity of triethanolamine by the oral, dermal, and inhalation routes is very low. Triethanolamine is not a skin or eye irritant; it is not a skin sensitizer to guinea pigs, but it may cause an allergic skin reaction in a small proportion of individuals. Repeated exposure by the oral route in rats showed no adverse effects. Repeated exposure by the inhalation caused effects to the respiratory tract and skin, respectively, in rats as a result of chronic irritation; but no target organs were identified from systemic exposure. Triethanolamine is not genotoxic, and lifetime oral and dermal studies in rats showed no clear carcinogenic effects. Developmental toxicity was seen in rats at oral doses that caused maternal toxicity.

B. Acute Toxicity

The oral LD_{50} in rats is 6,400 mg/kg (ECHA) [Kl. score = 2], and the dermal LD_{50} in rabbits is >2,000 mg/kg (ECHA) [Kl. score = 2]. No deaths seen in rats following an 8-hour exposure to a saturated vapor atmosphere [approximately 1.8 mg/m^3] (ECHA) [Kl. score = 2].

C. Irritation

Application of 0.5 mL to the skin of rabbits for 4 hours under occlusive conditions was not irritating. The mean of the 24, 48, and 72 hours erythema and edema scores were zero (ECHA). [Kl. score = 1]

Instillation of 0.1 mL into the eyes of rabbits were minimally irritating (Griffith *et al.*, 1980). [Kl. score = 2]

D. Sensitization

Triethanolamine was not considered a skin sensitizer when tested in a guinea pig maximization test (ECHA). [Kl. score = 1]

Patch test results with triethanolamine on patients from 1992 to 2007 were collected and evaluated. There were 85,098 patients that were tested with triethanolamine; of these, 323 (0.35%) patients tested positively to triethanolamine. The positive reactions that were interpreted as allergic seem to be caused by exposure to triethanolamine in cosmetics and/or topical therapeutic preparations possibly on damaged skin (Lessmann *et al.*, 2009).

E. Repeated Dose Toxicity

<u>Oral</u>

Male and female Cox CD rats were fed diets containing 0, 250, 500 or 1,000 mg/kg triethanolamine for 91 days. There were no effects that were considered treatment-related. The NOAEL for this study is 1,000 mg/kg-day (ECHA). [Kl. score = 2]

Inhalation

Male and female Wistar rats were exposed (nose-only) by inhalation to 0, 0.02, 0.1, or 0.5 mg/L triethanolamine aerosol 6 hours/day, 5 days/week for 28 days. There was no mortality; the only clinical signs were reddish crusts on the nasal edges in the 0.5 mg/L animals during the second half of the exposure period. Body weights and body weight gain were similar across all groups. There was no treatment-related changes in the hematology parameters, clinical chemistry, and neurobehavioral endpoints. Local inflammatory changes were observed in the submucosa of the larynx region. In both sexes, there was a tendency for a concentration-dependent increase in incidence and severity of the inflammatory lesions, with the effects greater in males than females. The NOAEC for systemic effects is 0.5 mg/L; the NOAEC for localized effects is 0.02 mg/L (ECHA) [Kl. score = 1].

Dermal

Male and female F344 rats were given dermal applications of 0, 125, 250, 500, 1,000, and 2,000 mg/kg triethanolamine 5 days/week for 90 days. There was deaths during the study. Body weight gain was significantly reduced (-33%) in the 2,000 mg/kg males compared to controls. Body weight gain was also significantly reduced (-13% to 36%) for the ≥125 mg/kg females. The mean final body weights of the 2,000 mg/kg males and females were significantly reduced. The only treatment-related clinical signs occurred at the site of dermal application. Brain weights relative to body weights were significantly elevated in the 2,000 mg/kg animals; because absolute brain weights were unaffected, the changes in brain weights is likely due to reduced body weights in these animals. Absolute kidney weights were increased in the ≥1,000 mg/kg animals; relative kidney weights were elevated in the ≥250 mg/kg males and ≥1,000 mg/kg females. Absolute and relative spleen weights were lower in the 2,000 mg/kg females; relative spleen weights were elevated in the ≥1,000 mg/kg males. Absolute and relative thymus weights were increased in the 2,000 mg/kg males. Relative liver weights were increased in the 500 and 1,000 mg/kg males. Absolute and relative lung weights were lower in the 2,000 mg/kg males. Relative testes weights were increased in the 2,000 mg/kg males. Hematological changes were seen in the 2,000 mg/kg animals and were considered to be due to an inflammatory response from dermal irritation at the application site. Elevated SGOT levels were noted in the 250 and 2,000 mg/kg males; and mean SGPT levels were significantly increased in the 2,000 mg/kg males. Elevated serum urea nitrogen, albumin, SGOT, and SGPR levels were noted in the 2,000 mg/kg females. At study termination, the specific gravity of urine was elevated in the 2,000 mg/kg males; urine protein levels for the ≥500 mg/kg males were significantly lower. The specific gravity of urine was elevated in the ≥1,000 mg/kg females; urine

glucose concentrations were also increased in these two dose groups. Apart for skin lesions at the site of application, there were no treatment-related histopathologic changes. The NOAEL for localized effects is 125 mg/kg-day based on chronic-active inflammation and acanthosis at the site of application in males. The NOAEL for systemic toxicity is 125 mg/kg-day based on increased relative kidney weights in males (ECHA) [Kl. score = 2].

F. Genotoxicity

In Vitro Studies

The findings from the *in vitr*o genotoxicity studies on triethanolamine are presented below in Table 2.

Table 2: *In vitro* Genotoxicity Studies on Triethanolamine

Test System	**Results***		**Klimisch Score**	**Reference**
	-S9	**+S9**		
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	Mortelsman *et al.* (1986); ECHA
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	-	-	1	ECHA
Chromosomal aberration (CHO cells)	-	-	2	Galloway *et al.* (1987); ECHA
Sister chromatid exchange (CHO cells)	-	-	2	Galloway *et al.* (1987); ECHA

*+, positive; -, negative

In Vivo Studies

Male and female $B6C3F_1$ mice were given dermal applications of triethanolamine, 5 days/week for 13 weeks. There were no increase in the frequency of micronucleated erythrocytes in the peripheral blood (NTP, 2004).

Triethanolamine did not induce sex-linked recessive lethal mutations in germ cells of adult male *Drosophila melanogaster* exposed by feeding or injection (Yoon *et al.*, 1985).

G. Carcinogenicity

Oral

Male and female F344 were given triethanolamine in their drinking water for two years. The doses were 0, 1, and 2%; but starting on week 69, the doses for females were 0.5 and 1%. The estimated daily intakes for 1 and 2% dose groups were approximately 667 and 1,333 mg/kg-day; and the estimated daily intakes for the 0.5% and 1% in females were approximately 333 and 667 mg/kg-day. There were no statistically significant increases in the incidence of tumors between treated and control groups when analyzed by Chi-square test. However, there was an increase in nephrotoxicity which appeared to have an adverse effect on the life expectancy of the treated animals, especially the females. So, an age-adjusted statistical analysis was conducted. There was a positive trend ($p<0.05$) in the occurrence of liver tumors in males and of uterine endometrial sarcomas and renal-cell adenomas in females. These tumors have been observed spontaneously in this strain of rats, and their incidences in the controls were lower than historical controls for other laboratories. The results may indicate that a positive trend in the occurrence of these tumors is not attributable to triethanolamine exposure. Increased incidence of kidney tumors in the high-dose females may have been connected with kidney damage. Histopathologic examination of the kidney effects observed in the treated groups, especially the high-dose females, showed acceleration of chronic nephropathy. Also, mineralization of the renal papilla, nodular hyperplasia of the pelvic mucosa, and pyelonephritis with or without papillary necrosis were also observed (Maekawa *et al.*, 1986; ECHA) [Kl. score = 2]

Male and female B6C3F$_1$ mice were given in their drinking water 0, 1 or 2% triethanolamine (0 and approximately 1,600 and 3,200 mg/kg-day) for 82 weeks. Mortality, organ weights and tumor incidences were similar between treated and control animals (Konishi *et al.*, 1992; ECHA). [Kl. score = 2]

Inhalation

No studies are available.

Dermal

Male and female F344 rats were given dermal applications of triethanolamine, 5 days/week for two years. The doses were: 0, 32, 63 or 125 mg/kg-day for males, and 0, 63, 125 or 250 mg/kg-day for females. There were no treatment-related carcinogenic effects in either sexes (NTP, 1999). [Kl. score = 1]

Male and female B6C3F$_1$ mice were given dermal applications of triethanolamine, 5 days/week for two years. The doses were: 0, 200, 630 and 2,000 mg/kg-day for males, and 0, 100, 300 and 1,000 mg/kg-day for females. In females, there was some evidence of carcinogenicity activity based on increased incidences of hepatocellular adenomas. In males, there was equivocal evidence of carcinogenicity activity based on the incidence of liver hemangiosarcomas (NTP, 2004). [Kl. score = 1]

H. Reproductive/Developmental Toxicity

In a reproductive and developmental toxicity screening (OECD 421) study, male and female Wistar rats were dosed by oral gavage with 0, 100, 300 or 1,000 mg/kg-day triethanolamine. Most of the 1,000 mg/kg-day animals and one 100 mg/kg-day animals showed transient salivation for a few minutes immediately after each treatment. This effect was considered to be induced by the unpalatability of the test substance or from local irritation of the upper digestive tract. Body weight gain was slightly lower in the 1,000 mg/kg-day females during gestation and was considered to be caused by the increased postimplantation loss rather than by a systemic effect of the test substance. In the 1,000 mg/kg-day group, there were lower mean number of implantation sites, increased postimplantation loss, and lower average litter size. There were no treatment-related effects in the F_1 pups. The NOAEL for systemic toxicity is 1,000 mg/kg-day. The NOAEL for reproductive toxicity is 1,000 mg/kg-day. The NOAEL for developmental toxicity is 300 mg/kg-day (ECHA). [Kl. score = 1]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for triethanolamine follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

There were no effects seen in a 91-day dietary study in rats, with a NOAEL of 1,000 mg/kg-day (ECHA). This NOAEL will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 10
UF_D (database uncertainty) = 1

Oral RfD = 1,000/(10 x 10 x 1 x 10 x 1) = 1,000/1,000 = <u>1.0 mg/kg-day</u>

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (1.0 x 70 x 0.1)/2 = 3.5 mg/L

B. Cancer

There were no carcinogenic effects in male and female mice given triethanolamine in their drinking water for 82 weeks (Konishi et al., 1992). In a two-year drinking water study, age-adjust tumor incidence showed increased liver tumors in males, and uterine endometrial sarcomas and renal tubule adenomas in females. These tumors were not attributed to triethanolamine exposure because, in comparison with historical control incidences, the tumors reflected low incidences in the control groups rather than increased incidences in the exposed groups.

In dermal carcinogenicity studies, there was no evidence of carcinogenicity in male and female rats (NTP, 1999). In female mice, there was some evidence of carcinogenicity activity based on increased incidences of hepatocellular adenomas. In male mice, there was equivocal evidence of carcinogenicity activity based on the incidence of liver hemangiosarcomas (NTP, 2004).

A cancer reference value for triethanolamine was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Triethanolamine does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Triethanolamine has low acute toxicity concern to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies conducted on triethanolamine.

Table 3: Acute Aquatic Toxicity Studies on Triethanolamine

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Pimephales promelas	96-h LC_{50}	11,800	2	ECHA
Ceriodaphnia dubia	48-h EC_{50}	610	2	Warne and Schifko, 1999
Desmodesmus subspicatus	72-h EC_{50} EC_{10}	512 (neutralized) 216 (un-neutralized) 26 (neutralized)	2	ECHA

Chronic Studies

In a 21-day *Daphnia* reproduction test, the NOEC for mortality is 16 mg/L, the NOEC for reproduction rate was 125 mg/L, and the NOEC for reproduction on the appearance of first offspring was 250 mg/L (Kuehn *et al.*, 1989). [Kl. score = 2]

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for triethanolamine follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (11,800 mg/L), invertebrates (610 mg/L), and plants (512 mg/L). Results

from chronic studies are available for invertebrates (NOEC = 16 mg/L) and algae (EC_{10} = 26 mg/L). On the basis that the data consists of chronic studies for two trophic levels, an assessment factor of 50 has been applied to the lowest reported EC_{10} of 16 mg/L for *Daphnia*. The $PNEC_{aquatic}$ is 0.32 mg/L.

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 0.25 mg/kg sediment wet weight.

The calculations are as follows:

$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$
$= (0.99/1280) \times 1000 \times 0.32$
$= 0.25$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$K_{sed\text{-}water} = 0.8 + [0.2 \times Kp_{sed})/1000 \times BD_{solid}]$
$= 0.8 + [0.2 \times 0.4/1000 \times 2400]$
$= 0.99$

Where:
Kp_{sed} = solid-water partition coefficient (L/kg).
BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$Kp_{sed} = K_{oc} \times f_{oc}$
$= 10 \times 0.04$
$= 0.4$

Where:
K_{oc} = organic carbon normalized distribution coefficient (L/kg). The K_{oc} for triethanolamine calculated from EPISUITE™ using MCI is 10 L/kg .
F_{oc} = fraction of organic carbon in sediment = 0.04 [default].

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is 0.04 mg/kg soil dry weight.

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
$= (0.2/1500) \times 1000 \times 0.32$
$= 0.04$

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
$= 10 \times 0.02$
$= 0.2$

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for triethanolamine calculated from EPISUITE™ using the MCI is 10 L/kg .
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Triethanolamine is readily biodegradable; thus it does not meet the screening criteria for persistence.

The BCF values for triethanolamine in fish was <3.9; thus it does not meet the criteria for bioaccumulation.

The NOEC or EC_{10} values from chronic aquatic toxicity studies on triethanolamine is >0.1 mg/L. Thus triethanolamine does not meet the criteria for toxicity.

The overall conclusion is that triethanolamine is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Not classified.

B. Labelling

No signal word.

C. Pictogram

None.

X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
Immediately flush open eyes with plenty of water for at least 15 minutes. Remove contacts, if present and easy to do. If effects occur, get medical attention immediately, preferably a physician for an ophthalmologic examination.

Skin Contact
Remove contaminated clothing. Wash thoroughly with soap and water. Seek medical attention if irritation persists.

Inhalation
If inhaled, remove from area to fresh air. Give artificial respiration if victim is not breathing. Get medical attention.

Ingestion
Rinse mouth with water and then drink plenty of water. Get medical attention. Never give anything by mouth to an unconscious person.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
Keep product and empty container away from heat and sources of ignition. May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: nitrogen oxides, carbon monoxide, carbon dioxide.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus and chemical-protective clothing.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Use appropriate protective equipment. Handle in accordance with good industrial hygiene and safety practice. Avoid contact with skin, eyes, and clothing.

Environmental Precautions
Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled
For large amounts: dike spillage and pump off product. For residues: pick up with suitable absorbent material. Dispose of contaminated material as prescribed.

D. STORAGE AND HANDLING

General Handling
Keep product and empty container away from heat and sources of ignition. Ensure adequate ventilation, especially in confined areas.

Storage
Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
The workplace exposure standard for triethanolamine in Australia is 5 mg/m^3 as an 8-hour TWA, with a sensitization notation.

Engineering Controls
Good general ventilation should be used. Use local exhaust ventilation, or other engineering controls to maintain airborne levels below exposure limit guidelines.

Personal Protection Equipment

Respiratory Protection:
Use respiratory protection in case of vapor or aerosol release.

Hand Protection:
Chemical resistant protective gloves.

Skin *Protection*:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Safety glasses with side-shields.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Wearing of closed work clothing is recommended. Ensure that eyewash stations and safety showers are close to the workstation location.

F. TRANSPORT INFORMATION

Triethanolamine is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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TRIBUTYL TETRADECYL PHOSPHONIUM CHLORIDE

This dossier on tributyl tetradecyl phosphonium chloride (TTPC) does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of TTPC in its use in drilling muds and hydraulic fracturing fluids. Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC): Tributyl(tetradecyl)phosphonium;chloride

CAS RN: 81741-28-8

Molecular formula: $C_{26}H_{56}PCl$

Molecular weight: 435.15

Synonyms: Tributyl tetradecyl phosphonium chloride; TTPC; tri-n-butyltetradecylphosphonium chloride; Bellacide 350; Bellacide 355

SMILES: CCCCCCCCCCCCCC[P+](CCCC)(CCCC)CCCC.[Cl-]

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of TTPC

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Clear, colorless liquid	4	BWA Additives (2016)
Boiling Point	100°C*	4	BWA Additives (2016)
Specific Gravity	0.98 – 1.00 @ 20°C	4	BWA Additives (2016)
Partition Coefficient (log K_{ow})	2.45	4	BuruEnergy
Viscosity	55-65 mm^2/s @ 25°C	4	BWA Additives (2016)

*5% aqueous solution of TTPC

TTPC is a non-oxidizing biocide. Information on TTPC in this dossier has been obtained from BWA™ Water Additives, a producer of TTPC. BWA™ Water Additives produces a 5% or 50% aqueous solution of TTPC, which is sold under the product names Bellacide® 355 and Bellacide® 350, respectively.

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

TTPC is stable over a wide pH range and is not susceptible to photodegradation. TTPC is biodegradable, but not readily biodegradable. It will strongly adsorb to soil and sediment. TTPC is not expected to bioaccumulate.

B. Abiotic Degradation

Hydrolysis

TTPC is stable over a wide pH range (BuruEnergy). [Kl. score = 4]

Photolysis

TTPC is not susceptible to photodegradation. (BuruEnergy). [Kl. score = 4]

C. Biodegradation

TTPC was not readily biodegradable in an OECD 301 test (BuruEnergy). [Kl. score = 4]

A die-away [simulation] test was conducted with radiolabelled TTPC for 168 hours at concentration of 0.31 mg/L. The first-order rate constant was 0.69/hour and the half-life was 6.6 hours. After 24 and 168 hours, degradation was >81% and >98%, respectively (BuruEnergy). [Kl. score = 4]

TTPC was evaluation in a simulation test over a 40-day period using double ^{14}C labeled TTPC. In activated sludge, there was >40% degradation after 30 days with 50 ppb TTPC and >30% degradation after 7 days with 5 ppb TTPC. In river water, there was >20% after 35 days with 5 ppb TTPC. In sea water, there was >30% degradation after 35 days with 5 ppb TTPC (BuruEnergy). [Kl. score = 4]

D. Environmental Distribution

Adsorption/desorption

TTPC strongly adsorbs to soil. In a study involving three different soil types (sand, silt, and clay), 93 to 96% of TTPC adsorbed to soil (BuruEnergy). [Kl. score = 4]

No experimental studies are available for determining the K_{oc} of TTPC. Using KOCWIN in EPISUITE™ (EPA, 2017), the estimated K_{oc} value for TTPC using the MCI method is 4.555×10^7 L/kg.

E. Bioaccumulation

No bioaccumulation studies are available on TTPC. TTPC is not expected to bioaccumulate based on the experimental log K_{ow} of 2.45 (BuruEnergy). [Kl. score = 4]

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

TTPC exhibits moderate acute toxicity by the oral route, but is very highly toxic by the inhalation route. It is corrosive to the skin and eyes, but it is not a skin sensitizer. No target organ effects were noted in a 90-day rat drinking water study. TTPC was not mutagenic in a bacterial reverse mutation (Ames) test. There are no carcinogenicity studies on TTPC. In rats, developmental toxicity was shown to occur at oral dose levels that were not maternally toxic; whereas, in rabbits, developmental toxicity occurred only at maternally toxic doses.

B. Acute Toxicity

An oral LD_{50} in rats for Bellacide 350 (50% aq. solution of TTPC) was reported to be >1,002 mg/kg (BWA Additives, 2011) [Kl. score = 4]. An oral LD_{50} in rats for Bellacide 355 (5% aqueous solution of TTPC) was reported to be >4,000 mg/kg (BWA Additives, 2009) [Kl. score = 4].

The 4-hour inhalation LC_{50} in male and female rats for a 50% aq. solution of TTPC was <0.05 mg/L (aerosol). The mass median aerodynamic diameter for the aerosol was 1.93 μm (Cytec, 2012) [Kl. score = 1]. The 1-hour inhalation LC_{50} in male and female rats for a 50% aq. solution of TTPC is 0.227 mg/L (aerosol). The mass median aerodynamic diameter for the aerosol was 1.92 μm (Cytec, 2013) [Kl. score = 1].

C. Irritation

Both Bellacide 350 (50% aq. solution TTPC) and Bellacide 355 (5% aq. solution TTPC) are considered to be corrosive to the skin and eyes (BWA Additives, 2011; 2015). [Kl. score = 4]

D. Sensitization

TTPC is not considered to be a skin sensitizer (BWA Additives, 2011; 2015). [Kl. score = 4]

E. Repeated Dose Toxicity

Oral

A 90-day rat drinking water study has been conducted on a product containing TTPC. The LOAEL for the active ingredient (TTPC) is 27.2 and 32.3 mg/kg-day in males and females, respectively, based on various clinical signs and significantly reduced body weights, feed and water consumption. The NOAEL for this study is 8.66 mg/kg-day (EPA, 2006). [Kl. score = 2]

Inhalation

No data are available.

Dermal

No data are available.

F. Genotoxicity

In Vitro Studies

TTPC was not mutagenic in a reverse mutation bacterial (Ames) test (BWA Additives, 2015). [Kl. score = 4]

In vivo Studies

No studies are available.

G. Carcinogenicity

No studies are available.

H. Reproductive Toxicity

No studies are available.

I. Developmental Toxicity

Female Tif:RAIf(SPF) rats were dosed by oral gavage with 0, 20, 60, or 120 mg/kg Belclene® [50% active ingredient: TTPC] during gestational days (GD) 6 through 15. In the high-dose group, there were two possible treatment-related spontaneous deaths (GD 9 and 14) and another death on GD 15 due to an intubation error. Clinical signs included dyspnea in one mid-dose and 4 high-dose animals, and vaginal bleeding in one mid-dose female on GD 15. In the high-dose group, maternal body weight gain was significantly lower during the treatment period (GD 6-15) and throughout the gestational period (GD 0-20). Mean food consumption was significantly reduced during GD 6-11 for both the mid- and high-dose animals. The number of females with implantations and the number of implantations/females were similar across all groups. Embryonic and fetal deaths were similar between treated and control groups. There were no soft tissue changes. There was an increased incidence of incomplete ossification of the 5th sternebra in the mid- and high-dose groups. The NOAELs for maternal and developmental toxicity for the active ingredient TTPC in this study is 30 and 10 mg/kg-day, respectively (EPA, 2006). [Kl. score = 2]

Female chinchilla rabbits were dosed by oral gavage with 0, 7.5, 22.5, or 45 mg/kg Belclene® [50% active ingredient: TTPC] during gestational days (GD) 6 through 18. In the mid- and high-dose groups, body weight gain was significantly reduced during GD 6-18 and feed consumption was reduced during GD 6-11. Fetal body weights were significantly reduced in the mid-(males only) and high-dose dose groups. There was also an increased incidence of delayed ossification of the hindlimb phalangeal nuclei in the mid- and high-dose groups. The NOAEL for maternal and developmental toxicity for the active ingredient TTPC in this study is 3.75 mg/kg-day (EPA 2006). [Kl. score = 2]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for TTPC follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

<u>Oral</u>

The NOAEL from a rat 90-day drinking water study based on various clinical signs and significantly reduced body weight and reduced feed and water consumption is 8.66 mg a.i./kg-day (EPA, 2006). This NOAEL will be used to derive the oral Reference Dose.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 10
UF_D (database uncertainty) = 1

Oral RfD = 8.66/(10 x 10 x 1 x 10 x 1) = 8.66/1000 = 0.009 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (0.009 x 70 x 0.1)/2 = 0.03 mg/L

B. Cancer

No carcinogenicity studies are available on TTPC. Thus, a cancer reference dose was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

TTPC does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

TTPC has a very high acute toxicity concern to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

Table 2 lists the results of acute aquatic toxicity studies conducted on TTPC.

Table 2: Acute Aquatic Toxicity Studies on TTPC

Test Species	Endpoint	Results (µg/L)	Klimisch score	Reference
Bluegill sunfish	96-h LC_{50}	58.6	2	ECOTOX
Common Carp	96-h LC_{50}	87	2	ECOTOX
Rainbow trout	96-h LC_{50}	490	2	ECOTOX
Rainbow trout	96-h LC_{50}	200	2	ECOTOX
Daphnia magna	48-h EC_{50}	25.2	2	ECOTOX
Selenastrum capricornutum	72-h EC_{50}	19	4	BuruEnergy

Chronic Studies
No studies are available.

C. Terrestrial Toxicity

Table 3 lists the avian toxicity studies conducted on TTPC.

Table 3: Avian Toxicity Studies on TTPC

Test Species	Endpoint	Results	Kl. score	Reference
Bobwhite Quail	8-d dietary	LC_{50}: 4,215 ppm NOEL: 1,980 ppm	2	ECOTOX

Mallard Duck	8-d dietary	LC_{50}: 3,663 ppm NOEL: 1,780 ppm	2	ECOTOX
Mallard Duck	14-d oral gavage	LD_{50}: 232 mg/kg NOEL: <178 mg/kg	2	ECOTOX

D. Calculation of PNEC

The PNEC calculations for TTPC follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (58.6 µg/L), *Daphnia* (25 µg/L), and algae (19 µg/L). No chronic toxicity studies are available on TTPC. On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the effect concentration of 19 µg/L for algae. The $PNEC_{aquatic}$ is calculated to be 0.019 µg/L (1.9×10^{-5} mg/L).

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 12,982 µg/kg (13.0 mg/kg) sediment wet weight.

The calculations are as follows:

$$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$$
$$= (874{,}561/1280) \times 1000 \times 0.019$$
$$= 12{,}982$$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$$K_{sed\text{-}water} = 0.8 + [0.2 \times Kp_{sed}/1000 \times BD_{solid}]$$
$$= 0.8 + [0.2 \times 1{,}822{,}000/1000 \times 2400]$$
$$= 874{,}561$$

Where:
Kp_{sed} = solid-water partition coefficient (L/kg).

BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$Kp_{sed} = K_{oc} \times f_{oc}$
= 45,550,000 x 0.04
= 1,822,000

Where:
K_{oc} = organic carbon normalized distribution coefficient (L/kg). The K_{oc} for TTPC calculated from EPISUITE™ using the MCI method is 4.555×10^7 L/kg.
F_{oc} = fraction of organic carbon in sediment = 0.04 [default].

PNEC soil
There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is 11,539 µg/kg (11.5 mg/kg) soil dry weight.

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
= (911,000/1500) x 1000 x 0.019
= 11,539

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
= 45,550,000 x 0.02
= 911,000

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for TTPC calculated from EPISUITE™ using the MCI method is 4.555×10^7 L/kg.
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

In a simulation test using river water, there was >20% after 35 days; however, no information is available on longer time points. TTPC is not readily biodegradable; thus it meets the screening criteria for persistence.

The log K_{ow} for TTPC is 2.45. Thus, TTPC does not meet the screening criteria for bioaccumulation.

There are no chronic aquatic toxicity studies available on TTPC. The lowest acute $E(L)C_{50}$ value for TTPC is <1 mg/L in algae. Thus TTPC meet the criteria for toxicity.

The overall conclusion is that TTPC is not a PBT substance.

IX. CLASSIFICATION AND LABELING (Australia GHS)

A. Classification

Acute Toxicity Category 4 [Oral]
Acute Toxicity Category 1 [Inhalation]
Skin Corrosion Category 1
Eye Damage Category 1
STOT RE Category 2
Aquatic Acute Category 1
Aquatic Chronic Category1

B. Labelling

Danger

C. Pictogram



In addition to the hazard statements corresponding the GHS classifications, the following non-GHS hazard statement is to be added to the SDS: AUH071: Corrosive to the Respiratory Tract.

X. SAFETY AND HANDLING

A. First Aid

<u>Eye Contact</u>

Flush with plenty of fresh water for 15 minutes holding eyelids open, lifting eyelids occasionally to ensure complete removal of the product. DO NOT allow rubbing of eyes or keeping eyes closed. Remove contact lenses. Seek medical advice.

Skin Contact

Rinse with soap and plenty of water for several minutes. Remove contaminated clothing. Seek medical attention immediately.

Inhalation

Remove person to fresh air. Apply artificial respiration if not breathing. Seek medical attention.

Ingestion

Rinse mouth with water (only if the person is conscious). Do NOT induce vomiting. Seek medical advice immediately.

B. FIRE FIGHTING INFORMATION

Extinguishing Media

Suitable Extinguishing Media: carbon dioxide, water spray, foam, dry chemical.

Specific Exposure Hazards

Containers may explode when heated. May form explosive mixtures with strong acids. Hazardous combustion products may include the following materials: carbon monoxide, carbon dioxide, phosphorus oxides, chlorine.

Special Protective Equipment for Firefighters

Full protective clothing and approved self-contained breathing apparatus required for firefighting personnel.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions

Use appropriate protective equipment and avoid direct contact. Do not touch damaged containers or spilled material unless wearing appropriate protective clothing. Ventilate the area before entry.

Environmental Precautions

Prevent spills from entering storm drains or sewers and contact with soil.

Steps to be Taken if Material is Released or Spilled

Use an absorbent material to recover as much product as possible, then, rinse the affected area with water to dilute the residue. Disposal of leftover product and used containers should be carried out in accordance with all local, state and federal regulations.

D. STORAGE AND HANDLING

General Handling

Wear appropriate personal protective equipment. Avoid contact with eyes, skin or clothing. Avoid breathing mist, vapours or spray. Use only with adequate ventilation. Wash hands after use. Launder contaminated clothing.

Storage

Keep container closed when not in use. Store in a cool well ventilated area.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
Workplace Australia has not established an occupational exposure standard for TTPC.

Engineering Controls

Good general ventilation should be used. Ventilation rates should be matched to conditions. If applicable, use process enclosures, local exhaust ventilation, or other engineering controls to maintain airborne levels below recommended exposure limits. If exposure limits have not been established, maintain airborne levels to an acceptable level.

Personal Protection Equipment

Respiratory Protection: Use a mask or approved air-purifying respirator with appropriate cartridge or canister in spray applications or in confined spaces.

Hand Protection: Wear impervious gloves to prevent skin contact and absorption of this material. Rubber or Neoprene gloves may afford adequate skin protection.

Skin Protection: Wear appropriate clothes (*i.e*., coveralls). Use non-slip footwear.

Eye protection: Wear eye protection in situations where splash or thick mists are possible.

Other Precautions: Avoid contact with skin, eyes and clothing. When using, do not eat or drink. Wash hands thoroughly with soap and water before eating or drinking. Remove contaminated clothing and launder before reuse.

F. TRANSPORT INFORMATION

UN2922 CORROSIVE LIQUID, TOXIC N.O.S. (contains tributyltetradecyl phosphonium chloride)
Class 8 and 6.1
Packing Group: II

Environmentally Hazardous Substance

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

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ULEXITE

This dossier on ulexite does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of ulexite in its use in drilling muds and hydraulic fracturing fluids. Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name: Sodium-calcium pentaborate octahydrate

CAS RN: 1319-33-1

Molecular formula: $(NaCaB_5O_6(OH)_6 \bullet 5H_2O)$

Molecular weight: Not applicable

Synonyms: Ulexite; sodium-calcium pentaborate octahydrate

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Commercially Available Ulexite

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	White, granular, ground, or powder form	4	Etimine USA, Inc. (2016)
Melting Point	870°C	4	Etimine USA, Inc. (2016)
Bulk Density	1,410 to 1,500 kg/m^3	4	Etimine USA, Inc. (2016)
Water solubility	26.67% as dissolved Ulexite @ 25°C by weight of solution	4	American Borate Company (2016)

Ulexite is a naturally-occurring mineral that is slightly soluble in water.

In a study investigating the relative rates of boron from soluble and controlled-release boron fertilizers, ulexite showed releases of boron of 20% in just under 10 weeks; 40% in approximately 25 weeks; 60% by 40 weeks; and 80% by 60 weeks (Broschat, 2008).

III. ENVIRONMENTAL FATE PROPERTIES

No information is available. Ulexite is a naturally-occurring mineral and is not expected to biodegrade or bioaccumulate.

IV. HUMAN HEALTH HAZARD ASSESSMENT

No information is available.

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

No values were derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Ulexite does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

No information is available.

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Ulexite is a naturally-occurring mineral. For the purposes of this PBT assessment, the persistence criteria is not considered applicable to this inorganic substance.

Bioaccumulation is not applicable to naturally-occuring minerals, such as ulexite. Although boron is slowly released from ulexite, limited data indicate that bioaccumulation is not significant in aquatic and terrestrial food chains. Thus, it does not meet the criteria for bioaccumulation.

There are no mammalian or aquatic toxicity studies on ulexite. Ulexite, being a slightly water-soluble mineral, is not expected to be bioavailable. Thus, it does not meet the criteria for toxicity.

The overall conclusion is that ulexite is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Not classified.

B. Labelling

No signal word.

C. Pictogram

None

X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. If symptoms persist, seek medical advice.

Skin Contact
Wash thoroughly with soap and water.

Inhalation
If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Ingestion
Rinse mouth with water and then drink plenty of water. Never give anything by mouth to an unconscious person. If symptoms develop, seek medical advice.

B. FIRE FIGHTING INFORMATION

Extinguishing Media

Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
Ulexite is non-flammable, combustible, or explosive. It is a flame retardant.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus and protective clothing.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Use appropriate protective equipment.

Environmental Precautions
Ulexite is slightly water-soluble; at high concentrations it may cause damage to trees or vegetation by root absorption. Do not flush to drains.

Steps to be Taken if Material is Released or Spilled
Scoop up and remove.

D. STORAGE AND HANDLING

General Handling
No special measures necessary provided product is used correctly.

Other Handling Precautions
Avoid eye and skin contact. Avoid creating or inhaling dust.

Storage
Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
Workplace Australia has not established an occupational exposure standard for ulexite.

Engineering Controls
None

Personal Protection Equipment

Respiratory Protection:
Respiratory protection is not required.

Hand Protection:
Chemical resistant protective gloves.

Skin *Protection*:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Safety glasses with side-shields.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible.

F. TRANSPORT INFORMATION

Ulexite is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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APPENDIX G ENVIRONMENTAL ASSESSMENT PROFILES

APPENDIX G.1 SCHLUMBERGER GUAR BASED SYSTEMS

Environmental Assessment

Acetic Acid
(CAS No. 64-19-7)

Acetic acid and its salts undergo dissociation in aqueous media into the acetate anion ($H_3C_2O_2^-$) and the respective cations (H^+, NH_4^+, Ca^{2+}, Mg^{2+}, Mn^{2+}, K^+, Na^+). The toxicity of each compound is driven by acetate, with the cations playing a minor role. The pH is 2.5 at 50 g/L and 20°C; and the pK_a is 4.76 at 20°C.

Environmental Transport

Level I fugacity modeling predicts that about 73% of any acetic acid released to the environment would partition to water, with the remainder partitioning into the air (U.S. HPVIS database).

Biodegradation

Acetic acid and its salts readily dissociate into their respective cations and the acetate anion; the anion acetate is readily biodegraded. In aerobic conditions using adapted wastewater from domestic sewage, degradation was 96% after 20 days (Price *et al.*, 1974). It was also shown to be readily biodegradable under anaerobic conditions using activated sludge (99% after 7 days) (Kameya *et al.*, 1995).

Aquatic Toxicity

The 96-hour LC_{50} in bluegill sunfish is 75 mg/L (Price *et al.*, 1974), and the 96-hour LC_{50} in mosquito fish is 251 mg/L (Wallen *et al.*, 1957). The 96-hour LC_{50} of 60% acetic acid in *Oncorhynchus mykiss* is 108 mg/L (64.8 mg acetic acid/L) (unpublished data, ECHA). In a chronic study with *Oncorhynchus mykiss*, the 21-day LC_{50} and NOEC for 60% acetic acid were 87 mg/L and 57.2 mg/L, respectively (unpublished data, ECHA). The 21-day LC_{50} and NOEC for 100% acetic acid were 52.2 mg/L and 34.3 mg/L, respectively (unpublished data, ECHA).

The 24-hour EC_{50} to Daphnia was reported to be 95 mg/L (un-neutralized) and 6,000 mg/L (neutralized to pH 8.0) (Bringmann and Kuehn, 1982). One other study showed the 48-hour EC_{50} to be 65 mg/L (Janssen *et al.*, 1993). In a chronic Daphnia study, the 21-day NOEC for reproduction was reported to be 22.7 mg/L for 100% acetic acid (unpublished data, ECHA). In another chronic Daphnia study, the 21-day NOEC for reproduction was 31.4 mg/L for 100% acetic acid (unpublished data, ECHA).

In an algae growth inhibition study, the reported nominal ErC_{50} to *Desmodesmus subspicatus* was 810.9 mg/L for 60% acetic acid (unpublished data, ECHA). The

reported nominal ErC_{50} was 486.5 mg/L for 100% acetic acid (unpublished data, ECHA). The toxicity threshold to algae after 8 days in a growth inhibition test was reported to be 4,000 mg/L (Bringmann and Kuehn, 1980).

Toxicity to Terrestrial Organisms

No data could be located.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (65 mg/L) and Daphnia (65 mg/L), and algae (487 mg/L). Long-term results are also available for fish (NOEC = 34 mg/L) and Daphnia (NOEC = 23 mg/L). On the basis that the data consists of short-term results from three trophic levels and two chronic study for fish and another chronic study for Daphnia, an assessment factor of 50 has been applied to the lowest NOEC of 23 mg/L for Daphnia. The $PNEC_{aquatic}$ was calculated to be 0.5 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Acetic acid dissociates completely in water with its environmental distribution dominated by its high water solubility. Since log Kow and Koc are only applicable to the non-ionized forms of a substance, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Thus, the determination of the $PNEC_{sediment}$ is not possible. Based on its properties, no adsorption of acetic acid to sediment is to be expected and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. Acetic acid dissociates completely in water with its environmental distribution dominated by its high water solubility. Since log Kow and Koc are only applicable to the non-ionized forms of a substance, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Thus, the determination of the $PNEC_{soil}$ is not possible. Based on its properties, no adsorption of acetic acid to soil is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

The acetate ion of acetic acid is readily biodegradable and thus it does not meet the screening criteria for persistence.

The log Kow for acetic acid is reported to be -0.17 (Verschueren, 1966). Acetate is also found in the body and is metabolized as part of the body's biochemical pathways. Thus,

acetic acid (specifically, the acetate ion) does not meet the screening criteria for bioaccumulation.

The NOECs from the chronic aquatic toxicity data on acetic acid are >0.01 mg/L. Thus, acetic acid does not meet the criteria for toxicity.

The overall conclusion is that acetic acid is not a PBT substance.

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Environmental Assessment

Ammonium C6-C10 Alcohol Ethoxysulfate
(CAS No. 68187-17-7)

Alcohol ethoxysulfates (AES) are a widely used class of anionic surfactants. No data could be located on alcohol ethoxysulfates in the C6 to C10 range.

In the HERA report, the alcohol ethoxysulfate family covers commercial grades of linear-type primary alcohol ethoxysulfates of either sodium, ammonium or triethanolamine (TEA) salts. Sodium salts of AES are by far the commonly used grades.

In the absence of data, the C12-C14 alcohol ethoxysulfates were used as read-across to the C6-C10 alcohol ethoxysulfates.

Biodegradation

AES are readily biodegradable under aerobic conditions, with alkyl-chain length having little effect. AES are expected to be easily biodegradable under anaerobic conditions based on the biodegradation data on alcohol ethoxylates and alkyl sulfates. In a stringent anaerobic biodegradability test (ECETOC test) on C12-14EO2S, gas (CO_2 and methane) production of 75% occurred within the 41-day incubation period.

Surface-water degradation rate of 0.48 per day has been applied to all chain lengths based on measured data for C14-15EO2.25S.

Biodegradation Pathways

The risk assessment of a parent compound should be restricted to that compound unless the metabolites are persistent and/or more ecotoxic than the parent. There are three starting routes of AES degradation which all seem to occur: i) ω-/β-oxidation of the alkyl chain, ii) enzymatic cleavage of the sulfate substituent leaving an alcohol ethoxylate, iii) cleavage of an ether bond in the AES molecule producing either the alcohol (central cleavage) or an alcohol ethoxylate and an oligo (ethylene glycol) sulfate. The subsequent degradation of the resulting intermediates encompasses oxidation of the alcohol to the corresponding fatty acid (itself then degraded via ß-oxidation) or degradation of the alcohol ethoxylate (via central cleavage or degradation from either end of the molecule) or degradation of the oligo (ethylene glycol) sulfate. The ultimate biodegradability of alcohol ethoxylates is well established and glycol ether sulfates have also been shown to be fully degradable by mixed cultures forming inorganic sulfate and carbon dioxide. The conclusion that AES degradation will not produce any recalcitrant metabolite is in line with the experimental findings on AES in the "Test for Detecting Recalcitant Metabolites" (Gerike and Jasiak, 1986). In addition, Yoshimura and Matsuda (1982) reported test data showing that the (fish) toxicity of AES decreases in the course of AES

degradation. Consequently, there is no indication for the formation of persistent or markedly toxic metabolites from AES.

Aquatic Toxicity

Acute toxicity data are available in several review articles. As a large chronic data base exists the acute data have not been further considered for the HERA risk assessment. The abundance of chronic toxicity data is such that it is justified to base the PNEC on chronic toxicity data.

Determination of PNECs

$PNEC_{aquatic}$: The chronic toxicity QSAR (Dyer *et al.*, 2000) has been used to derive PNEC values, using an assessment factor of 10. The assessment factor of 10 is justified by the taxonomic diversity of the overall dataset. The resulting PNEC are shown in the table below.

PNECaquatic (mg/L)

Carbon #	12	13	14
$PNEC_{aquatic}$ (mg/L)	0.27	0.076	0.038

A $PNEC_{aquatic}$ value of 0.27 mg/L was used for C6-C10 alcohol ethoxysulfates based on the value for C12 alcohol ethoxysulfates.

$PNEC_{sediment}$: There are no measured sediment exposure data nor any sediment toxicity data on AES. Since the log Kow of none of the AES homologues exceeds log Kow 5, the TGD states that the risk characterization for the aquatic compartment should be used for the sediment compartment. Consequently $PNEC_{sediment}$ was not calculated in the HERA report.

$PNEC_{soil}$: To estimate $PNEC_{soil}$ by equilibrium partitioning, the sorption behavior of AES homologues is needed. The only sorption value found for AES was measured for $C_{12}EO_5S$ in river sediments and gave K_{oc} =1.1 (Urano *et al.*, 1984). This compares to a K_{oc} of 2.3 calculated using the QSAR for 'Predominantly hydrophobics' from Sablijic & Gusten (1995) referenced in the TGD (log Koc=0.81 log Kow + 0.1). The applicability of this QSAR to surfactants is questionable, but in the absence of other measured K_{oc} values, $PNEC_{soil}$ have been derived using this QSAR. Using a Koc of 2.3 and a $PNEC_{aquatic}$ of 0.27 mg/L, the $PNEC_{soil}$ was calculated to be 0.0083 mg/kg.

References

Dyer, S.D., Stanton, D.T., Lauth, J.R. and Cherry, D.S. (2000). Structure-activity relationships for acute and chronic toxicity of alcohol ether sulfates. Environmental Toxicology and Chemistry 19: 608-616.

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Yoshirmura, K., and Masuda, F. (1982). Biodegradation of Sodium Alkyl Poly(oxyalkylene)sulfates J. Am. Oil Chem. Soc. 59: 328-332.

Environmental Assessment

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Determination of PNECs

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$PNEC_{soil}$: To estimate $PNEC_{soil}$ by equilibrium partitioning, the sorption behavior of AES homologues is needed. The only sorption value found for AES was measured for $C_{12}EO_5S$ in river sediments and gave K_{oc} =1.1 (Urano *et al.*, 1984). This compares to a K_{oc} of 2.3 calculated using the QSAR for 'Predominantly hydrophobics' from Sablijic & Gusten (1995) referenced in the TGD (log Koc=0.81 log Kow + 0.1). The applicability of this QSAR to surfactants is questionable, but in the absence of other measured K_{oc} values, $PNEC_{soil}$ have been derived using this QSAR. Using a Koc of 2.3 and a $PNEC_{aquatic}$ of 0.27 mg/L, the $PNEC_{soil}$ was calculated to be 0.0083 mg/kg.

References

Dyer, S.D., Stanton, D.T., Lauth, J.R. and Cherry, D.S. (2000). Structure-activity relationships for acute and chronic toxicity of alcohol ether sulfates. Environmental Toxicology and Chemistry 19: 608-616.

Gerike P., and Jasiak, W. (1986). How completely are surfactants biodegraded? Tenside Deterg. 23: 300-304.

Human and Environmental Risk Assessment (HERA) on Ingredients of Household Cleaning Products: Alcohol Ethoxysulphates, Human Risk Assessment (2003), Draft http://www.heraproject.com

Sabljic, A., and Güsten, H. (1995). QSARs for soil sorption. In: Overview of structure-activity relationships for environmental endpoints. Hermens JLM (ed), Report prepared within the framework of the project 'QSAR for Prediction of Fate and Effects of Chemicals in the Environment', an international project of the Environmental Technologies RTD Programme (DG XII/D-1) of the European Commission under contract number EV5V-CE92-0211.

Urano, K, and Saito, M. (1985). Biodegradability of surfactants and inhibition of surfactants to biodegradation of other pollutants. Chemosphere 14: 1333-1342.

Yoshirmura, K., and Masuda, F. (1982). Biodegradation of Sodium Alkyl Poly(oxyalkylene)sulfates J. Am. Oil Chem. Soc. 59: 328-332.

Environmental Assessment

Amorphous/Non-crystalline Silica
(CAS No. 7631-86-9[1])

Silica Gel
(CAS No. 112926-00-8)

Amorphous Silica and silica gel have been reviewed in the OECD-SIDS program (OECD, 2004a,b).

The CAS No. 7631-86-9 is the general CAS registry number for silicon dioxide which includes all forms of silicas (*e.g.*, also crystalline and natural forms). Only the silica sub-classes, the synthetic amorphous silicas, are subject of this assessment.

Synthetic amorphous silica and silicates are in powder form which have a low water solubility, based on the sum of soluble SiO_2 and cations (water-soluble fraction): ≤70 mg/l (SAS), approx. 70 – 80 mg/l (NAS), and approx. 260 mg/l (CS) at 20 °C.

Environmental Fate and Transport

Silicon oxides are the most abundant compounds in the earth's crust mass. Synthetic amorphous silica and silicates are released into the environment are expected to be distributed mainly into soils and sediments, weakly into water and probably not at all in the air due to their physico-chemical properties, particularly low water solubility and very low vapor pressure.

Synthetic amorphous silica and silicates released into the environment are expected to combine indistinguishably with the soil or sediment due to their similarity with inorganic soil/sediment matter and will be subjected to natural processes under environmental conditions (cation exchange, dissolution, sedimentation).

Biodegradation is not applicable to these inorganic substances. The bioavailable form of synthetic amorphous silica and silicates is the dissolved form which exists exclusively as monosilicic [$Si(OH)_4$] acid under environmental pH. In analogy to the general chemical reaction of weak acids and salts of weak acids with water, the water-soluble fraction of silica acts as a weak acid and, therefore, will tend to lower the pH value, while that of a silicate acts as a base tending to bind protons and, thus, raise the pH value by forming hydroxyl ions. But pH shifts which are measurable at high loadings under laboratory conditions are not expected to occur from the anthropogenic deposition in the aquatic environment of synthetic amorphous silicas due to low aquatic releases and sufficient natural buffer capacities. Finally, these materials are supposed to combine indistinguishably with the soil layer or sediment due to their chemical similarity with inorganic soil matter.

Dissolved silica can be actively assimilated by some marine and terrestrial organisms as normal natural processes mainly related to structural function.

Aquatic Toxicity

Studies on fish, Daphnia and algae using excess loadings of SAS or NAS showed no acute toxicity, although physical effects on Daphnia were observed in tests using unfiltered test medium. Test results, based on loading rates, are as follows: 96-hour LL_0 *(Brachydanio rerio)* is 10,000 mg/L for SAS and NAS; 24-hour EL_{50} *(Daphnia magna)* >10,000 mg/L for SAS; 72-hour NOEL *(Scenedesmus subspicatus)* is 10,000 mg/L for NAS.

There are no chronic aquatic toxicity data, but due to the known inherent physico-chemical properties, absence of acute toxic effects as well as the ubiquitous presence of silica/silicates in the environment, there is no evidence of harmful long-term effects arising from exposure to synthetic amorphous silica/silicates.

Toxicity to Terrestrial Organisms

No data are available.

PBT Assessment

Noncrystalline silica (silica gel) is silicon dioxide, an inorganic compound which is ubiquitous in the environment. For the purposes of this PBT assessment, the persistent criteria is not considered applicable to this inorganic salt.

A log Kow is not applicable to noncrystalline silica. Noncrystalline silica (silica gel), as a stable crystalline solid, is expected to have negligible uptake through the gill or gut of aquatic organisms. Thus, noncrystalline silica (silica gel) is not expected to bioaccumulate.

No chronic toxicity data exist on noncrystalline silica or silica gel; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, noncrystalline silica (silica gel) does not meet the screening criteria for toxicity.

The overall conclusion is that noncrystalline silica (silica gel) is not a PBT substance.

References

OECD (2004a). IUCLID Data Set for Synthetic Amorphous Silica and Silicates: Silicon Dioxide (CAS No. 7631-86-9, 112945-52-5, 112926-00-8; Silicic Acid, Aluminum Sodium Salt (CAS No. 1344-00-9); Silicic Acid, Calcium Salt (CAS No. 1344-95-2), UNEP Publications.

OECD (2004b). Screening Information Dataset (SIDS) Initial Assessment Report for Synthetic Amorphous Silica and Silicates: Silicon Dioxide (CAS No. 7631-86-9, 112945-52-5, 112926-00-8; Silicic Acid, Aluminum Sodium Salt (CAS No. 1344-00-9); Silicic Acid, Calcium Salt (CAS No. 1344-95-2), UNEP Publications.

Environmental Assessment

Boric acid
(CAS No. 10043-35-3)

In natural waters, boron forms stable species and exists primarily as undissociated boric acid [$B(OH)_3$] and complex polyanions (*e.g.*, $B(OH)_4^-$). These forms of boron are highly soluble and not easily removed from solution by natural mechanisms. Borate and boric acid are in equilibrium depending on the pH of the water. At an acidic pH, boron exists in solution mainly as undissociated boric acid, whereas at alkaline pH it is present as borate ions.

Boric acid is a persistent molecule, not subject to hydrolysis, photodegradation or biodegradation. Other borates yield boric acid upon dissolution in water (or borate anion in higher pH conditions).

Determination of PNECs

$PNEC_{aquatic}$: Canadian Water Quality Guidelines for the Protection of Aquatic Life: Long–term Exposure to Boron is 1.5 mg/L (2009).

$PNEC_{sediment}$: The environmental distribution of boric acid is dominated by its water solubility. Sorption of boric acid should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Koc and Kow parameters do not readily apply to inorganics, such as boric acid. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on its properties, boric acid is not expected to significantly adsorb to sediment, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$:

[From: Draft EU RAR on Boric Acid and Sodium Tetraborates V2.0]

Selection of the critical study
"Selection of the lowest plant NOEC would lead to a criterion of 1 mg-B/kg-dry soil based on Riley et al (1994) study of *Hordeum vulgare.* However, this endpoint is based on plant appearance and may not reflect more ecologically and socially relevant endpoints (plant structure and biomass or yield). From the same study, plant structure (root/shoot ratio) had a NOEC of 2 mg/kg dry soil, and yield had a NOEC of 4 mg/kg-dry soil. A later study with the same strain of barley indicated no toxicity but rather improved biomass and yield at 0.75 mg- B/kg-soil addition (Wongmo et al. 2004)."

"The next lowest NOEC was 1.5 mg-B/kg dry soil based on the Gupta and Cutcliffe (1984) field study with *Phaseolus vulgaris.*"

"A NOEC of 1.0 mg-B/kg dry soil is recommended because it is based on a suitable

study, and it is consistent with published reviews from soil solution data in combination with an equilibrium partitioning approach."

Selection of an Application Factor
"Given the nature of the data set which includes long-term field studies (e.g. entire growing seasons) plus laboratory studies, the history of use of boron in agricultural applications to benefit plant growth, the evidence of deficiency at low exposures, ample justification exists for the selection of an application factor less than 10."

"First, tolerance of higher plants for high concentrations in soils has been demonstrated for several metals where metal-tolerant populations have developed in environments with increased metals, whereas in uncontaminated areas non-tolerant populationsof the same species are present. The cultivar of barley used to determine the critical NOEC has been recognized as one of the more sensitive varieties being used."

"In addition, the PNEC added, terrestrial is regarded as a concentration that can be added to the background without inducing toxic adverse effects on the terrestrial ecosystem. However, background concentratons of boron can be as high as 200 mg-B/kg with usual levels of 45-124 mg/kg dw. A PNEC added, terrestrial that is < 1/10th of the natural background will be hard to detect and this will have implications for field studies and monitoring programs."

"Plants are likely the most sensitive species; NOECs for earthworms, springtails and microorganisms are about a factor of 10 higher. Calculations of the HC5 values for seedling emergence data from Aquaterra by the Netherlands (2006) indicate that the EC20 is 4 mg-B/kg dry soil for monocotyledons, and 16 mg-B/kg-dry soil for dicotyledons. Although the EC20 is not a NOEC, the data do suggest that the low NOEC of 1 mg-B/kg dry soil is protective for the majority of plant species."

"The endpoint in the barley NOEC of 1 mg-B/kg dry soil was for the number of tillers lodged. Other endpoints for root/shoot ratio and relative grain yield in that study were 2 and 4 mg-B/kg dry soil, are more in line with other available data and can be considered as more relevant to long-term population effects."

"The use of boron as a micronutrient fertilizer is widespread and effective in improving crop yields. Because of the narrow range between toxicity and deficiency, a smaller AF for agricultural soil would be justified. Agricultural practice applies boron to soil at rates varying with crop, but generally at rates which correspond to a added soil concentrations of 0.15 to 2.3 mg-B/kg."

"Given these factors, it is considered justified to use an AF of 5 (instead of 10) with the NOEC of 1, and set the PNEC added, terrestrial to 0.2 mg-B/kg dry soil. For agricultural soil, a smaller AF would be appropriate to reflect the necessities of current practice; an AF of 1 would conform to current fertilization practices."

"Therefore two PNEC added, terrestrial values are established:

A PNEC added, terrestrial of 0.2 mg-B/kg dry soil for natural/grassland soils, and a PNEC added, terrestrial of 1.0 mg-B/kg dry soil for agricultural soils where fertilization with boron is practiced."

References

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Draft EU Risk Assessment Report on Boric Acid and Sodium Tetraborates, Version 2.0, 19 October 2007

Environmental Assessment

Reaction mass of 5-chloro-2-methyl-4-isothiazolin-3-one and 2-methyl-2H-isothiazolin-3-one [3:1]
(CAS No. 55965-84-9)

Environmental Fate

5-Chloro-2-methyl-4-isothiazolin-3-one and 2-methyl-4-isothiazolin-3-one, the active ingredients in DOW™ CMIT/MIT antimicrobial products, have a low bioconcentration potential (tendency to accumulate in the food chain) and a high potential for mobility in soil. They are completely soluble in water. In the environment these compounds would tend to partition into water where they would rapidly biodegrade to non-persistent substances which are several orders of magnitude less toxic than parent compound. They would also be removed by common biological wastewater treatment facilities.

Biodegradation

The primary aerobic biodegradability of MIT has been examined in a river sediment-water system by use of a ^{14}C-labelled model compound. During the 7-day experiment ^{14}C-labelled MIT was rapidly metabolized as only 12.6% of the initial MIT was present after 24 hours of incubation at 25 The calculated half-life for the parent compound was 9.1 hours (Reynolds, 1994a). MIT was metabolized to several unidentified metabolites. One of the major metabolites reached a level corresponding to 18.2% of the ^{14}C added after 24 hours of incubation. This metabolite decreased to 6.8% after 7 days which indicates further transformation. Other metabolites tended to increase during the 7-day experiment. At the end of the experiment metabolites that were bound in the sediment corresponded to 55%, whereas $^{14}CO_2$ attained 9% of the added ^{14}C. Most of the formed metabolites have shorter chromatographic retention times than MI which indicates that they are polar compounds. On the basis of the identification of metabolites from transformation of 4,5-dichloro-2-(n-octyl)-4-isothiazolin-3-one, it has been proposed that MI is transformed via N-methyl malonamic acid, N-methyl acetamide, and malonic acid (Madsen, 2000).

The primary biodegradability of CMIT has been examined with the same type of sediment and water as described for MIT. The ^{14}C-labelled CMIT was rapidly metabolized as only 30% of the initial CMI remained after 24 hours of incubation at 25 The calculated half-life for the intact CMIT was 17.3 hours (Reynolds, 1994b). At the end of the 7-day experiment, the sediment bound metabolites corresponded to 57.1% of the added ^{14}C, whereas 2.8% of the added ^{14}C was released as $^{14}CO_2$. Due to the structural similarities of MI and CMIT, it is suggested that the major metabolites for the transformation of CMIT are the same as described for MIT.

MIT was tested in an OECD 301B test modified for low concentrations of ^{14}C-labelled

compounds. The accumulated $^{14}CO_2$ attained 54.1%, 55.8%, and 47.6% in the respective concentrations (0.1, 0.03 and 0.01 mg/l) after 29 days. During the 10-day window, 37%, 30% and 30%, respectively, of the initial MIT was mineralized to $^{14}CO_2$ (Bashir, 1998a).

CMIT was tested in an OECD 301B modified for low concentrations of ^{14}C-labelled compounds. The accumulated $^{14}CO_2$ attained 38.8%, 55.3%, and 62% in the respective concentrations (0.3, 0.1, and 0.03 mg/l) after 29 days. During the 10- day window, 25%, 40%, and 48%, respectively, of the initial CMIT was mineralized to $^{14}CO_2$. The ultimate biodegradability of CMIT exceeded the 60%-pass level for ready biodegradability at the lowest test concentration of 0.03 mg/L, but the pass level was not reached within the 10-day window Bashir, 1998b).

From Dow Chemicals MSDS for ROCIMA GT:
Biodegradation (aquatic metabolism): 5-Chloro-2-methyl-4-isothiazolin-3-one (CMIT): t ½ anaerobic = 0.2 day, t ½ aerobic = 0.38 – 1.3 days; 2-Methyl-4-isothiazolin-3-one (MIT): t ½ aerobic = 0.38 – 1.4 days.

Bioaccumulation

The bioaccumulation of CMIT in bluegill sunfish *(Lepomis macrochirus)* resulted in BCF values of 102, 114, and 67 at nominal concentrations of 0.02, 0.12, and 0.8 mg/L (Erikson *et al*. 1995). These BCF values are based on total accumulated ^{14}C and include both the parent compound and metabolites. The BCF for MIT has been determined to 2.3 at a nominal concentration of 0.12 mg/L (Erikson *et al*. 1995).

Aquatic Toxicity

From Dow Chemicals MSDS for ROCIMA GT:
The 96-hour LC_{50} for Bluegill sunfish (*Lepomis macrochirus*) is 0.28 mg/L, and the 96-hour LC_{50} for Rainbow trout (*Oncorhynchus mykiss*) is 0.188 mg/L. The 48-hour EC_{50} for *Daphnia magna* is 0.126 mg/L. The 72-hour ErC_{50} for algae (*Selenastrum capricornutum*) is 0.027 mg/L.

Toxicity to Terrestrial Organisms

No data were located.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (0.188 mg/L), Daphnia (0.126 mg/L), and algae (0.027 mg/L). On the basis that the data consists of short-term results from three trophic levels,

an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 0.027 mg/L for Daphnia. The $PNEC_{aquatic}$ is 2.7×10^{-5} mg/L or 0.027 µg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$. The Koc was calculated using EPISUITE (MCI Method). CMIT: Using a Koc of 19.38 and a $PNEC_{aquatic}$ of 0.027 µg/L, the $PNEC_{sediment}$ was calculated to be 0.025 µg/kg. MIT: Using a Koc of 12.08 and a $PNEC_{aquatic}$ of 0.027 µg/L, the $PNEC_{sediment}$ was calculated to be 0.022 µg/kg.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The equilibrium partition method was used to determine a $PNEC_{soil}$. The Koc was calculated using EPISUITE (MCI Method). CMIT: Using a Koc of 19.38 and a $PNEC_{aquatic}$ of 0.027 µg/L, the $PNEC_{soil}$ was calculated to be 0.007 µg/kg. MIT: Using a Koc of 12.08 and a $PNEC_{aquatic}$ of 0.027 µg/L, the $PNEC_{soil}$ was calculated to be 0.0043 µg/kg.

PBT Assessment

The half-lives of CMIT and MIT is a river water-sediment system were 17.3 hours and 9.1 hours, respectively. Thus, CMIT/MIT do not meet the criteria for persistence.

The experimental BCF for CMIT is 67-114 in bluefish sunfish, and the BCF for MIT was determined to be 2.3. Thus, CMIT/MIT do not meet the criteria for bioaccumulation.

No chronic toxicity data are available for CMIT/MIT; however, the acute $E(L)C_{50}$ values for algae are >0.01 but <0.1 mg/L. Thus, CMIT/MIT meet the screening criteria for toxicity.

The overall conclusion is that CMIT/MIT mixture is not PBT substances.

References

Bashir, M. (1998a). Ready biodegradability of 14C-RH-573: Modified Sturm Test . Covance Laboratories Inc., Madison, WI. Rohm and Haas Technical Report No. TR-97-076.

Bashir, M. (1998b). Ready biodegradability of 14C-RH-651: Modified Sturm Test . Covance Laboratories Inc., Madison, WI. Rohm and Haas Technical Report No. TR-97-15.

Dow Chemicals MSDS for ROCIMA GT

Dow Chemicals MSDS for ROCIMA 625

Dow Product Safety Assessment for DOW™ Methylisothiazoline (MIT) AntiMicrobial Products. DOW™ 5-Chloro-2-Methyl-2H-Isothiazol-3-one/2-Methyl-2H- Isothiazol-3-one (CMIT/MIT)-Based Antimicrobial Products (www.dow.com/productsafety/finder/)

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Environmental Assessment

C6-C10 Alcohol Ethoxylates

The alcohol ethoxylate (AE) family is defined for the HERA report purposes to be of the basic structure Cx-yAEn. The subscript following the 'C' indicates the range of carbon chain units. AEs with carbon unit range between C8 to C18 are most commonly used in household detergent products. Further, AEs contain an ethylene oxide (E) chain attached to the alcohol. The degree of ethylene oxide polymerization is indicated by a subscript which indicates the average number of ethylene oxide units. In household products the average ethylene oxide chain length commonly ranges between 3 and 12 units.

Biodegradation

AE homologues with hydrocarbon chain lengths ranging from 8 to 18 and with from 2 to more than 20 ethylene oxide units are readily biodegradable.

As a class, AE undergo rapid primary and ultimate biodegradation under both laboratory and field conditions. The biodegradability of the different AE homologues used in HERA applications is relatively unaffected by the alkyl carbon chain length and the number of EO units.

Proposed half-lives in river water at 12^{o}C: 4 to 24 hours (based on experimental data).

AE are also anaerobically biodegradable.

Bioaccumulation

The AE homologues used for domestic cleaning applications are very likely to have a log Kow value greater than 3.

Environment Canada and Health Canada (2006) has established that the degree of bioaccumulation expected from AE is well below the Canadian bioconcentration criterion of 5000. The sixteen measured BCF values for 15 AE homologues showed the lack of a linear relationship between alkyl or ethoxylate chain length and BCF, with the highest measured BCF value being under 800. Environment Canada (2006) concluded that it is evident that the AE metabolism rates prevent any significant accumulation. The data indicated that there may be an optimal structural combination of ethoxylate and alkyl chain lengths, at or around C14EO7, where BCF is maximized, but even the measured BCF for this chemical is well below the criterion of 5000. Thus Environment Canada (2006) concluded that ethoxylated aliphatic alcohols are not bioaccumulative.

Aquatic Toxicity

Acute aquatic effects data are presented in the HERA report to only establish that the essentially linear and branched AE used in household detergents are not more toxic than the linear AE which have the same uses. The toxicity mechanism for AE is accepted to be non-polar narcosis, in which the AE homologues with longer hydrocarbon chains and higher log K_{ow} are more efficient at penetration of the cell membrane, and thus more toxic. However, the AE homologues must be sufficiently soluble in water to allow a toxic concentration to reach the target organism. For the long chain alcohols, generally the least soluble and the most toxic of the AE homologues, the long chain alcohol OECD-Screening Information Assessment Report (SIAR) (SIAR, 2006) shows that the toxicity is restricted by solubility considerations at hydrocarbon chain lengths of 15 and above. Although the addition of ethylene oxide groups makes the other AE homologues more soluble, solubility considerations may reduce the toxicity of several higher hydrocarbon chain length and lower EO chain length AE. The available acute toxicity data follows this generally accepted pattern, and also indicates that the linear, essentially linear and branches AE are of similar toxicity.

Toxicity to Terrestrial Organisms

Acute soil toxicity measurements for both plants and soil invertebrates are available from standard tests carried out on commercial AE mixtures, which contain differing distributions of AE homologues. The available data are reviewed in the HERA report.

A range of chronic soil tests has been carried out for two pure AE homologues, C12EO4 and C16EO4. The two AE homologues chosen for the chronic tests span the hydrocarbon chain length range of high tonnage AE, and have an EO chain length value at which the toxicity is expected to be in the high range for each hydrocarbon chain length. The chronic tests, to assess the survival and reproduction of earthworms (*Eisenia fetida fetida)*, springtails (*Folsomia candida*), and nematodes (*Caenorhabditas elegans*), were carried out using a natural sandy loam soil, with an organic carbon content of 1.3%, which could be assumed to be free of pesticide. If an application factor of 10 were applied to the lowest chronic NOEC value to determine a PNEC, a PNEC of 22 mg/kg would result for C12EO4 and a PNEC of 46 mg/kg would result for the C16EO4 AE homologue. Comparison of the acute test data with the equilibrium partition soil PNEC values show very similar values. Thus, the chronic soil toxicity results for C12EO4 and C16EO4 support the validity of the PNEC values determined by equilibrium partitioning.

Information showing the relatively small difference between acute and chronic toxicity for soil organisms means that available single homologue acute data also supports the PNEC calculated by equilibrium partitioning from aquatic monitoring data. In addition, available data for AE mixtures is consistent with the equilibrium partitioning PNEC values.

Determination of $PNEC_{aquatic}$

The chronic *Daphnia magna* QSAR developed by Boeije *et al.* (2006) can be used, with an appropriate application factor, to determine the PNEC for each AE homologue. Of the three trophic level QSARs discussed here, the chronic *Daphnia magna* QSAR is the most robust. The algal QSAR work by Wind and Belanger (2006) has shown that AE toxicity to algae, daphnia, and fish are of similar magnitude, while the chronic AE toxicity data given indicates that *Daphnia magna* are among the most sensitive invertebrates.

The PNEC values determined for each AE homologue using both the chronic *Daphnia magna* QSAR with an application factor of 10 given in Table 4.38 of the HERA report. For the *Daphnia magna* QSAR, the application factor of 10 is used as three chronic QSARs are available for AE homologues. The *Daphnia magna* QSAR has been chosen as it is the most robust of these three chronic QSARs, and has the most sensitive endpoint over much of the range of AE homologues.

The composition of C6-C10 alcohol ethoxylates are unknown. It is possible that it is a mixture of linear and branched alcohol ethoxylates with varying EO chain lengths. Therefore, a mean PNEC for this CASRN was calculated as follows: for each hydrocarbon chain length number, the PNEC value AE with EO units 1 to 20 were average together, providing a mean value that covers the range of PNECs for that hydrocarbon chain length number. Each of these mean PNECs were then averaged together to cover the hydrocarbon chain lengths included in this CASRN. It should be noted that the HERA document does not cover hydrocarbon numbers less that C8 and therefore PNEC values were not calculated for the C6 and C7 alcohol ethoxylates. Without knowing the hydrocarbon distribution in the supplier product, it is unclear how the limited data will influence the overall PNEC value for this substance.

$PNEC_{aquatic}$: Chronic Daphnia magna QSAR and an Application Factor of 10

	C8 + C9 (mg/L)	**C10 (mg/L)**
Mean	3.54	1.71
Range	0.171 – 11.9	0.118 – 6.23

$PNEC_{aquatic}$ (freshwater) = (3.54 + 1.71)/2 = 2.63 mg/L

Determination of $PNEC_{sediment}$

The equilibrium partitioning method is used to predict the sediment PNEC from the aquatic PNEC, if no sediment data are available. A probabilistic QSAR has been developed for aquatic species based on chronic data (see HERA report). This QSAR contains aquatic test data for species which live in sediment, such as *Chironomus tentans* and *Corbicula fluminea*, and others which live near or in the top sediment surface such as *Hyallela azteca*, *Dugesia gonocephala*, *Chlorella vulgaris* and *Navicula pelliculosa.*

Comparison of the chronic *Daphnia magna* data (which was used to derive the aquatic PNEC) with that for the sediment dwelling organisms shows that *Daphnia magna* is of similar sensitivity to the sediment dwelling organisms. As the deterministic chronic *Daphnia magna* QSAR is quite robust, and for the purposes of consistency, it was decided that the aquatic PNEC derived from the chronic *Daphnia magna* QSAR be used with the equilibrium partitioning method to determine the PNEC sediment for all the AE homologues. A mean PNEC for this CASRN was calculated similar to the approach for $PNEC_{aquatic}$.

The HERA report used the TGD (2003) approach to calculate the PNEC sediment using the equilibrium partitioning method according to PNECsed = (Ksusp-water / Rhosusp) * PNEC water *1000.

$PNEC_{sediment}$ values determined by the equilibrium partitioning method, based on the deterministic method using the chronic *Daphnia magna* QSAR

	C8 + C9 (mg/kg)	**C10 (mg/kg)**
Mean	232	254
Range	2.76 - 1140	3.11 - 1250

$PNEC_{sediment}$ = (232 + 254)/2 = 243 mg/kg

Determination of $PNEC_{soil}$

The equilibrium partitioning calculation for $PNEC_{soil}$ has was carried out using the $PNEC_{aquatic}$ values determined by using the deterministic *Daphnia magna* QSAR with an application factor of 10. The results of this calculation are shown in Table 4.47 of the HERA report for each AE homologue. A mean PNEC for this CASRN was calculated similar to the approach for $PNEC_{aquatic}$.

$PNEC_{soil}$ values determined by the equilibrium partitioning method, based on the deterministic method using the chronic *Daphnia magna* QSAR

	C8 + C9 (mg/kg)	**C10 (mg/kg)**
Mean	89	187
Range	1.03 - 440	2.14 - 1012

$PNEC_{soil}$ = (89 + 187)/2 = 138 mg/kg

References

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Environmental Assessment

Crystalline Silica, Quartz
(CAS No. 14808-60-7)

Crystalline Silica, Cristobalite
(CAS No. 14464-46-1)

Silica is an off-white granule that occurs naturally in various crystalline and amorphous or other non-crystalline forms. Crystalline silica is characterized by silicon dioxide (SiO_2) molecules oriented in fixed, periodic patterns to form stable crystals. The primary crystalline form of silica is quartz. Other crystalline forms of silica include cristobalite, tripoli and tridymite.

Crystalline silica, quartz and crystalline silica, cristobalite are naturally occurring minerals that are insoluble in water.

They are persistent in the environment.

Crystalline silica, quartz, and crystalline silica, cristobalite as minerals, are not expected to bioaccumulate or be toxic to aquatic organisms because of their water insolubility and lack of bioavailability.

Crystalline silica, quartz and crystalline silica, cristobalite are not considered to be PBT substances.

Environmental Assessment

Diammonium peroxidisulfate
Ammonium persulfate
(CAS No. 7727-54-0)

Diammonium peroxisulfate or ammonium persulfate has been reviewed in the OECD-SIDS program (OECD, 2005a,b).

Environmental Fate

The inorganic persulfates are soluble in water (≥ 60 g/L) and their vapor pressures are negligible. Ammonium persulfate will be distributed into the water compartment in the ionic form of the ammonium cation and persulfate anion. Ammonium persulfate is expected to degrade in the environment mainly via hydrolysis, but metal catalyzed decomposition, and reactions with organic chemicals in the soil or water also are possible.

Persulfates are not expected to adsorb to soil due to its dissociation properties, instability (hydrolysis) and high water solubility. Persulfates should behave as free ions or decompose into sulfate ions. In soils, upon decomposition, the cation could form more stable sulfate or bisulfate salts.

Persulfates are not expected to bioaccumulate in the soil or in aqueous solution. They will decompose into inorganic sulfate or bisulfate.

Aquatic Toxicity

The 96-hour LC_{50} values for ammonium persulfate to fish are from 76 to 323 mg/L. The acute toxicity EC_{50} values for invertebrates are from 120 to 391 mg/L. The 72-hour EC_{50} values for ammonium persulfate to algae are 83.7 mg/L.

Toxicity to Terrestrial Organisms

No data were available.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (76 mg/L), Daphnia (120 mg/L), and algae (84 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 76 mg/L for fish. The $PNEC_{aquatic}$ is 0.076 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Diammonium peroxidisulfate dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc do not readily apply to inorganics, such as diammonium peroxidisulfate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of diammonium peroxidisulfate to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The environmental distribution of diammonium peroxidisulfate is dominated by its water solubility. Sorption of diammonium peroxidisulfate should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Kow and Koc parameters do not readily apply to inorganics, such as diammonium peroxidisulfate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, diammonium peroxidisulfate is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

References

OECD (2005a). IUCLID Data Set for Ammonium persulfate (CAS No. 7727-54-0); Potassium persulfate (CAS No. 7727- 27-1); Sodium persulfate (CAS No. 7775-27-1), UNEP Publications.

OECD (2005b). Screening Information Dataset (SIDS) Initial Assessment Report for Ammonium persulfate (CAS No. 7727-54-0); Potassium persulfate (CAS No. 7727- 27-1); Sodium persulfate (CAS No. 7775-27-1), UNEP Publications.

Environmental Assessment

Diatomaceous Earth
(CAS No. 61790-53-2)

Uncalcined diatomaceous earth (CAS No. 61790-53-2) typically contains around 1% crystalline silica. When diatomaceous earth is subjected to pressure or is processed ("calcined") at temperatures above 1000°C some of the amorphous silica is converted to crystalline silica in the form of cristobalite. Calcined diatomaceous earth can contain anywhere from 1% to 75% cristobalite.

Diatomaceous earth and crystalline silica are naturally occurring minerals that are insoluble in water.

The are persistent in the environment.

Diatomaceous earth and crystalline silica as minerals, are not expected to bioaccumulate or be toxic to aquatic organisms because of their water insolubility and lack of bioavailability.

Diatomaceous earth and crystalline silica, quartz are not considered to be PBT substances.

Environmental Assessment

Ethylene Glycol Monobutyl Ether
2-Butoxylethanol
(CASRN 111-76-2)

Ethylene Glycol Monobutyl ether (EGBE) or 2-butoxyethanol has been reviewed in the OECD-SIDS program (OECD, 2005; 2006).

Environmental Transport

The results from a fugacity model (MacKay level I) show that EGBE would be expected to partition almost entirely to water (99.2%), with a small fraction to soil (0.55%).

Biodegradation

EGBE is readily biodegradable. Degradation was 88% after 20 days (APHA test). In an OECD 302B test, degradation was 100% after 5 days. Degradation was 95% after 28 days in an OECD 301E test.

Bioaccumulation

EPIWIN-generated log BCF = 0.5.

Aquatic Toxicity

The lowest concentrations for each trophic level in short-term studies were as follows: 7-day LC_{50} in *Poecilia reticulata* is 983 mg/L; the 72-hour EC_{50} in *Hydra attenuata* is 540 mg/L; and the 72-hour EC_{50} in *Pseudokirchneriella subcapitata* is 911 mg/L.

Chronic studies have been conducted on fish, invertebrates, and algae. In a 21-day fish (*Brachydanio rerio*) study, the NOEC was >100 mg/L. In a 21-day Daphnia study, the NOEC was 100 mg/L. The 72-hr NOEC for *Pseudokirchneriella subcapitata* was 286 mg/L.

Toxicity to Terrestrial Organisms

No data are available.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (983 mg/L), invertebrates (540 mg/L), and algae (911 mg/L). Results from chronic studies are also available with NOECs for fish (>100 mg/L), Daphnia (100 mg/L), and algae (286 mg/L). On the basis of the long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported NOEC of 100 mg/L for Daphnia. The $PNEC_{aquatic}$ is 10 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$. The Koc was calculated using EPISUITE. Using a Koc of 2.823 and a $PNEC_{aquatic}$ of 10 mg/L, the $PNEC_{sediment}$ was calculated to be 6.7 mg/kg.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The equilibrium partition method was used to determine a $PNEC_{soil}$. The Koc was calculated using EPISUITE. Using a Koc of 2.823 and a $PNEC_{aquatic}$ of 10 mg/L, the $PNEC_{soil}$ was calculated to be 0.3755 mg/kg.

PBT Assessment

EGBE is readily biodegradable and thus it does not meet the screening criteria for persistence.

The estimated BCF for EGBE is 3.16 based on QSAR modeling. Thus, EGBE does not meet the screening criteria for bioaccumulation.

The chronic toxicity values for fish, invertebrates and algae are $\geq$100 mg/L. Thus, EGBE does not meet the criteria for toxicity.

The overall conclusion is that EGBE is not a PBT substance.

Reference

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Environmental Assessment

Ethanol
(CAS No. 64-17-5)

Ethanol has been reviewed in the OECD-SIDS program (OECD, 2004a,b).

Environmental Transport

Fugacity-based modelling data show that ethanol released into the environment will become distributed mainly into air and water (OECD, 2004a,b).

Biodegradation

In aerobic conditions using adapted wastewater from domestic sewage, degradation was 74% after 5 days rising to 95% by day 15 and in similar conditions in synthetic seawater, ethanol was 45% degraded after 5 days rising to 75% by day 20 (Price, 1974).

Using a MITI protocol study, there was degradation of 89% after 14 days (>70% after 10 days, CERI, 2004) and (>90% within 10 days, Birch, 1991). Activated domestic sludges were capable of aerobically oxidizing ethanol, as measured by BOD, which was 37.3% of maximum after 1 day (Gerhold, 1966).

The rate of biodegradation in anaerobic conditions was calculated to be 17.9 ppm ethanol per day with a total methane recovery of 91% of the theoretical limit (Suflita, 1993). Biodegradation is the main method of removal of ethanol from water. Ethanol is stable to hydrolysis. Reaction with hydroxyl radicals in aquatic media will not likely be a significant process (Anbar, 1969).

Bioaccumulation

The bioconcentration factor (BCF) was estimated to be 3.16 L/kg using BCFBAF v. 3.01 (US EPA, 2011).

Aquatic Toxicity

The aquatic toxicity data in fish, invertebrates, and algae indicate a low order of acute toxicity with LC_{50}/EC_{50} values >1,000 mg/L (OECD, 2004a,b). The most sensitive species were algae, with a 96-hr EC_{50} for *Chlorella vulgaris* of 1,000 mg/L (El Jay, 1996).

Chronic toxicity studies in a variety of freshwater invertebrates show LC_{50} values of

>100 mg/L (Cowgill and Milazzo,1991). The lowest reported NOEC was 9.6 mg/L for *Cerodaphnia sp*.

A 5-day study using *Skeletonema costatum* gave a NOEC ranging from 3,240 to 5,400 mg/L based on cell count, with corresponding EC_{50} values of 10,943 - 11,619 mg/L. The authors commented that ethanol was used as a carbon source stimulating growth of the alga before inhibition began (Cowgill, 1989).

Toxicity to Terrestrial Plants

The 7-d NOEC values of higher (vascular) plants *Lemna gibba* and *L. minor* were 280 and 778 mg/L, respectively. The EC_{50} values for both plants were 4,432 mg/L (Cowgill, 1991).

Toxicity to Terrestrial Organisms

In the only study of the effect of ethanol on soil dwelling organisms found, the oligochaete worm *Eisenia foetida* showed a 48- hr LC_{50} of 0.1-1.0 mg/cm^2 loading on a filter paper test. The 'dosage', presented in terms of concentration in a given area of substrate is difficult to interpret but would have equated to the worms being exposed to a theoretical vapor concentration in the range 200-2000 mg/L (Roberts, 1984).

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (>1,000 mg/L), Daphnia (>1,000 mg/L), and algae (1,000 mg/L). Results from chronic studies are also available for all three trophic levels, with the lowest NOEC being 9.6 mg/L for invertebrates. On the basis that the data consists of short-term and long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported long-term NOEC of 9.6 mg/L for invertebrates. The $PNEC_{aquatic}$ is 0.96 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$. The Koc was calculated using EPISUITE (MCI method). Using a Koc of 1.0 and a $PNEC_{aquatic}$ of 0.96 mg/L, the $PNEC_{sediment}$ was calculated to be 0.61 mg/kg.

$PNEC_{soil}$: No relevant experimental toxicity data on terrestrial organisms are available. The equilibrium partition method was used to determine a $PNEC_{soil}$. The Koc was calculated using EPISUITE (MCI method). Using a Koc of 1.0 and a $PNEC_{aquatic}$ of 0.96 mg/L, the $PNEC_{soil}$ was calculated to be 0.0128 mg/kg.

PBT Assessment

Ethanol is readily biodegradable and thus it does not meet the screening criteria for persistence.

Based on an experimental log Kow of -0.31 and a calculated BCF of 3.16, ethanol does not meet the screening criteria for bioaccumulation.

The chronic toxicity data on ethanol show NOECs of >0.01 mg/L. Thus, ethanol does not meet the screening criteria for toxicity.

The overall conclusion is that ethanol is not a PBT substance.

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Environmental Assessment

Guar Gum
(CAS No. 9000-30-0)

Guar gum (CAS No. 9000-30-0) is the milled endosperm of the leguminous plant *Cyanopsis tetragonolobus*. Structurally, it is a galactomannan (a polysaccharide) consisting of a main chain of D-mannose with a side chain of D-galactose at approximately every second mannose unit. The mannose units are β-(l-4) linked, and the single D-galactose units are joined to the main chain by α-(1-6) linkages. The estimated molecular weight of guar gum ranges from 200,000 to 300,000 daltons (Glickman, 1969).

Biodegradation

No information was found. Guar gum, being a polysaccharide composed of galactomannan, would be expected to be readily biodegradable.

Bioaccumulation

Not expected to bioaccumulate as a polysaccharide composed of galactomannans.

Aquatic Toxicity

The 48-hour LC_{50} for *Daphnia magna* was reported to be 42 mg/L (Biesinger *et al.*, 1976).

Toxicity to Terrestrial Organisms

No data were located.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for one trophic level. An acute LC_{50} value is available for the invertebrate Daphnia (42 mg/L). On the basis that the data consists of only one short-term result from one trophic level, an assessment factor of 1,000 has been applied to the reported effect concentration of 42 mg/L for Daphnia. The $PNEC_{aquatic}$ is 0.042 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The Kow and Koc of guar gum cannot be calculated using EPISUITE because the molecular weight of guar gum greatly exceeds the limit of 1,000. Thus, the equilibrium partition

method cannot be used to determine a $PNEC_{sediment}$ and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on soil organisms are available. The Kow and Koc of guar gum cannot be calculated using EPISUITE because the molecular weight of guar gum greatly exceeds the limit of 1,000. Thus, the equilibrium partition method cannot be used to determine a $PNEC_{soil}$ and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

No biodegradation was found on guar gum. However, guar gum is a naturally occurring polysaccharide which would be expected to readily biodegrade. Thus, it is not expected to meet the screening criteria for persistence.

The molecular weight of guar gum ranges from 200,000 to 300,000 daltons, and it is also water soluble. Thus, guar gum is not expected to meet the criteria for bioaccumulation.

The acute aquatic toxicity of guar gum is >0.1 mg/L. Thus, guar gum is not expected to meet the screening criteria for toxicity.

The overall conclusion is that guar gum is not a PBT substance.

References

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Environmental Assessment

Hydrochloric acid
(CAS No. 7647-01-0)

Hydrochloric acid has been reviewed in the OECD-SIDS program (OECD, 202a,b).

Environmental Fate and Transport

Hydrochloric acid is readily dissociated in water into hydrated protons and chloride ions.

The increase in the concentration of hydrochloric acid in water decreases the pH in the aquatic ecosystem. Generally, the buffer capacity to maintain the pH in the aquatic ecosystem is important and the equilibrium between CO_2, HCO_3^- and CO_3^{2-} in the aquatic ecosystem is mainly responsible for the buffer capacity of receiving water.

$CO_2 + H_2O \leftrightarrow HCO_3^- + H^+$ ($pKa_1 = 6.35$)

$HCO_3^- \leftrightarrow CO_3^{2-} + H^+$ ($pKa_2 = 10.33$)

According to UNEP (1995), the mean, the 10th-percentile and the 90th-percentile of bicarbonate concentrations for 77 rivers in North-America, South-America, Asia, Africa, Europe and Oceania were 106, 20 and 195 mg/L, respectively. The buffering capacity for neutralization of receiving water with bicarbonate concentrations of 20, 106 and 195 mg/L is calculated to be 2.19, 11.60 and 21.3 mg/L, respectively.

Aquatic Toxicity

Several studies on the acute toxicity to fish have been published. The lowest 96-hour LC_{50} was reported to be 4.92 mg/L for *Cyprinus carpio* at pH 4.3 which was conducted according to OECD 203 guidelines (MLIT, 1999). The 96-hour LC_{50} for *Oncorhynchus mykiss* was 7.45 mg/L at pH 4.12 for hard water and 10.3 mg/L at pH 3.98 for soft water (Graham and Wood, 1981). The 96-hour LC_{50} in *Lepomis macrochirus* is 55.1 to 30.9 mg/L at pH 3.25 - 3.5; the low pH caused a reduction in the oxygen carrying capacity of hemoglobin and excessive secretion of mucus from the gills which in turn interfered with gas exchange (Ellgaard and Glimore, 1984).

Generally, the results of toxicity tests with acid or base depend on the buffer capacity of the test medium. Dechlorinated tap water was used as a test medium in the three tests described above. A 96-hour LC_{50} of 30.9 to 24.6 at pH 3.5-3.6 was obtained for *Lepomis macrochirus* using artificial water prepared from distilled water and analytical or reagent grade chemicals (Cairns and Scheier, 1959); other reported values are a 96-hour LC_{50} of 282 mg/L for *Gambusia affinis* (Wallen *et al.*, 1957) and a 16-hour LC_{100} value of 0.492 mg/L at pH 5.3 for the pike perch fry (*Lucioperca lucioperca*) conducted with pond water

(pH 6.0-8.2) are reported (Stangenberg, 1975). A 24-hr LC_{50} value of 60-80 mg/L for *Semotitus astromaculatus* with river water (pH 8.3) has also been reported. No long-term or chronic toxicity data on fish were located (Gillette *et al.*, 1952).

The 48-hour EC_{50} for *Daphnia magna* is 0.492 mg/L at pH 5.3 based on immobilization (MLIT, 1999). No long-term or chronic toxicity data on invertebrates have been reported. The 72-hour EC_{50} to *Selenastrum capriornutum* is 0.78 mg/L (pH 5.1) for biomass; 0.492 mg/L (pH 5.3) for growth rate; and the 72-hr-NOEC is 0.097 mg/L (pH 6.0) for biomass and growth rate (MLIT, 1999).

The hazard of hydrochloric acid for the environment is caused by the proton (pH effect). For this reason the effect of hydrochloric acid on the organisms depends on the buffer capacity of the aquatic ecosystem. Also, the variation in acute toxicity for aquatic organisms can be explained to a significant extent by the variation in buffer capacity of the test medium. For example, LC_{50} values of acute fish toxicity tests varied from 4.92 to 282 mg/L.

It is not considered useful to calculate a PNEC for hydrochloric acid because factors such as the buffer capacity, the natural pH, and the fluctuation of the pH are very specific for a certain ecosystem.

Toxicity to Terrestrial Organisms

No data are available.

Determination of PNECS

$PNEC_{aquatic}$: Based on the information above, a $PNEC_{aquatic}$ was not derived for hydrochloric acid.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Kow and Koc parameters do not readily apply to inorganics, such as hydrochloric acid. Thus;, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of hydrochloric acid to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. Sorption of hydrochloric acid should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Koc and Kow parameters do not readily apply to inorganics, such as hydrochloric acid. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, hydrochloric acid is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Hydrochloric acid is an organic salt that dissociates completely to hydrogen and chloride ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both hydrogen and chloride ions are also ubiquitous and are present in most water, soil and sediment. Thus, the persistent criteria is not considered applicable to this inorganic salt.

Hydrogen and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, hydrochloric acid is not expected to bioaccumulate.

No chronic toxicity data exist on hydrochloric acid; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, hydrochloric acid does not meet the screening criteria for toxicity.

The overall conclusion is that hydrochloric acid is not a PBT substance.

References

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Environmental Assessment

2-Propanol or Isopropanol
(CAS No. 67-63-0)

2-Propanol or isopropanol has been reviewed in the OECD-SIDS program (OECD, 1997a,b).

Environmental Fate and Transport

Based on calculated results from a Level I fugacity model, isopropanol is expected to partition primarily to the aquatic compartment (77.7%) with the remainder to the air (22.3%) (OECD, 1977a,b).

Biodegradation

Aerobic biodegradation of isopropanol has been shown to occur rapidly under non-acclimated conditions, based on a result of 49% biodegradation from a 5-day BOD test (Bridie *et al.*, 1979). Additional biodegradation data developed using standardized test methods show that isopropanol is readily biodegradable in both freshwater and saltwater media (72 to 78% biodegradation in 20 days) (Price *et al.*, 1974).

Bioaccumulation

Bioconcentration of isopropanol in aquatic organisms is not expected to occur based on a measured log n-octanol/water partition coefficient (log Kow) of 0.05, a calculated bioconcentration factor of 1 for a freshwater fish, and the unlikelihood of constant, long-term exposures (OECD 1977a,b).

Aquatic Toxicity

The 96-hour LC_{50} in *Pimephales promelas* is 9,640 mg/L (Veith *et al.*, 1983). The 24-hour EC_{50} in *Daphnia magna* is >10,000 mg/L (Brinkmann and Kuehn, 1977). Chronic aquatic toxicity has also been shown to be of low concern, based on 16- and 21-day NOEC values of 141 and 30 mg/L, respectively, for the freshwater invertebrate *Daphnia magna* (Hermens *et al.*, 1985); OECD, 1977a,b). Toxicity of isopropanol to plants is expected to be low, based on a 7-day toxicity threshold value of 1,800 mg/L for a freshwater algae (Bringmann and Kuehn, 1980).

Toxicity to Terrestrial Plants

Toxicity of isopropanol to plants is expected to be low, based on an EC_{50} value of 2,100 mg/L from a lettuce seed germination test (Reynolds, 1977).

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (9,640 mg/L) and invertebrates (>10,000 mg/L). Results from chronic studies are available for invertebrates (16- and 21-day NOECs for Daphnia are 141 and 30 mg/L, respectively). On the basis that the data consists of a chronic study on one trophic level, an assessment factor of 100 has been applied to the lowest reported NOEC of 30 mg/L for Daphnia. The $PNEC_{aquatic}$ is 0.3 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$. The Koc was calculated using EPISUITE. Using a Koc of 1.53 and a $PNEC_{aquatic}$ of 0.3 mg/L, the $PNEC_{sediment}$ was calculated to be 0.19 mg/kg.

$PNEC_{soil}$: Insufficient experimental toxicity data on terrestrial organisms are available. The equilibrium partition method was used to determine a $PNEC_{soil}$. The Koc was calculated using EPISUITE. Using a Koc of 1.53 and a $PNEC_{aquatic}$ of 0.3 mg/L, the $PNEC_{soil}$ was calculated to be 0.0061 mg/kg.

PBT Assessment

Isopropanol is readily biodegradable and thus it does not meet the screening criteria for persistence.

Based on a measured log Kow of 0.05 and a calculated BCF of 1, isopropanol does not meet the screening criteria for bioaccumulation.

The chronic toxicity data on isopropanol show NOECs of >0.01 mg/L. Thus, isopropanol does not meet the screening criteria for toxicity.

The overall conclusion is that isopropanol is not a PBT substance.

References

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Environmental Assessment

Magnesium chloride
(CAS No. 7786-30-3)

Environmental Fate

Magnesium chloride dissociates completely in water to the Mg^{++} cation and the chloride anion (Cl^-).

Aquatic Toxicity

The 96-hour LC_{50} of magnesium chloride to *Pimephales promelas* is 541 mg of Mg/L (or 2,119.3 mg of $MgCl_2$/L).

The 48-hour LC_{50} for *Daphnia magna* is 140 mg Mg/L (or 548.4 mg of $MgCl_2$/L). In another study, the 48-hour LC_{50} to *Daphnia magna* and *Ceriodaphnia dubia* were 339 mg of Mg/L and 225 mg of Mg/L, respectively (or 1328 and 881.4 mg of $MgCl_2$/L, respectively).

The 72-hour EC_{50} of magnesium chloride for algae *Scenedesmus subspicatus* is >100 mg/L and the NOEC is 100 mg/L.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (2,119 mg/L as $MgCl_2$), Daphnia (548 mg/L as $MgCl_2$), and algae (100 mg/L $MgCl_2$). Even though a NOEC was obtained from the algae study, there were no chronic studies conducted on fish or Daphnia. On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 100 mg/L for algae. The $PNEC_{aquatic}$ was calculated to be 0.1 mg/L. The $PNEC_{aquatic}$ is 0.1 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Magnesium chloride dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc parameters do not readily apply to inorganics, such as magnesium chloride. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of magnesium chloride to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The environmental distribution of magnesium chloride is dominated by its water solubility.

Sorption of magnesium chloride should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Koc and Kow parameters do not readily apply to inorganics, such as magnesium chloride. Thus, the equilibrium partitioning methods cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, magnesium chloride is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Magnesium chloride is an organic salt that dissociates completely to magnesium and chloride ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both magnesium and chloride ions are also ubiquitous and are present in most water, soil and sediment. Thus, the persistent criteria is not considered applicable to this inorganic salt.

Magnesium and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, magnesium chloride is not expected to bioaccumulate.

No chronic toxicity data exist on magnesium chloride; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, maganesium chloride does not meet the screening criteria for toxicity.

The overall conclusion is that magnesium chloride is not a PBT substance.

Reference

ECHA REACH database: http://apps.echa.europa.eu/registered/registered-sub.aspx

Environmental Assessment

Magnesium nitrate (CAS No. 10377-60-3)

Environmental Fate

Magnesium nitrate dissociates completely in water to Mg^{++} and the nitrate anion (NO_3^-).

Determination of PNECs

$PNEC_{aquatic}$: The ANZECC water quality guideline (2000) uses acute and chronic laboratory toxicity data for the derivation of "trigger values" for nitrate. The guideline summary for freshwaters is: *"A freshwater moderate reliability trigger value for nitrate toxicity as NO_3 (nitrate) of 700 µg/L was calculated using the statistical distribution method 95% protection and the default ACR."*

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Magnesium nitrate dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc parameters do not readily apply to inorganics, such as magnesium nitrate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of magnesium nitrate to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The environmental distribution of magnesium nitrate is dominated by its water solubility. Sorption of magnesium nitrate should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Koc and Kow parameters do not readily apply to inorganics, such as magnesium nitrate. Thus, the equilibrium partitioning methods cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, magnesium nitrate is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Magnesium nitrate is an organic salt that dissociates completely to magnesium and nitrate ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both magnesium and nitrate ions are also ubiquitous and are present in most water, soil and sediment. Thus, the persistent criteria is not considered applicable to this inorganic salt.

Magnesium ions are essential to all living organisms and its intracellular and extracellular concentrations are actively regulated. Nitrates are ions that are very soluble in aqueous solutions. Thus, magnesium nitrate is not expected to bioaccumulate.

No chronic toxicity data exist on magnesium nitrate; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, maganesium nitrate does not meet the screening criteria for toxicity.

The overall conclusion is that magnesium nitrate is not a PBT substance.

Reference

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Environmental Assessment

Polyethylene Glycol
(CAS No. 25322-68-3)

Polyethylene glycols (PEGs) are water-soluble linear polymers formed by the addition reaction of ethylene oxide to an ethylene glycol equivalent. The general formula for polyethylene glycol is: $H-(OCH_2CH_2)_n-OH$ where "n" is the average number of repeating oxyethylene groups. PEGs are available in average molecular weights ranging from 200 to 8000.

No information on the aquatic toxicity and environmental fate and transport could be located for the PEGs. There are, however, data available on tetraEG and pentaEG, both being major constituents of the low molecular weight PEG 200. PEG 200 is a mixture consisting of ethylene glycols with an average molecular weight of approximately 200; there is an average of 4 oxyethylene units, but the range is from 2 to 8 oxyethylene units. The approximate composition of PEG 200 is as follows: 3% diethylene glycol (DEG), 17% triethylene glycol (TEG), 29% tetraEG, 25% pentaEG, 16% hexaEG, 8% heptaEG, and 2% octaEG (Bailey and Koleske, 1966).

Environmental Fate and Transport

PEG is a water-soluble polymer with molecular weights ranging from 200 to 8,000. PEG 200 consists of approximately 29% tetraEG and 25% pentaEG. A Mackay III fugacity model predicts that tetraEG and pentaEG will essentially distribute to water (45.3%) to soil (54.6%) (OECD, 2004).

Biodegradation

Both tetraEG and pentaEG are inherently biodegradable. For tetraEG, there was 22% degradation after 20 days in a BOD test and 40% degradation after 28 days in an OECD 301D test (Waggy *et al.*, 1994). For pentaEG, there was 34% degradation after 20 days in a BOD test (OECD, 2004).

Bioaccumulation

The log K_{ow} values for the PEG polymers were not found. Log K_{ow} and BCF values were estimated for tetraEG and pentaEG, the major constituents of the low molecular weight PEG 200. The log K_{ow} values for tetraEG and pentaEG were estimated to be -2.0 and -2.3, respectively, using EPISUITE v.4.11. The BCF values were estimated to be 3.16 for both tetraEG and pentaEG.

Aquatic Toxicity

No aquatic toxicity data were found on the PEG polymers. However, data are available on tetraEG and pentaEG.

For tetraEG, the acute 96-hour LC_{50} to fathead minnows (*Pimephales promelas*) is >10,000 mg/L (OECD, 2004), and the acute 48-hour LC_{50} to *Daphnia magna* is 7,746 mg/L (OECD, 2004).

For pentaEG, the acute 96-hour LC_{50} to fathead minnows (*Pimephales promelas*) is >50,000 mg/L (OECD, 2004); the acute 48-hour LC_{50} to *Daphnia magna* is >20,000 mg/L (OECD, 2004); and the 72-hour EC_{50} to algae *Pseudokirchneriella subcapitata* is >100 mg/L; the NOEC is 100 mg/L (OECD, 2004).

A 7-day LC_{50} for triethylene glycol in guppies was reported to be 63,000 mg/L (Könemann, 1981).

Toxicity to Terrestrial Organisms

No data were located on either PEG 200 or on the higher ethylene glycols, such as tetraEG and pentaEG.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels for PEG 200 constituents tetraEG and pentaEG. Acute $E(L)C_{50}$ values are available for fish (>10,000 mg/L), Daphnia (7,746 mg/L), and algae (>100 mg/L). Chronic toxicity data on pentaEG are available for algae (NOEC = 100 mg/L); and a chronic fish toxicity study has been conducted on triethylene glycol (NOEC = 63,000 mg/L), which is also found in PEG 200 but at lower concentrations than either tetraEG or pentaEG. On the basis that the data consists of short-term results from three trophic levels and long-term results from two trophic levels, an assessment factor of 50 has been applied to the lowest reported short-term EC_{50} of 100 mg/L for algae. The $PNEC_{aquatic}$ was calculated to be 2.0 mg/L.

PBT Assessment

No biodegradation data could be found on the PEG polymers. PEG is a water-soluble polymer, with molecular weights ranging from 200 to 8,000. The high molecular weight PEGs would be expected to meet the screening criteria for persistence. TetraEG and pentaEG are major constituents of the low molecular weight PEG 200. Biowin 2 predicts that both tetraEG and pentaEG will not biodegrade fast and Biowin 3 predicts the ultimate biodegradation timeframe is in weeks. Thus, the low molecular weight PEGs do not meet the screening criteria for persistence.

No information on log K_{ow} or BCF could be found on the PEG polymers. The molecular weights of PEGs range from 200 to 8,000. The high molecular weight PEGs would not be expected to bioaccumulate due to limitations in bioavailability because of the size of the polymer. TetraEG and pentaEG are major constituents of the low molecular weight PEG 200. The log K_{ow} values for tetraEG and penta were estimated to be -2.0 and -2.3, respectively; the BCF values were estimated to be 3.16 for both tetraEG and pentaEG. Thus, the low molecular weight PEGs are also not expected to meet the criteria for bioaccumulation.

No aquatic toxicity data could be located for the PEG polymers. The molecular weights of PEGs range from 200 to 8,000. The high molecular PEGs are not expected to meet the screening criteria of toxicity because the molecular size would limit bioavailability. TetraEG and pentaEG are major constituents of the low molecular weight PEG 200. There are no chronic aquatic toxicity on tetraEG or pentaEG; however, the acute aquatic toxicity is >0.1 mg/L. Thus, the low molecular weight PEGs are also not expected to meet the screening criteria for toxicity.

The overall conclusion is that the polyethylene glycol polymers are not PBT substances.

References

Bailey, F.E., Jr., and Koleske, J.V. (1966). Chapter 23. Configuration and hydrodynamic properties of the polyoxyethylene chain in solution. In: Nonionic Surfactants. Edited by M.J. Schick, Marcel Dekker, Inc., New York.

Könemann, H. (1981). Quantitative structure-activity relationships in fish toxicity studies. Part 1: relationship for 50 industrial pollutants. Toxicology 19: 209-221.

OECD (2004). SIDS Initial Assessment Report on the Ethylene Glycol Category: Ethylene Glycol (CAS No. 107-21-1), Diethylene Glycol (CAS No. 111-46-6), Triethylene Glycol (CAS No. 112-27-6), Tetraethylene Glycol (CAS No. 112-60-7), Pentaethylene glycol (CAS No. 4792-15-8).

Waggy, G.T., Conway, R.A., Hansen, J.L., and Blessing, R.L. (1994). Comparison of 20-d BOD and OECD closed-bottle biodegradation tests. Environ. Toxicol. Chem. 13: 1277-1280.

Environmental Assessment

Benzenesulfonic acid, 4-ethyenyl-, sodium salt, homopolymer (CAS No. 25704-18-1)

Acetic acid ethenyl ester, polymer with ethanol (CAS No. 25213-24-5)

Vinylidene chloride/methacrylate copolymer (CAS No. 25038-72-6)

Polyvinyl acetate, partially hydrolyzed (CAS No. 30443-60-5) THIS IS NOT THE CORRECT CASRN

All of these substances are polymers. Aquatic toxicity data was located for only for acetic acid, ethenyl ester, polymer with ethanol (CAS No. 25213-24-5) on a supplier's MSDS. However, all of the polymers listed above are expected to exhibit similar environmental fate and aquatic toxicity (Boethling and Nabholz, 1997).

Biodegradation

Generally, polymers are considered to be essentially non-biodegradable.

Bioaccumulation

Polymers are not generally absorbed through biological membranes to bioaccumulate in tissues.

Aquatic Toxicity

These polymers are not very insoluble in water and are expected to be essentially non-toxic to aquatic organisms.

The MSDS for DuPont's product ELVANOL 60-30, a polyvinyl alcohol with CAS No. 25213-24-5 (>93%) reported that concentrations of "ELVANOL" up to 10,000 mg of liter of water showed no mortality or other effect when tested on bluegill sunfish.

Determination of PNECs

$PNEC_{aquatic}$: Not determined.

PBT Assessment

These polymers are not expected to biodegrade and thus meets the criteria for persistence.

Polymers are not generally absorbed through biological membranes to bioaccumulate in tissues. Thus, these polymers do not meet the criteria for bioaccumulation.

The acute aquatic toxicity to fish (LC_{50} of >10,000 mg/L) for CASRN 25213-24-5 indicates that these polymers do not meet the criteria for toxicity.

Thus, these polymers are not considered to be PBT substances.

References

Boethling, R.S. and Nabholz, J.V. (1997). Environmental Assessment of Polymers under the U.S. Toxic Substances Control Act. In: Ecological Assessment of Polymers Strategies for Product Stewardship and Regulatory Programs (Hamilton, J.D. and Sutcliffe, R. eds.), pp. 187-234, Van Nostrand Reinhold.

DuPont (2006) MSDS for “ELVANOL” 60-30, revised 27-Oct-2006.

Environmental Assessment

Sodium carbonate
(CAS No. 497-19-8)

Sodium carbonate has been reviewed in the OECD-SIDS program (OECD, 2002a,b).

Sodium carbonate is a strong alkaline compound with a pH of 11.6 for a 0.1M aqueous solution (The Merck Index, 1983; Johnson and Swanson, 1987). The pKa of CO_3^{2-} is 10.33, which means that at a pH of 10.33 both carbonate and bicarbonate are present in equal amounts.

Environmental Fate

The high water solubility and low vapor pressure indicate that sodium carbonate will be found predominantly in the aquatic environment. In water, sodium carbonate dissociates into sodium (Na^+) and carbonate (CO_3^{2-}) and both ions will not adsorb on particulate matter or surfaces and will not accumulate in living tissues. Addition of potassium carbonate to water will result in an increase in alkalinity and a tendency to raise the pH value. The carbonate ions will react with water, resulting in the formation of bicarbonate (HCO_3^-) and hydroxide (OH^-), until an equilibrium is established.

Background concentration of carbonate
If carbonate (CO_3^{2-}) is dissolved in water a re-equilibration takes place according to the following equations:

$HCO_3^- \rightleftharpoons CO_3^{2-} + H^+$ pKa=10.33
$CO_2 + H_2O \rightleftharpoons HCO_3^- + H^+$ pKa = 6.35

Only a small fraction of the dissolved CO_2 is present as H_2CO_3, the major part is present as CO_2. The amount of CO_2 in water is in equilibrium with the partial pressure of CO_2 in the atmosphere. The CO_2/ HCO_3^-/ CO_3^{2-} equilibria are the major buffer of the pH of freshwater and seawater throughout the world.

Based on the above equations, CO_2 is the predominant species at a pH smaller than 6.35, while HCO_3^- is the predominant species at a pH in the range of 6.35-10.33 and CO_3^{2-} is the predominant species at a pH higher than 10.33.

The natural concentration of CO_2/ HCO_3^-/ CO_3^{2-} in freshwater is influenced by geochemical and biological processes. Many minerals are deposited as salts of the carbonate ion and for this reason the dissolution of these minerals is a continuous source of carbonate in freshwater. Carbon dioxide is produced in aquatic ecosystems from microbial decay of organic matter. On the other hand plants utilize dissolved carbon dioxide for the synthesis of biomass (photosynthesis). Because many factors influence the

natural concentration of CO_2/ HCO_3^-/ CO_3^{2-} in freshwater, significant variations of the concentrations do occur.

If the pH is between 7 and 9 then the bicarbonate ion is the most important species responsible for the buffer capacity of aquatic ecosystems. UNEP (1995) reported the bicarbonate concentration for a total number of 77 rivers in North-America, South-America, Asia, Africa, Europe and Oceania. The 10th – percentile, mean and 90th-percentile were 20, 106 and 195 mg/L, respectively.

Aquatic Toxicity

The acute 96-hour LC_{50} to three sizes of Bluegill sunfish (*Lepomis macrochirus*) exposed to sodium carbonate is 300 mg/L for all sizes. The acute 96-hour LC_{50} to mosquitofish (*Gambusia affinis*) is 740 mg/L. The acute 48-hour EC_{50} value to the invertebrate *Ceriodaphnia* cf. *dubia* is from 200 to 227 mg/L.

Toxicity to Terrestrial Organisms

Toxicity tests which determined the effect of sodium carbonate on terrestrial organisms are not available. The results of the tests will depend strongly on the buffer capacity of the soil and can probably be predicted based on the buffer capacity of the soil. Furthermore, carbonates are natural components of soil minerals.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for two trophic levels. Acute $E(L)C_{50}$ values are available for fish (300 mg/L) and *Ceriodaphnia* (200 mg/L). On the basis that the data consists of short-term results from two trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 200 mg/L for Daphnia. The $PNEC_{aquatic}$ is 0.2 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Sodium carbonate dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc parameters do not readily apply to inorganics, such as sodium carbonate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of sodium carbonate to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The environmental distribution of sodium carbonate is dominated by its water solubility. Sorption of sodium carbonate should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Koc and Kow parameters do not

readily apply to inorganics, such as sodium carbonate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, sodium carbonate is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

References

OECD (2002a). IUCLID Data Set for Sodium carbonate (CAS No. 497-19-8), UNEP Publications (http://www.chem.unep.ch/irptc/sids/OECDSIDS/Naco.pdf)

OECD (2002b)b Screening Information Dataset (SIDS) Initial Assessment Report for Sodium carbonate (CAS No. 497-19-8), UNEP Publications (http://www.chem.unep.ch/irptc/sids/OECDSIDS/Naco.pdf)

UNEP (1995). Water quality of world river basins, UNEP Environment Library No.14.

Environmental Assessment

Sodium hydroxide
(CAS No. 1310-73-2)

Sodium hydroxide (NaOH) has been reviewed in the OECD-SIDS program (OECD, 2002a,b).

Environmental Fate

The high water solubility and low vapor pressure indicate that sodium hydroxide (NaOH) will be found predominantly in the aquatic environment. NaOH is present in the environment as sodium (Na^+) and hydroxyl (OH^-) ions, which implies that it will not adsorb on particulate matter or surfaces and will not accumulate in living tissues.

Measured concentrations in aquatic ecosystems
The concentration of hydroxyl ions in the environment has been determined very extensively via pH measurements. The pH is a very important parameter of aquatic ecosystems and it is a standard parameter of water quality monitoring programs. The most important freshwater aquatic ecosystems of the world revealed average annual pH values between 6.5 and 8.3 but lower and higher values have been measured in other aquatic ecosystems (UNEP, 1995). In aquatic ecosystems with dissolved organic acids a pH of less than 4.0 has been measured, while in waters with a high chlorophyll content the bicarbonate assimilation can result in pH values of higher than 9.0 at midday (UNEP, 1995). The pH of an aquatic ecosystem is mainly determined by geochemical, hydrological and/or biological processes.

Also sodium has been measured extensively in aquatic ecosystems. For example UNEP (1995) reported the concentration for a total number of 75 rivers in North-America, South-America, Asia, Africa, Europe and Oceania. The 10th –percentile, mean and 90th-percentile were 1.5, 28 and 68 mg/l, respectively.

NaOH addition and buffer capacity
An addition of NaOH to an aquatic ecosystem may increase the pH depending on the buffer capacity of the receiving water. In general the buffer capacity is regulated by the equilibria between CO_2, HCO_3^- and CO_3^{2-}:

$CO_2 + H_2O \leftrightarrow HCO_3^- + H^+$ ($pKa_1 = 6.35$)
$HCO_3^- \leftrightarrow CO_3^{2-} + H^+$ ($pKa_2 = 10.33$)

If the pH is between 7 and 9 then the bicarbonate ion is the most important species responsible for the buffer capacity of aquatic ecosystems. UNEP (1995) reported the bicarbonate concentration for a total number of 77 rivers in North-America, South-America, Asia, Africa, Europe and Oceania. The 10th– percentile, mean and 90th-percentile were 20, 106 and 195 mg/l, respectively.

Aquatic Toxicity

At concentrations reported in publications and study reports, the toxicity has been assumed to be due to hydroxide only, because at these effect concentrations the concentration of sodium is too low to explain the effects. However, it should be realized that the results of toxicity tests with NaOH depend on the buffer capacity of the test medium. In a highly buffered test medium the hydroxyl ion will be neutralized and the observed toxicity will be low, while in a poorly buffered test medium the pH will increase rapidly and therefore the observed toxicity will be relatively high. Besides the direct effects (pH change) NaOH could also have indirect effects. The pH change could influence the speciation of other chemicals and therefore increase and/or decrease the toxicity *e.g.*, NH_3 is more toxic than NH_4^+.

The 24-hour LC_{50} to *Carassius auratus* (goldfish) is 160 mg/L . At 100 mg/L, which was equivalent to a pH of 9.8, no mortality was observed. The 48-hour LC_{50} to *Leuciscus idus melanotus*, is 189 mg/L. The 96-hour LC_{50} of *Gambusia affinis* (mosquitofish) is 125 mg/L. At 84 mg/L, no effects on the fish were observed. The pH was 9 at 100 mg/L. The 48-hour LC_{50} is 40 mg/L for *Ceriodaphnia* cf. *dubia*. The toxicity threshold concentration of NaOH for *Daphnia magna* was reported to range from 40 to 240 mg/L.

No data are available on the effects of NaOH on algae.

Toxicity to Terrestrial Organisms

Toxicity tests, which determined the effects of NaOH on terrestrial organisms, are not available. Significant exposure of the terrestrial environment is not expected and for this reason there is no need to perform toxicity test with terrestrial organisms. The results of terrestrial toxicity tests will depend strongly on the buffer capacity of the soil and can probably be predicted based on the buffer capacity of the soil.

Determination of PNECs

In many cases pH, buffer capacity and/or medium composition were not discussed in the publications, although this is essential information for toxicity tests with NaOH. This is the most important reason why most of the studies, mentioned above were considered invalid. Although valid acute ecotoxicity tests and chronic ecotoxicity tests with NaOH are not available there is no need for additional testing with NaOH. A significant number of acute toxicity tests are available and the results of the tests are more or less consistent. Altogether they give a sufficient indication about acute toxicity levels of sodium hydroxide.

Furthermore acute toxicity data cannot be used to derive a PNEC or a PNEC added for sodium hydroxide. Aquatic ecosystems are characterized by an alkalinity/pH and the organisms of the ecosystem are adapted to these specific natural conditions. Based on the natural alkalinity of waters, organisms will have different optimum pH conditions, ranging from poorly buffered waters with a pH of 6 or less to very hard waters with pH values up to 9. A lot of information is available about the relationship between pH and ecosystem structure and also natural variations in pH of aquatic ecosystems have been quantified and reported extensively in ecological publications and handbooks.

Normally a PNEC or a PNEC added has to be derived from the available ecotoxicity data. A PNEC added is a PNEC which is based on added concentrations of a chemical (added risk approach). Based on the available data it is not considered useful to derive a PNEC or a PNEC added for NaOH because:

- The natural pH of aquatic ecosystems can vary significantly between aquatic ecosystems,

- Also the sensitivity of the aquatic ecosystems to a change of the pH can vary significantly between aquatic ecosystems and

- The change in pH due to an anthropogenic NaOH addition is influenced significantly by the buffer capacity of the receiving water.

Although a PNEC or a PNEC added was not calculated for NaOH there is a need to assess the environmental effect of an NaOH (alkaline) discharge. Based on the pH and buffer capacity of effluent and receiving water and the dilution factor of the effluent, the pH of the receiving water after the discharge can be calculated. Of course the pH change can be measured also very easily via a laboratory experiment or by conducting field measurements. The change in pH should be compared with the natural variation in pH of the receiving water and based on this comparison it should be assessed if the pH change is acceptable.

$PNEC_{aquatic}$: Based on the information above, a PNEC was not derived for sodium hydroxide.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Sodium hydroxide dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc parameters do not readily apply to inorganics, such as sodium hydroxide. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of sodium hydroxide to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The environmental distribution of sodium hydroxide is dominated by its water solubility.

Sorption of sodium hydroxide should probably be regarded as a reversible situation, i.e., the substance is not tightly nor permanently bound. Koc and Kow parameters do not readily apply to inorganics, such as sodium hydroxide Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, sodium hydroxide is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Sodium hydroxide is an organic salt that dissociates completely to sodium and hydroxide ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both sodium and hydroxide ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria is not considered applicable to this inorganic salt.

Sodium and hydroxide ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, sodium hydroxide is not expected to bioaccumulate.

No chronic toxicity data exist on sodium hydroxide; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, sodium hydroxide does not meet the screening criteria for toxicity.

The overall conclusion is that sodium hydroxide is not a PBT substance.

References

OECD (2002a). IUCLID Data Set for Sodium hydroxide (CAS No. 1310-73-2), UNEP Publications.

OECD (2002b). Screening Information Dataset (SIDS) Initial Assessment Report for Sodium hydroxide (CAS No. 1310-73-2), UNEP Publications.

Environmental Assessment

Talc
(CAS No. 61789-40-0)

Talc is a mineral composed of hydrated magnesium silicate with the chemical formula $Mg_3Si4O_{10}(OH)_2$ or $H_2Mg_3(SiO_3)_4$. Talc is not soluble in water.

Biodegradation

As a mineral, talc does not biodegrade.

Aquatic Toxicity

No data were found. As an insoluble mineral, talc is not expected to be bioavailable; therefore, it is not expected to toxic to aquatic organisms.

Toxicity to Sediment Organisms

No data were found. As an insoluble mineral, talc is not expected to be bioavailable; therefore, it is not expected to toxic to sediment organisms.

Toxicity to Terrestrial Organisms

No data were found.

Determination of PNECs

PNEC values for talc cannot be calculated.

PBT Assessment

Talc is an inorganic mineral that is insoluble in water. Talc is not expected to be bioavailable to aquatic organisms; thus, it is does not meet the criteria for bioaccumulation or toxicity. Talc does not biodegrade in the environment. It is a naturally-occurring mineral and is persistent in the environment. However, for the purposes of this PBT assessment, it does not meet the criteria for persistence.

Environmental Assessment

Tetramethylammonium chloride
(CAS No. 75-57-0)

Environmental Fate

No measured data could be located on tetramethylammonium chloride.

The following information was obtained from EPISUITE v. 4.11 for this assessment (U.S. EPA, 2012). The water solubility was calculated to be 1 x 10^6 mg/L at 25^{o}C, and the octanol-water partition coefficient (log K_{ow}) was estimated to be -4.1817. A Mackay Level III model predicts that tetramethylammonim chloride will distribute 68.4% to soil, 31.6% to water, and 0.07% to sediment. Tetramethylammonium chloride is expected to biodegrade fast based on the Biowin 2 model and with an ultimate biodegradation timeframe of weeks based on the Biowin 3 model.

Bioaccumulation

No measured data could be located on tetramethylammonium chloride. The BCF was calculated to be 3.162, indicating a low bioaccumulation potential.

Aquatic Toxicity

A 96-hour LC_{50} for tetramethylammonium chloride xxxxxin fathead minnows has been reported to be 462 mg/L (ECOTOX).

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for one trophic level. The acute 96-hour LC_{50} value for fish is 462 mg/L. Using an assessment factor of 1,000, the $PNEC_{aquatic}$ is 0.5 mg/L.

References

ECOTOX. United States Environmental Protection Agency ECOTOX database, http://cfpub.epa.gov/ecotox/ecotox_home.cfm

U.S. EPA (2012). EPISuite v. 4.11, United States Environmental Protection Agency, Office of Pollution Prevention and Toxics and Syracuse Research Corporation.

Environmental Assessment

Tetrasodium ethylenediaminetetraacetate
(CAS No. 64-02-8)

An EU Risk Assessment Report was completed for tetrasodium ethylenediaminetetra-acetate (2004).

Environmental Transport

As no value for the vapor pressure is known, a Henry's law constant cannot be calculated from vapor pressure and water solubility. Because of the ionic properties of ethylenediaminetetraacetate (EDTA) and its metal complexes, it has to be assumed that volatilization from aqueous solution will not occur. Due to the ionic structure under environmental relevant pH conditions, no adsorption onto the organic fraction of soils or sediments is expected. In a laboratory test, the mobility of EDTA in soil was tested. A solution of H_4EDTA was eluted through cores of two various surface soils. H_4EDTA was found to be very slightly adsorbed and moved quite readily through both soils.

Based on the physico-chemical properties of H_4EDTA, a calculation with the fugacity model Mackay level I predicts that the hydrosphere is the preferred environmental compartment (99.999%).

Biodegradation

"EDTA is not readily biodegradable. The results of different tests on inherent biodegradability are unequal. The available, not well documented tests show for instance biodegradation rates from 0 and 37% under application of pre-adapted inoculum after 14 days. In a Modified Zahn-Wellens Test (OECD 302 B) a biodegradation of < 20% could be found after 28 days with non-adapted sludge."

"Recent data suggest that under alkaline conditions EDTA can be degraded. Environmental samples from a river, a ditch and a lake were examined in the Closed Bottle test for their potential to degrade CaNa2EDTA in a concentration of 8.0 mg/l at pH 6.5 and 8.0 over a period of few weeks. The results show for all environmental samples that at pH 6.5 no or little biodegradation (2-12%) occurs within the first 28 days. After 49 days a biodegradation between 60 and 83% was obtained. At pH 8, rates of 53, 62 and 72% were obtained after 28 days and 75-89% after 35 days."

"Results obtained at pH of 8 could be relevant because the pH value of lake and river water ranges from 7.7 to 8.5. However, in surface waters, EDTA is preferably complexed with heavy metal ions. Regarding the degradation tests cited above, no biological degradation is expected. Ca-EDTA can only occur in the environment where strong point

sources release this species into a river with a low flow. Therefore, in the present exposure assessment EDTA is regarded as not biodegradable in surface waters, and a biodegradation rate constant of 0 d-1 is used."

Bioaccumulation

"Bishop and Maki (1980) studied bioaccumulation of EDTA on the fish *Lepomis macrochirus*, using the kinetic and the plateau method. Under actual requirements only the results of the plateau method can be used. After 28 days, the EDTA level in the fish, as determined by the plateau method, was of the same order of magnitude as the level in the ambient water. Depending on the used concentration BCF of 1.8±1.1 (0.08mg/l EDTA) and 1.1±0.95 (0.76 mg/l EDTA) could be obtained. From this data it can be concluded that no bioaccumulation takes place."

Aquatic Toxicity

"Most of the acute tests performed with fish and daphnids revealed LC/EC_{50} values well above 100 mg/L, indicating for complexed and non complexed EDTA no need for classification as dangerous for the environment. Exceptions are two fish tests using H_4EDTA, where the tests were performed in very soft (LC_{50} = 41 mg/L) or soft water (LC_{50} = 59.8 mg/L). In the test media a surplus of uncomplexed EDTA was present which is not expected in the environment, therefore this tests are not relevant for the assessment."

"Tests on acute toxicity with *Daphnia magna* resulted in 24-hr EC_{50} values of 480 and 790 mg/L."

"Algae tests performed in standard media resulted in effect values below 1 mg/L. The effect is probably caused by nutrient deficiency. This indirect effect is an artifact and not used in the effects assessment. Further experiments with increased nutrient metal concentrations reveal that the direct toxicity on algae is above 310 mg/L. Indirect effects like nutrient deficiency and eutrophication could only qualitatively be assessed; they are unlikely to occur in the environment although it cannot absolutely be excluded."

Determination of $PNEC_{aquatic}$

"According to the results from different ecotoxicological studies discussed above, the toxicological profile of EDTA is based on disturbances of metal metabolism. For the interpretation of toxicity tests, the complex formation properties of EDTA have to be taken into account."

"Beside Ca and Mg, test media contain a certain amount of heavy metal ions being necessary as trace nutrients. The complex forming constants of heavy metal complexes

are by several orders of magnitude higher than of Ca/Mg-complexes, thus after addition of the test substance EDTA (as acid or Na-salt) the concentration of uncomplexed trace metals decreases drastically. The degree of Ca/Mg complexation is dependent on the amount of added EDTA. Uncomplexed EDTA is only present when it is present in overstoichiometric concentrations."

"The choice of the complex species being relevant for effect testing should consider their different ecotoxicological properties. A mixture of metal complexes is always released or is being formed in surface waters. Effect tests should be conducted with a complex for which metal toxicity can be excluded. We propose to use the Ca-complex as test substance for all release scenarios. Effects from complexes with a higher toxicity are caused by the dissociated metal ions and should be covered by the risk assessment of the respective metals."

"Short-term tests on fish reveal that EDTA and Na-EDTA are more toxic in an uncomplexed form. This can only occur if they are available in over-stoichiometric amounts to the chelants. Under these conditions the complexing agents can cause nutrient deficiency by reducing the essential concentration of different ions. The higher the water hardness the higher was the concentration of EDTA necessary to cause a toxic effect expressed as mortality: 96-hr LC_{50} values for H_4EDTA between 41 mg/L and 1590 mg/L were found. The lowest acute toxicity recorded with H_4EDTA for the fish *Lepomis macrochirus* in very soft water with LC_{50} of 41 mg/L should not be used because it is probably influenced by pH effects. In the test result obtained with Na-EDTA and a water hardness of 103 mg/L $CaCO_3$ (96-hr LC_{50} =374 mg/L) pH effects of the acid are completely suspended. However, uncomplexed EDTA was applied in a stoichiometric excess which is in contrast to environmental conditions. Using $CaNa_2$EDTA as test substance, a LC_{50} of 1,827 mg/L was obtained being in a concentration range where unspecific effects are expected. The results of the test with *Pimephales promelas* (96-hour LC_{50} = 59.8 mg/L, obtained in water hardness of 40-48 mg/l $CaCO_3$ are doubtful, as the effects might have been caused by a low pH value. All tests on acute fish toxicity are of limited relevance for the PNEC derivation."

"In an early-life stage test on the zebrafish *Danio rerio*, the NOEC was determined to > 26.8 mg/L H_4EDTA based on analytically determined concentrations. CaNa2EDTA was used as test substance. This test is considered to be the most relevant fish test for the PNEC derivation."

"For daphnids no investigation on the influence of water hardness or possible reduced nutrient conditions are available. The available acute tests are carried out by in hard water (160 mg/l CaO). It is known, that calcium deficiency inhibited the development of fresh water crawfish. 24-hr EC_{50} values of 480 to 790 mg/L for *Daphnia magna* were found. In a long-term test a 21-day NOEC of 22 mg/lLfor reproduction could be obtained. In the latter test a surplus of Ca was present, thus mainly Ca-EDTA was formed in the medium being the active test substance."

“The apparent effects of complexing agents to algal growth are related to essential trace metal bioavailability. Trace metal levels tend to be more important in algae tests than in short-term tests on fish or daphnia, the main reason is the rapid increase of biomass during the test. It was demonstrated that not the absolute EDTA concentration, but rather the ratio of the EDTA concentration to the metal cations is crucial to algae growth. With sufficient trace metal amounts, H_4EDTA concentrations up to 310 mg/L caused no effects. Similar results are obtained when Fe(III)EDTA is used as test substance, due to its slow metal exchange kinetics overchelation of the nutrient metal ions is avoided. Therefore direct effects caused by the intrinsic toxicity of EDTA are not expected in surface waters, where in nearly every case a stoichiometric surplus of metal ions is present.”

“A standard growth inhibition test on *Scenedesmus subspicatus* resulted in an EC10 of 0.37 mg/L H_4EDTA. The effect is probably caused by nutrient deficiency, as essential metal ions like Cu, Zn and Co are largely complexed leading to drastically reduced concentrations. In a test with *Pseudokirchnerella subcapitata* (formerly *Selenastrum capricornutum*) with Fe(III)EDTA as an active test substance following OECD TG 201, ECb50 and ECr50 higher than 100 mg/L were found. The NOEC based on nominal concentrations was determined to 79.4 mg/L and to 48.4 mg/L when based on mean measured concentration.”

“Therefore, this inhibition of algae growth is an artifact which is caused by the drastic increase of biomass during the test. Indirect effects cannot be quantified from the laboratory tests, thus only theoretical considerations can be made. In German and Dutch rivers, heavy metal concentrations in the range of 10-20 µmol/L (predominantly Fe and Mn) are detected. In the environment heavy metals are generally present in over-stoichiometric amounts, thus those effects are not expected in low concentrations like in the tests. Nutrient deficiency in surface waters can only occur when essential metal ions are overchelated by high EDTA amounts. On the other hand, plant growth is influenced by many limiting parameters; probably the presence of macronutrients like phosphate or nitrate is of greater importance. Therefore, it is unlikely that nutrient deficiency occurs in the environment, although it cannot be excluded absolutely.”

“In addition to the discussed adverse effects, like growth inhibition, mortality and immobilization of EDTA the growth stimulating effects like eutrophication occurs. Standard media for algae tests contain EDTA (OECD 201: 100 µg/L) to prevent precipitation of nutrient metals as hydroxide. For two different river waters a significant increase in phytoplankton production was observed after addition of 30 to 300 µg/L EDTA. The observed increase in growth varied with algae species, preloading of the water with trace elements and other complexing agents e.g. humic acids from 22 to 50%. Thus, the higher availability of trace elements through the complexing agent EDTA depends on the preloading of the water and can significantly stimulate the processes of eutrophication. If trace elements like Fe, Co, Mn, and Zn are sufficiently available in a soluble form, the algae growth will be increased after addition of EDTA only insignificantly. This aspect of effects cannot be assessed quantitatively with the available methods.”

"The effects assessment of EDTA is based on long-term tests, which are available for fish, daphnids and algae. The most sensitive endpoint could be found for *Daphnia magna* with a NOEC of 22 mg/L H_4EDTA. According to TGD an assessment factor of 10 has to be used."

The $PNEC_{aquatic}$ is 2.2 mg/L.

Determination of $PNEC_{sediment}$

"There are no test results available with sediment dwelling organisms. A determination of the PNEC sediment is not possible. Based on the properties no adsorption of EDTA onto the sediment has to be expected, thus the assessment of this compartment will be covered by the aquatic assessment."

Determination of $PNEC_{soil}$

"There are only test results available which investigate the decrease of heavy metal toxicity caused by EDTA. It is not possible to derive a PNEC with this data. Therefore, the assessment can be based on the pore water concentration only."

Reference

EU (2004). European Union Risk Assessment Report for Tetrasodium ethylenediamineacetate (CAS No. 64-02-8), Volume 51.

APPENDIX G.2 HALLIBURTON WATER AND GUAR BASED SYSTEMS

Environmental Assessment

Acetic Acid
(CAS No. 64-19-7)

Acetic acid and its salts undergo dissociation in aqueous media into the acetate anion ($H_3C_2O_2^-$) and the respective cations (H^+, NH_4^+, Ca^{2+}, Mg^{2+}, Mn^{2+}, K^+, Na^+). The toxicity of each compound is driven by acetate, with the cations playing a minor role. The pH is 2.5 at 50 g/L and 20°C; and the pK_a is 4.76 at 20°C.

Environmental Transport

Level I fugacity modeling predicts that about 73% of any acetic acid released to the environment would partition to water, with the remainder partitioning into the air (U.S. HPVIS database).

Biodegradation

Acetic acid and its salts readily dissociate into their respective cations and the acetate anion; the anion acetate is readily biodegraded. In aerobic conditions using adapted wastewater from domestic sewage, degradation was 96% after 20 days (Price *et al.*, 1974). It was also shown to be readily biodegradable under anaerobic conditions using activated sludge (99% after 7 days) (Kameya *et al.*, 1995).

Aquatic Toxicity

The 96-hour LC_{50} in bluegill sunfish is 75 mg/L (Price *et al.*, 1974), and the 96-hour LC_{50} in mosquito fish is 251 mg/L (Wallen *et al.*, 1957). The 96-hour LC_{50} of 60% acetic acid in *Oncorhynchus mykiss* is 108 mg/L (64.8 mg acetic acid/L) (unpublished data, ECHA). In a chronic study with *Oncorhynchus mykiss*, the 21-day LC_{50} and NOEC for 60% acetic acid were 87 mg/L and 57.2 mg/L, respectively (unpublished data, ECHA). The 21-day LC_{50} and NOEC for 100% acetic acid were 52.2 mg/L and 34.3 mg/L, respectively (unpublished data, ECHA).

The 24-hour EC_{50} to Daphnia was reported to be 95 mg/L (un-neutralized) and 6,000 mg/L (neutralized to pH 8.0) (Bringmann and Kuehn, 1982). One other study showed the 48-hour EC_{50} to be 65 mg/L (Janssen *et al.*, 1993). In a chronic Daphnia study, the 21-day NOEC for reproduction was reported to be 22.7 mg/L for 100% acetic acid (unpublished data, ECHA). In another chronic Daphnia study, the 21-day NOEC for reproduction was 31.4 mg/L for 100% acetic acid (unpublished data, ECHA).

In an algae growth inhibition study, the reported nominal ErC_{50} to *Desmodesmus subspicatus* was 810.9 mg/L for 60% acetic acid (unpublished data, ECHA). The

reported nominal ErC_{50} was 486.5 mg/L for 100% acetic acid (unpublished data, ECHA). The toxicity threshold to algae after 8 days in a growth inhibition test was reported to be 4,000 mg/L (Bringmann and Kuehn, 1980).

Toxicity to Terrestrial Organisms

No data could be located.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (65 mg/L) and Daphnia (65 mg/L), and algae (487 mg/L). Long-term results are also available for fish (NOEC = 34 mg/L) and Daphnia (NOEC = 23 mg/L). On the basis that the data consists of short-term results from three trophic levels and two chronic study for fish and another chronic study for Daphnia, an assessment factor of 50 has been applied to the lowest NOEC of 23 mg/L for Daphnia. The $PNEC_{aquatic}$ was calculated to be 0.5 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Acetic acid dissociates completely in water with its environmental distribution dominated by its high water solubility. Since log Kow and Koc are only applicable to the non-ionized forms of a substance, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Thus, the determination of the $PNEC_{sediment}$ is not possible. Based on its properties, no adsorption of acetic acid to sediment is to be expected and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. Acetic acid dissociates completely in water with its environmental distribution dominated by its high water solubility. Since log Kow and Koc are only applicable to the non-ionized forms of a substance, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Thus, the determination of the $PNEC_{soil}$ is not possible. Based on its properties, no adsorption of acetic acid to soil is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

The acetate ion of acetic acid is readily biodegradable and thus it does not meet the screening criteria for persistence.

The log Kow for acetic acid is reported to be -0.17 (Verschueren, 1966). Acetate is also found in the body and is metabolized as part of the body's biochemical pathways. Thus,

acetic acid (specifically, the acetate ion) does not meet the screening criteria for bioaccumulation.

The NOECs from the chronic aquatic toxicity data on acetic acid are >0.01 mg/L. Thus, acetic acid does not meet the criteria for toxicity.

The overall conclusion is that acetic acid is not a PBT substance.

References

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Wallen I.E., Greer, W.C., and Lasater, R. (1957). Toxicity to *Gambusia affinis* of certain pure chemicals in turbid waters. Sewage Ind. Wastes 23: 695-711.

Environmental Assessment

Alkylated Quaternary chloride

Environmental Fate

No measured data could be located on alkylated quaternary chloride.

The following information was obtained from EPISUITE v. 4.11 for this assessment (U.S. EPA, 2012). The water solubility was calculated to be 1 x 10^6 mg/L at 25°C, and the octanol-water partition coefficient (log K_{ow}) was estimated to be -4.1817. A Mackay Level III model predicts that alkylated quaternary chloride will distribute 68.4% to soil, 31.6% to water, and 0.07% to sediment. Alkylated quaternary chloride is expected to biodegrade fast based on the Biowin 2 model and with an ultimate biodegradation timeframe of weeks based on the Biowin 3 model.

Bioaccumulation

No measured data could be located on alkylated quaternary chloride. The BCF was calculated to be 3.162, indicating a low bioaccumulation potential.

Aquatic Toxicity

A 96-hour LC_{50} for alkylated quaternary chloride in fathead minnows has been reported to be 462 mg/L (ECOTOX).

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for one trophic level. The acute 96-hour LC_{50} value for fish is 462 mg/L. Using an assessment factor of 1,000, the $PNEC_{aquatic}$ is 0.5 mg/L.

References

ECOTOX. United States Environmental Protection Agency ECOTOX database, http://cfpub.epa.gov/ecotox/ecotox_home.cfm

U.S. EPA (2012). EPISuite v. 4.11, United States Environmental Protection Agency, Office of Pollution Prevention and Toxics and Syracuse Research Corporation.

Environmental Assessment

Amorphous/Non-crystalline Silica
(CAS No. 7631-86-9[1])

Silica Gel
(CAS No. 112926-00-8)

Amorphous Silica and silica gel have been reviewed in the OECD-SIDS program (OECD, 2004a,b).

The CAS No. 7631-86-9 is the general CAS registry number for silicon dioxide which includes all forms of silicas (*e.g.*, also crystalline and natural forms). Only the silica sub-classes, the synthetic amorphous silicas, are subject of this assessment.

Synthetic amorphous silica and silicates are in powder form which have a low water solubility, based on the sum of soluble SiO_2 and cations (water-soluble fraction): ≤70 mg/l (SAS), approx. 70 – 80 mg/l (NAS), and approx. 260 mg/l (CS) at 20 °C.

Environmental Fate and Transport

Silicon oxides are the most abundant compounds in the earth's crust mass. Synthetic amorphous silica and silicates are released into the environment are expected to be distributed mainly into soils and sediments, weakly into water and probably not at all in the air due to their physico-chemical properties, particularly low water solubility and very low vapor pressure.

Synthetic amorphous silica and silicates released into the environment are expected to combine indistinguishably with the soil or sediment due to their similarity with inorganic soil/sediment matter and will be subjected to natural processes under environmental conditions (cation exchange, dissolution, sedimentation).

Biodegradation is not applicable to these inorganic substances. The bioavailable form of synthetic amorphous silica and silicates is the dissolved form which exists exclusively as monosilicic [$Si(OH)_4$] acid under environmental pH. In analogy to the general chemical reaction of weak acids and salts of weak acids with water, the water-soluble fraction of silica acts as a weak acid and, therefore, will tend to lower the pH value, while that of a silicate acts as a base tending to bind protons and, thus, raise the pH value by forming hydroxyl ions. But pH shifts which are measurable at high loadings under laboratory conditions are not expected to occur from the anthropogenic deposition in the aquatic environment of synthetic amorphous silicas due to low aquatic releases and sufficient natural buffer capacities. Finally, these materials are supposed to combine indistinguishably with the soil layer or sediment due to their chemical similarity with inorganic soil matter.

Dissolved silica can be actively assimilated by some marine and terrestrial organisms as normal natural processes mainly related to structural function.

Aquatic Toxicity

Studies on fish, Daphnia and algae using excess loadings of SAS or NAS showed no acute toxicity, although physical effects on Daphnia were observed in tests using unfiltered test medium. Test results, based on loading rates, are as follows: 96-hour LL_0 *(Brachydanio rerio)* is 10,000 mg/L for SAS and NAS; 24-hour EL_{50} *(Daphnia magna)* >10,000 mg/L for SAS; 72-hour NOEL *(Scenedesmus subspicatus)* is 10,000 mg/L for NAS.

There are no chronic aquatic toxicity data, but due to the known inherent physico-chemical properties, absence of acute toxic effects as well as the ubiquitous presence of silica/silicates in the environment, there is no evidence of harmful long-term effects arising from exposure to synthetic amorphous silica/silicates.

Toxicity to Terrestrial Organisms

No data are available.

PBT Assessment

Noncrystalline silica (silica gel) is silicon dioxide, an inorganic compound which is ubiquitous in the environment. For the purposes of this PBT assessment, the persistent criteria is not considered applicable to this inorganic salt.

A log Kow is not applicable to noncrystalline silica. Noncrystalline silica (silica gel), as a stable crystalline solid, is expected to have negligible uptake through the gill or gut of aquatic organisms. Thus, noncrystalline silica (silica gel) is not expected to bioaccumulate.

No chronic toxicity data exist on noncrystalline silica or silica gel; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, noncrystalline silica (silica gel) does not meet the screening criteria for toxicity.

The overall conclusion is that noncrystalline silica (silica gel) is not a PBT substance.

References

OECD (2004a). IUCLID Data Set for Synthetic Amorphous Silica and Silicates: Silicon Dioxide (CAS No. 7631-86-9, 112945-52-5, 112926-00-8; Silicic Acid, Aluminum Sodium Salt (CAS No. 1344-00-9); Silicic Acid, Calcium Salt (CAS No. 1344-95-2), UNEP Publications.

OECD (2004b). Screening Information Dataset (SIDS) Initial Assessment Report for Synthetic Amorphous Silica and Silicates: Silicon Dioxide (CAS No. 7631-86-9, 112945-52-5, 112926-00-8; Silicic Acid, Aluminum Sodium Salt (CAS No. 1344-00-9); Silicic Acid, Calcium Salt (CAS No. 1344-95-2), UNEP Publications.

Environmental Assessment

1,2-Benzothiazolin-3-one
(CAS 2634-33-5)

Environmental Transport

1,2-Benzisothiazolin-3-one is hydrolytically stable (half-life > 30 days), but breaks down fairly quickly in aerobic soils (half-life < 24 hours in sandy loam soil). 1,2-Benzisothiazolin-3-one shows moderate to strong binding to soils, with adsorption K_d values estimated to be between 1.24 and 9.56. If used outdoors, 1,2- benzisothiazolin-3-one may possibly move with soil during rainfall events and potentially reach surface waters. However, it breaks down aerobically on the surface soils. Since it has a moderate binding potential to soils, it is not likely to migrate into the ground and there is low potential for ground water contamination.

Bioaccumulation

With a K_{ow} value of 20 at 25ºC., 1,2-benzisothiazolin-3-one is unlikely to bioaccumulate in aquatic organisms.

Aquatic Toxicity

U.S. EPA RED: The acute LC_{50}s to rainbow trout are 1.3 mg/L and 1.6 mg/L. The acute LC_{50} to Sheepshead minnow is 12.2 mg/L. The acute LC_{50}s to Daphnia are 1.5 mg/L and 3.3 mg/L. The acute 72-hour EC_{50} to green algae is 0.15 mg/L.

Rohm & Haas MSDS for Koralone™ B-120: The acute 96-hour LC_{50} to rainbow trout is 1.9 mg/L, and the acute 96-hour LC_{50} to sheepshead minnow is 19 mg/L. The acute 48-hour EC_{50} to *Daphnia* is 3.7 mg/L. The acute 96-hoour EC_{50} to alga *Pseudokirschneriella subcapita* is 0.38 mg/L, and the acute 96-hour EC_{50} to *Skeletonema costatum* is 0.4 mg/L.

ISP MSDS for Nuosept® 498 Preservative: The acute EC_{50}s to algae are 0.084 and 0.15 mg/L.

Toxicity to Sediment Organisms

No data were located.

Toxicity to Soil Organisms

No data were located.

Toxicity to Terrestial Organisms

The acute oral LD_{50} to Bobwhite quail (*Colinus virginianus*) was reported to be 453 mg/kg. The subacute dietary LD_{50} to Bobwhite quail (*Colinus virginianus*) was reported to be >5,620 mg/kg.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (1.3 mg/L), Daphnia (1.5 mg/L), and algae (0.084 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 0.084 mg/L for algae. The $PNEC_{aquatic}$ is 8.4×10^{-5} mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$. The Koc was calculated using EPISUITE (MCI Method). Using a Koc of 34.48 and a $PNEC_{aquatic}$ of 0.084 µg/L, the $PNEC_{sediment}$ was calculated to be 0.096 µg/kg.

$PNEC_{soil}$: No adequate experimental toxicity data on terrestrial organisms are available. The equilibrium partition method was used to determine a $PNEC_{soil}$. The Koc was calculated using EPISUITE (MCI Method). Using a Koc of 34.48 and a $PNEC_{aquatic}$ of 0.084 µg/L, the $PNEC_{soil}$ was calculated to be 0.039 µg/kg.

PBT Assessment

1,2-Benzisothiazolin-3-one is hydrolytically stable (half-life > 30 days), but breaks down fairly quickly in aerobic soils (half-life < 24 hours in sandy loam soil). The results of BIOWIN v4.10 for 1,2-benzothiazolin-3-one are as follows: biodegrade fast (Biowin2); ultimate biodegradation timeframe is weeks (Biowin3); and does not biodegrade fast (Biowin 6). Thus, 1,2-benzothiazolin-3-one does not meet the screening criteria for persistence.

The log Kow for 1,2-benzothiazolin-3-one is 1.3 and thus does not meet the screening criteria for bioaccumulation.

No chronic toxicity data exist on 1,2-benzothiazolin-3-one; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, 1,2-benzothiazolin-3-one does not meet the screening criteria for toxicity.

The overall conclusion is that 1,2-benzothiazolin-3-one is not a PBT substance.

References

ISP MSDS for Nuosept® 498 Preservative

Rohm & Haas MSDS for Koralone™ B-120

U.S.Environmental Protection Agency, Reregistration Eligibility Decision for 1,2-Benzoisothiazolin-3-one (BIT), Office of Prevention, Pesticides and Toxic Substances, 739-R-05-007, September 2005.

Environmental Assessment

C10-C12 Alcohol Ethoxylates
(CAS No. 67254-71-1)

Alcohol ethoxylates (AE) are a class of non-ionic surfactants that have the basic structure $C_{x-y}AE_n$. The subscript (x-y) following the 'C' indicates the range of carbon chain units. AEs with carbon unit range between C8 to C18 are most commonly used in household detergent products. The hydrocarbon chain can be either linear or branched. AEs also contain an ethylene oxide (E) chain attached to the alcohol. The degree of ethylene oxide polymerization is indicated by the subscript (n) which indicates the average number of ethylene oxide units. In household products the average ethylene oxide chain length commonly ranges between 3 and 12 units.

The toxicity profile of C10-C12 alcohol ethoxylates has been developed from a risk assessment report on alcohol ethoxylates ranging from C8 to C18 prepared by the household cleaning product and chemical industry (HERA, 2009).

Biodegradation

AE homologues with hydrocarbon chain lengths ranging from 8 to 18 and with 2 to >20 ethylene oxide units are readily biodegradable.

As a class, AE undergo rapid primary and ultimate biodegradation under both laboratory and field conditions. The biodegradability of the different AE homologues used in HERA applications is relatively unaffected by the alkyl carbon chain length and the number of EO units.

Proposed half-lives in river water at 12^{o}C: 4 to 24 hours (based on experimental data).

AE are also anaerobically biodegradable.

Bioaccumulation

The AE homologues used for domestic cleaning applications are very likely to have a log Kow value greater than 3.

The Danish EPA report on surfactants (Danish EPA, 2001) found that bioaccumulation of alkyl ethoxylates in aquatic organisms had been determined only for fish. The majority of the limited data were based on studies with 14C-labelled compounds that do not allow the distinction between the parent compound and metabolites, or material incorporated into the cells during growth. Because alcohol ethoxylates are metabolized in aquatic organisms (Danish EPA, 2001), the bioconcentration factor for the parent compound may

well be overestimated in experiments in which 14C-labelled model surfactants are used. Tolls *et al.* (2000a,b) combined 14C-techniques and chemical analysis to determine the amount of AE actually present as the parent molecule in the fish. This showed that the parent AE (e.g. C13 EO8) was rapidly eliminated by transformation into metabolites, which were eliminated at a slower rate. The Danish EPA concluded that the data indicate that the more hydrophobic AE (e.g. C13 EO4, C14 EO4, and C16 EO8) have a moderate bioaccumulation potential (Danish EPA 2001). They also note that in the study by Tolls (1998) the BCF values ranged from < 5 to 387.5, whereas the uptake rates (*k*1) varied from 330 to 1660 (l x kg x d-1) and the elimination rates (*k*2) varied from 3.3 to 59 (d-1). The time to steady state and the BCF for AE increase with decreasing length of the ethoxylate chain (e.g., t95 for C13 EO8 = 2.4 h and BCF = 30-55, and t95 for C13 EO4 = 17.1 h and BCF = 233) (Danish EPA 2001).

Tolls *et al.* (2000a,b) concluded that the high values of the elimination rate constants suggest that fathead minnows efficiently biotransform AE, thereby preventing AE from attaining high concentrations in fish. They note that estimates of the bioconcentration potential of AE mixtures in influents and effluents of several wastewater treatment plants were similar to each other, implying that the bioconcentration potential was not significantly altered by the processes involved in wastewater treatment. These estimates of the bioconcentration potential were conservative and ranged around 140 L/kg.

Environment Canada and Health Canada (2006) has established that the degree of bioaccumulation expected from AE is well below the Canadian bioconcentration criterion of 5000. The sixteen measured BCF values for 15 AE homologues showed the lack of a linear relationship between alkyl or ethoxylate chain length and BCF, with the highest measured BCF value being under 800. Environment Canada (2006) concluded that it is evident that the AE metabolism rates prevent any significant accumulation. The data indicated that there may be an optimal structural combination of ethoxylate and alkyl chain lengths, at or around C14EO7, where BCF is maximized, but even the measured BCF for this chemical is well below the criterion of 5000. Thus Environment Canada (2006) concluded that ethoxylated aliphatic alcohols are not bioaccumulative.

Aquatic Toxicity

Acute aquatic effects data is presented in the HERA report only to establish that the essentially linear and branched AE used in household detergents are not more toxic than the linear AE which have the same uses. The toxicity mechanism for AE is accepted to be non-polar narcosis, in which the AE homologues with longer hydrocarbon chains and higher log K_{ow} are more efficient at penetration of the cell membrane, and thus more toxic. However, the AE homologues must be sufficiently soluble in water to allow a toxic concentration to reach the target organism. For the long chain alcohols, generally the least soluble and the most toxic of the AE homologues, the long chain alcohol OECD-Screening Information Assessment Report (SIAR) (SIAR, 2006) shows that the toxicity is restricted by solubility considerations at hydrocarbon chain lengths of 15 and above. Although the addition of ethylene oxide groups makes the other AE homologues more

soluble, solubility considerations may reduce the toxicity of several higher hydrocarbon chain length and lower EO chain length AE. The available acute toxicity data follows this generally accepted pattern, and also indicates that the linear, essentially linear and branches AE are of similar toxicity.

Toxicity to Terrestrial Organisms

Acute soil toxicity measurements for both plants and soil invertebrates are available from standard tests carried out on commercial AE mixtures, which contain differing distributions of AE homologues. The available data are reviewed in the HERA report.

A range of chronic soil tests has been carried out for two pure AE homologues, C12EO4 and C16EO4. The two AE homologues chosen for the chronic tests span the hydrocarbon chain length range of high tonnage AE, and have an EO chain length value at which the toxicity is expected to be in the high range for each hydrocarbon chain length. The chronic tests, to assess the survival and reproduction of earthworms (*Eisenia fetida fetida)*, springtails (*Folsomia candida*), and nematodes (*Caenorhabditas elegans*), were carried out using a natural sandy loam soil, with an organic carbon content of 1.3%, which could be assumed to be free of pesticide. If an application factor of 10 were applied to the lowest chronic NOEC value to determine a PNEC, a PNEC of 22 mg/kg would result for C12EO4 and a PNEC of 46 mg/kg would result for the C16EO4 AE homologue. Comparison of the acute test data with the equilibrium partition soil PNEC values show very similar values. Thus, the chronic soil toxicity results for C12EO4 and C16EO4 support the validity of the PNEC values determined by equilibrium partitioning.

Information showing the relatively small difference between acute and chronic toxicity for soil organisms means that available single homologue acute data also supports the PNEC calculated by equilibrium partitioning from aquatic monitoring data. In addition, available data for AE mixtures is consistent with the equilibrium partitioning PNEC values.

Determination of $PNEC_{aquatic}$

The chronic *Daphnia magna* QSAR developed by Boeije *et al.* (2006) can be used, with an appropriate application factor, to determine the PNEC for each AE homologue. Of the three trophic level QSARs discussed here, the chronic *Daphnia magna* QSAR is the most robust. The algal QSAR work by Wind and Belanger (2006) has shown that AE toxicity to algae, daphnia, and fish are of similar magnitude, while the chronic AE toxicity data given indicates that *Daphnia magna* are among the most sensitive invertebrates.

The PNEC values determined for each AE homologue using both the chronic *Daphnia magna* QSAR with an application factor of 10 given in Table 4.38 of the HERA report. For the *Daphnia magna* QSAR, the application factor of 10 is used as three chronic QSARs are available for AE homologues. The *Daphnia magna* QSAR has been chosen as it is the most robust of these three chronic QSARs, and has the most sensitive endpoint

over much of the range of AE homologues.

The composition of C10-C12 alcohol ethoxylates (CAS No. 67254-71-1) is unknown. It is possible that it is a mixture of linear and branched alcohol ethoxylates with varying EO chain lengths. Therefore, a mean PNEC for this CASRN was calculated as follows: for each hydrocarbon number, the PNEC value AE for EO units 1 to 20 were average together, providing a mean value that covers the range of PNECs calculated for that hydrocarbon number. Each of these mean PNECs were then averaged together to cover all of the hydrocarbon chain lengths included in this CASRN, *i.e.* C10 to C12.

$PNEC_{aquatic}$: Chronic Daphnia magna QSAR and an Application Factor of 10

	C10 (mg/L)	**C11 (mg/L)**	**C12 (mg/L)**
Mean	1.71	0.979	0.513
Range	0.118 – 6.23	0.0652 – 3.26	0.0358 – 1.7

$PNEC_{aquatic}$ (freshwater) = (1.71 + 0.979 + 0.513)/3 = 1.07 mg/L

Determination of $PNEC_{sediment}$

The equilibrium partitioning method is used to predict the sediment PNEC from the aquatic PNEC, if no sediment data are available. A probabilistic QSAR has been developed for aquatic species based on chronic data (see HERA report). This QSAR contains aquatic test data for species which live in sediment, such as *Chironomus tentans* and *Corbicula fluminea,* and others which live near or in the top sediment surface such as *Hyallela azteca, Dugesia gonocephala, Chlorella vulgaris* and *Navicula pelliculosa.* Comparison of the chronic *Daphnia magna* data (which was used to derive the aquatic PNEC) with that for the sediment dwelling organisms shows that *Daphnia magna* is of similar sensitivity to the sediment dwelling organisms. As the deterministic chronic *Daphnia magna* QSAR is quite robust, and for the purposes of consistency, it was decided that the aquatic PNEC derived from the chronic *Daphnia magna* QSAR be used with the equilibrium partitioning method to determine the PNEC sediment for all the AE homologues. A mean PNEC for this CASRN was calculated similar to the approach for $PNEC_{aquatic}$.

In order to account for uptake *via* sediment ingestion, an additional application factor of 10 will be applied to the PNEC for any chemicals with a log Kow value >5. This affect the following AEs: C12EO1-3.

The HERA report used the TGD (2003) approach to calculate the PNEC sediment using the equilibrium partitioning method according to PNECsed = (Ksusp-water / Rhosusp) * PNEC water *1000.

$PNEC_{sediment}$ values determined by the equilibrium partitioning method, based on the deterministic method using the chronic *Daphnia magna* QSAR (Log Kow ≤5)

	C10 (mg/kg)	**C11 (mg/kg)**	**C12EO4-20 (mg/kg)**
Mean	254	279	359
Range	3.11 - 1250	3.55 - 1370	12.8 - 1500

$PNEC_{sediment}$ = (254 + 279 + 359)/3 = 297 mg/kg

$PNEC_{sediment}$ values determined by the equilibrium partitioning method, based on the deterministic method using the chronic *Daphnia magna* QSAR (Log Kow>5)

	C12EO1-3 (mg/kg)
Mean	6.35
Range	4.06 – 8.9

$PNEC_{sediment}$ = 6.0 mg/kg

Determination of $PNEC_{soil}$

The equilibrium partitioning calculation for $PNEC_{soil}$ has was carried out using the $PNEC_{aquatic}$ values determined by using the deterministic *Daphnia magna* QSAR with an application factor of 10. The results of this calculation are shown in Table 4.47 of the HERA report for each AE homologue. An additional application factor of 10 will be applied to the PNEC for any chemicals with a log Kow value >5. This affect the following AEs: C12EO1-3. A mean PNEC for this CASRN was calculated similar to the approach for $PNEC_{aquatic}$.

$PNEC_{soil}$ values determined by the equilibrium partitioning method, based on the deterministic method using the chronic *Daphnia magna* QSAR (Log Kow ≤5)

	C10 (mg/kg)	**C11 (mg/kg)**	**C12EO4-20 (mg/kg)**
Mean	206	226	247
Range	2.5 - 1012	2.9 - 1111	10.3 - 1219

$PNEC_{soil}$ = (206 + 226 + 247)/3 = 226 mg/kg

$PNEC_{soil}$ values determined by the equilibrium partitioning method, based on the deterministic method using the chronic *Daphnia magna* QSAR (Log Kow>5)

	C12EO1-3 (mg/kg)
Mean	5.1
Range	3.3 – 7.2

$PNEC_{soil}$= 5.1 mg/kg

PBT Assessment

C10-C12 alcohol ethoxylates are readily biodegradable; thus, they not meet the screening criteria for persistence.

Based on the information provided in the bioaccumulation section above, the C10-C12 alcohol ethoxylates do not meet the criteria for bioaccumulation.

The chronic Daphnia NOEC values for C10-C12 alcohol ethoxylates are >0.1 mg/L. Thus, C10-C12 alcohol ethoxylates do not meet the criteria for toxicity.

The overall conclusion is that C10-C12 alcohol ethoxylates is not a PBT substance.

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Environmental Assessment

Calcium chloride
(CAS No. 10043-52-4)

Calcium chloride has been reviewed in the OECD-SIDS program (OECD, 202a,b).

Environmental Fate

Calcium chloride is soluble in water and its vapor pressure is negligible. This indicates that calcium chloride released into the environment is distributed into the water compartment in the form of calcium and chloride ions. Calcium chloride is not expected to be absorbed in soil due to its dissociation properties and high water solubility but may rather behave as free ions or may form stable inorganic or organic salts with other counter ions, leading to different fates between calcium and chloride ions in soil and water compartments in the environment. As for the behavior of calcium in soil, the calcium ion may bind to soil particulate or may form stable inorganic salts with sulfate and carbonate ions. The chloride ion is mobile in soil and eventually drains into surface water because it is readily dissolved in water.

Calcium chloride is not expected to undergo photolysis or biodegradation. The Fugacity model is not applied to estimate the distribution of this substance in the environment because the programs are designed for organic chemicals and not for inorganic salts. Considering its dissociation properties, calcium chloride *per se* is not expected to accumulate in living organisms.

Aquatic Toxicity

Several studies on acute toxicity to fish have been reported. The lowest 96-hour LC_{50} value was 4,630 mg/L in fathead minnow (*Pimephales promelas*). No chronic toxicity studies on fish conducted under standard guidelines have been reported.

There are seven acute toxicity data available for Daphnia. Two of these studies were conducted according to international or national guidelines, giving the 48-hour EC_{50} of 2,400 mg/L for *Daphnia magna* and the 48-hour LC_{50} of 1,830 mg/L for *Ceriodaphnia* sp. The lowest 48-hour EC_{50} was 1,062 mg/L for *Daphnia magna*. The chronic effect of 21-day exposure on reproduction of *Daphnia magna* has been investigated as a long-term study. The concentration required for 16% and 50% inhibition of reproduction (EC_{16} and EC_{50}) were 320 and 610 mg/L, respectively. The NOEC = $EC_{16}/2$ = 320/2 = 160 mg/L.

There is one study with fresh water algae, *Selenastrum capricornutum*, which was conducted according to OECD 201. The 72-hour EC_{50} and EC_{20} obtained on the basis of growth rate from the study were >4,000 and 2,700 mg/L, respectively. The 72-hour EC_{50} and EC_{20} obtained on the basis of biomass from the study were 2,900 and 1,000

mg/L, respectively. The NOECs are calculated as $EC_{20}/2$, which corresponds to 1,350 and 500 mg/L for growth rate and biomass, respectively.

Toxicity to Terrestrial Organisms

See Table 4-2 in OECD-SIDS SIAR (OECD, 2002b).

There are some studies that examined effects of deicing agents to plants and earthworm using calcium chloride, sodium chloride, CMA (calcium/magnesium acetate), urea, *etc.*. Although these studies were not conducted under the standard methods and were not necessarily providing reliable outcomes, they revealed a tendency to less damage to plants and earthworm from exposure to calcium chloride than to other deicing agents.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (4,630 mg/L), Daphnia (1,062 mg/L), and algae (2,900 mg/L). Results from a chronic Daphnia study (NOEC = 160 mg/L) and algae study (NOECs = 1,350 and 500 mg/L for growth rate and biomass, respectively) are also available. On the basis that the data consists of short-term results from three trophic levels and chronic studies on Daphnia and algae, an assessment factor of 50 has been applied to the lowest reported NOEC of 160 mg/L for *Daphnia*. The $PNEC_{aquatic}$ is 3.2 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Calcium chloride dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc parameters do not readily apply to inorganics, such as calcium chloride. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of calcium chloride to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The environmental distribution of calcium chloride is dominated by its water solubility. Sorption of calcium chloride should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Kow and Koc parameters do not readily apply to inorganics, such as calcium chloride. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, calcium chloride is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Calcium chloride is an organic salt that dissociates completely to calcium and chloride

ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both calcium and chloride ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria is not considered applicable to this inorganic salt.

Calcium and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, calcium chloride is not expected to bioaccumulate.

No chronic toxicity data exist on calcium chloride; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, calcium chloride does not meet the screening criteria for toxicity.

The overall conclusion is that calcium chloride is not a PBT substance.

References

OECD (2002a). IUCLID Data Set for Calcium Chloride (CASRN 10043-52-4), UNEP Publications.)

OECD (2002b). Screening Information Dataset (SIDS) Initial Assessment Report for Calcium chloride (CASRN 10043-52-4), UNEP Publications.

Environmental Assessment

Cocoamidopropyl betaine
(CAS No. 61789-40-0)

Cocoamidopropyl betaine has been reviewed in the OECD-SIDS program (OECD, 2006).

Cocamidopropyl betaines are mainly a mixture of C_{12}-C_{18} fatty acids from hydrolysis of coconut oil. Coconut oil has a mixed fatty acid composition, which varies slightly, as it is a natural product. Lauric acid - resulting in lauramidopropyl betaine - is the major ingredient of coconut oil. As the physical chemical properties of cocamidopropyl betaine are not fully available as measured values, calculated values of lauramidopropyl betaine (RCOOH=lauric acid, C_{12} fatty acid) - as the main component in the cocamidopropyl betaine - are indicated instead. If possible the calculated ranges for the cocamidopropyl betaine (C_{12} – C_{18}) are given. In terms of the environmental exposure assessment, the relevant calculated values of the respective betaine derived from the C_{18} fatty acid – Stearamidopropylbetaine are indicated. The characteristics of the stearamidopropylbetaine are regarded as to represent the most hydrophobic properties of the cocamidopropyl betaine.

Environmental Transport

Based on the calculation for caprylamidopropyl betaine (C8 fatty acid derivative) and stearamidopropyl betaine (C18 fatty acid derivative), cocamidopropyl betaine will be mainly distributed to the hydrosphere (59 - 100 %), and to a lesser extent to soil and sediment (0 - 20 % each). The Henry's law constants for alkylamidopropyl betaines calculated for every single fatty acid chain length indicate a very low potential for volatilization from surface waters under environmentally relevant conditions. The soil sorption coefficients (K_{OC}) calculated for the alkylamidopropyl betaines indicate a low to very high potential for sorption to organic matter of soils and sediments. The low sorption potential is confirmed by experimentally obtained values for laurylamidopropyl betaine (C12 derivative) and tetradecylamidopropyl betaine (C14 derivative) from the screening HPLC-method according to OECD Test Guideline 121. A high potential for sorption applies only for the alkylamidopropyl betaines with the C16 and C18 fatty acid chain length.

Biodegradation

Cocamidopropyl betaine can be considered as being readily biodegradable under aerobic conditions. In guideline tests biodegradation rates of 86 – 100 % after 28 days (OECD 301A/B/D/E), 90 – 93 % after 35 days (OECD 301B) and 100 % after 20 days (Directive 84/449/EEC, C.5) were determined with cocamidopropyl betaine. Under anaerobic

conditions, 80 – 90 % mineralization after 60 days or 56% after 56 days were observed for cocamidopropyl betaine.

Bioaccumulation

A low potential for bioaccumulation is to be expected for cocoamidopropyl betaines based on the calculated BCFs between 3 (with C8 fatty acid) and 71 (with C10 – C18 fatty acids).

Aquatic Toxicity

For cocoamidopropyl betaine, the lowest acute LC/EC_{50} values for fish, *Daphnia*, and algae are all in the range of 1.3 – 2 mg active substance/L. One long-term test with fish (according to OECD 215), and several chronic tests with *Daphnia* and algae were conducted on cocoamidopropyl betaine. The lowest NOECs are 0.16 mg active substance/L for fish (*Oncorhynchus mykiss*), 0.03 mg active substance/L for *Daphnia magna*, and 0.09 mg active substance/L for green algae (*Desmodesmus subspicatus*). These values were derived with analytical monitoring (photometric) except for the algae test. However, the effect values within the same species (*e.g.*, *Desmodesmus subspicatus*, *Daphnia magna*) have shown a high variability. Recent guideline studies performed in accordance with OECD 211 and 201 using state-of-the-art analytical monitoring and a quality of cocamidopropyl betaine currently commercialized, resulted in a lower aquatic toxicity. In these studies the lowest NOEC for *Daphnia* was determined to be 0.932 mg active substance/L. The lowest NOEC (72 hour, based on growth rate) for algae was determined to be 3.55 mg active substance/L (72-hour ErC_{50} = 9.86 mg active substance/L). This latter NOEC for algae is further supported by the similar NOEC of 3.53 mg active substance/L calculated using the geometric mean of all valid tests with this algae species. Furthermore, for algae a potential for recovery from the effect up to a concentration of 96 mg active substance/L has been observed.

Toxicity to Terrestrial Organisms

Two studies (without analytical monitoring) of effects on earthworms and higher plants showed low toxicity (no data given in the OECD-SIDS SIAP). Taking additionally into account that the adsorption potential of the main components of cocamidopropyl betaine (the C8 to C14 derivatives) is low, a risk for the terrestrial compartment is not expected.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. A recent state-of-the-art chronic study is available for invertebrates (lowest NOEC for Daphnia is 0.932 mg/L). A recent state-of-the-art OECD 211 study is also available with the lowest

NOEC (72 hour, based on growth rate) for algae was determined to be 3.55 mg/L. On the basis that the data consists of two chronic studies (Daphnia and algae), an assessment factor of 50 has been applied to the lowest reported NOEC of 0.932 mg/L for Daphnia. The $PNEC_{aquatic}$ is 0.019 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$. The Koc was calculated using PCKOCWIN v. 1.66 using specific betaine with C8, C10, C12, C14, C16, and C18 fatty acids. Using a Koc values of 264.7 to 120600 and a $PNEC_{aquatic}$ of 0.0.019 mg/L, the $PNEC_{sediment}$ was calculated to be 0.085 to 33.7 mg/kg.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The equilibrium partition method was used to determine a $PNEC_{soil}$. The Koc was calculated using PCKOCWIN v. 1.66 using specific betaine with C8, C10, C12, C14, C16, and C18 fatty acids. Using a Koc values of 264.7 to 120,600 and a $PNEC_{aquatic}$ of 0.0.01 mg/L, the $PNEC_{soil}$ was calculated to be 0.066 to 29.8 mg/kg.

PBT Assessment

Cocoamidopropyl betaine is readily biodegradable and thus it does not meet the screening criteria for persistence.

The estimated log Kow values for cocoamidopropyl betaine (with C8 to C18 fatty acids) is -1.28 to 3.63, calculated using KOWWIN v1.67 (HERA, 2005). Thus, cocoamidopropyl betaine does not meet the screening criteria for bioaccumulation.

The lowest chronic NOEC for cocoamidopropyl betaine is >0.1 mg/L. Thus, cocoamidopropyl betaine does not meet the criteria for toxicity.

The overall conclusion is that cocoamidopropyl betaine is not a PBT substance.

References

Human and Environmental Risk Assessment (HERA) on Ingredients of Household Cleaning Products: Cocoamidopropyl betaine (CAPB) (CAS No.: 61789-40-0, 70851-07-9, 4292-10-8), 2005; http://www.heraproject.com

OECD (2006). SIDS Initial Assessment Profile for Alkylamidopropyl betaines.

Environmental Assessment

Crystalline Silica, Quartz
(CAS No. 14808-60-7)

Crystalline Silica, Cristobalite
(CAS No. 14464-46-1)

Silica is an off-white granule that occurs naturally in various crystalline and amorphous or other non-crystalline forms. Crystalline silica is characterized by silicon dioxide (SiO_2) molecules oriented in fixed, periodic patterns to form stable crystals. The primary crystalline form of silica is quartz. Other crystalline forms of silica include cristobalite, tripoli and tridymite.

Crystalline silica, quartz and crystalline silica, cristobalite are naturally occurring minerals that are insoluble in water.

They are persistent in the environment.

Crystalline silica, quartz, and crystalline silica, cristobalite as minerals, are not expected to bioaccumulate or be toxic to aquatic organisms because of their water insolubility and lack of bioavailability.

Crystalline silica, quartz and crystalline silica, cristobalite are not considered to be PBT substances.

Environmental Assessment

Endo-1,4-beta-Mannanase
(CAS No. 37288-54-3)

No data could be located on endo-1,4-beta-mannanase. There is information, however, on α-amylases. α-Amylase catalyzes the endo-hydrolysis of 1,4-α-D-glycosidic linkages in polysaccharides like starches, glycogen, and oligosaccharides containing three or more 1,4-α-linked glucose units. Given the similarity of the substrates, amylases and endo-1,4-beta-mannanase would be expected to have similar physico-chemical properties relevant to evaluating their environmental fate and transport, and their aquatic toxicity potential.

The data on α-amylases have come from detergent amylases, the typical ones being *Bacillus*, which has an neutral isoelectric point and a broad pH optimum between pH 5 and 9. The enzyme is characterized by a molecular weight of 58 kD (HERA, 2005).

Biodegradation

Two different amylase enzymes were considered readily biodegradable based on the results of OECD 301E tests. In both tests, there was 99% DOC removal of the enzyme after 28 days. Likewise, endo-1,4-beta-mannanase is expected to be readily biodegradable (HERA, 2005).

Aquatic Toxicity

The 96-hour LC_{50} of α-amylase (Termamyl) to *Oncorhyncus mykiss* (rainbow trout) is >320 mg aep/L (HERA, 2005). The 48-hour LC_{50} of α-amylase to *Dapnia magna* is 450 mg aep/L (HERA, 2005). The 72-hour EC_{50} of α-amylase (Termamyl) to algae *Scenedesmus subspicatus* is 112 mg aep/L (HERA, 2005).

Toxicity to Sediment Organisms

No data could be located.

Toxicity to Terrestial Organisms

No data could be located.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (>320 mg aep/L), Daphnia (450 mg aep/L), and algae (112 mg aep/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 112 mg aep/L for fish. The $PNEC_{aquatic}$ is 0.112 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$. A calculated Koc of <1.3 was reported in the HERA report, calculated according to the TGD. Using a Koc of 1.3 and a $PNEC_{aquatic}$ of 0.112 mg aep/L, the $PNEC_{sediment}$ was calculated to be 0.07 mg aeg/kg.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The equilibrium partition method was used to determine a $PNEC_{soil}$. A calculated Koc of <1.3 was reported in the HERA report, calculated according to the TGD. Using a Koc of 1.3 and a $PNEC_{aquatic}$ of 0.112 mg aep/L, the $PNEC_{soil}$ was calculated to be 0.0019 mg aeg/kg.

PBT Assessment

Endo-1,4-beta-mannanase is expected to be readily biodegradable based on read-across to amylases. Thus, endo-1,4-beta-mannanase does not meet the screening criteria for persistence.

Based on the similarity to amylase, endo-1,4-beta-mannanase has a high molecular weight (20 to 80 kD), has hydrophilic properties (high water solubility, log Kow <0), and is readily metabolized in organisms by proteolytic enzymes or proteases. Thus, endo-1,4-beta-mannanase does not meet the screening criteria for bioaccumulation.

No chronic aquatic toxicity data exist for endo-1,4-beta-mannanase; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, endo-1,4-beta-mannanase does not meet the screening criteria for toxicity.

The overall conclusion is that endo-1,4-beta-mannanase is not a PBT substance.

Reference

Human and Environmental Risk Assessment (HERA) on Ingredients of Household Cleaning Products: α-amylase, CAS No. 9000-90-2; Cellulase (β-(1,4)-glucanase), CAS No. 9012-54-8; Lipase, 9001-62-1, 2005. http://www.heraproject.com

Environmental Assessment

Ethanol
(CAS No. 64-17-5)

Ethanol has been reviewed in the OECD-SIDS program (OECD, 2004a,b).

Environmental Transport

Fugacity-based modelling data show that ethanol released into the environment will become distributed mainly into air and water (OECD, 2004a,b).

Biodegradation

In aerobic conditions using adapted wastewater from domestic sewage, degradation was 74% after 5 days rising to 95% by day 15 and in similar conditions in synthetic seawater, ethanol was 45% degraded after 5 days rising to 75% by day 20 (Price, 1974).

Using a MITI protocol study, there was degradation of 89% after 14 days (>70% after 10 days, CERI, 2004) and (>90% within 10 days, Birch, 1991). Activated domestic sludges were capable of aerobically oxidizing ethanol, as measured by BOD, which was 37.3% of maximum after 1 day (Gerhold, 1966).

The rate of biodegradation in anaerobic conditions was calculated to be 17.9 ppm ethanol per day with a total methane recovery of 91% of the theoretical limit (Suflita, 1993). Biodegradation is the main method of removal of ethanol from water. Ethanol is stable to hydrolysis. Reaction with hydroxyl radicals in aquatic media will not likely be a significant process (Anbar, 1969).

Bioaccumulation

The bioconcentration factor (BCF) was estimated to be 3.16 L/kg using BCFBAF v. 3.01 (US EPA, 2011).

Aquatic Toxicity

The aquatic toxicity data in fish, invertebrates, and algae indicate a low order of acute toxicity with LC_{50}/EC_{50} values >1,000 mg/L (OECD, 2004a,b). The most sensitive species were algae, with a 96-hr EC_{50} for *Chlorella vulgaris* of 1,000 mg/L (El Jay, 1996).

Chronic toxicity studies in a variety of freshwater invertebrates show LC_{50} values of

>100 mg/L (Cowgill and Milazzo,1991). The lowest reported NOEC was 9.6 mg/L for *Cerodaphnia sp*.

A 5-day study using *Skeletonema costatum* gave a NOEC ranging from 3,240 to 5,400 mg/L based on cell count, with corresponding EC_{50} values of 10,943 - 11,619 mg/L. The authors commented that ethanol was used as a carbon source stimulating growth of the alga before inhibition began (Cowgill, 1989).

Toxicity to Terrestrial Plants

The 7-d NOEC values of higher (vascular) plants *Lemna gibba* and *L. minor* were 280 and 778 mg/L, respectively. The EC_{50} values for both plants were 4,432 mg/L (Cowgill, 1991).

Toxicity to Terrestrial Organisms

In the only study of the effect of ethanol on soil dwelling organisms found, the oligochaete worm *Eisenia foetida* showed a 48- hr LC_{50} of 0.1-1.0 mg/cm^2 loading on a filter paper test. The 'dosage', presented in terms of concentration in a given area of substrate is difficult to interpret but would have equated to the worms being exposed to a theoretical vapor concentration in the range 200-2000 mg/L (Roberts, 1984).

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (>1,000 mg/L), Daphnia (>1,000 mg/L), and algae (1,000 mg/L). Results from chronic studies are also available for all three trophic levels, with the lowest NOEC being 9.6 mg/L for invertebrates. On the basis that the data consists of short-term and long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported long-term NOEC of 9.6 mg/L for invertebrates. The $PNEC_{aquatic}$ is 0.96 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$. The Koc was calculated using EPISUITE (MCI method). Using a Koc of 1.0 and a $PNEC_{aquatic}$ of 0.96 mg/L, the $PNEC_{sediment}$ was calculated to be 0.61 mg/kg.

$PNEC_{soil}$: No relevant experimental toxicity data on terrestrial organisms are available. The equilibrium partition method was used to determine a $PNEC_{soil}$. The Koc was calculated using EPISUITE (MCI method). Using a Koc of 1.0 and a $PNEC_{aquatic}$ of 0.96 mg/L, the $PNEC_{soil}$ was calculated to be 0.0128 mg/kg.

PBT Assessment

Ethanol is readily biodegradable and thus it does not meet the screening criteria for persistence.

Based on an experimental log Kow of -0.31 and a calculated BCF of 3.16, ethanol does not meet the screening criteria for bioaccumulation.

The chronic toxicity data on ethanol show NOECs of >0.01 mg/L. Thus, ethanol does not meet the screening criteria for toxicity.

The overall conclusion is that ethanol is not a PBT substance.

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Environmental Assessment

Ethoxylated Fatty Acid Ester II

This ethoxylated fatty acid ester is a hydrophilic, non-ionic surfactant used in pharmaceutical preparations, and cosmetics as an emulsifier, dispersant, or stabilizer, and as a food additive. It is considered a mixture and thus a UVCB substance (substance of unknown or variable composition, complex reaction products or biological materials).

The water solubility for this substance has been reported to be 50-100 g/L at 23^{o} C (source unknown). This is consistent with the estimated water solubility of 25 g/L at 25^{o}C from the WATERNT program in EPISUITE.

There are no experimental data on the Kow. An estimated Kow is difficult to obtain since this is a UVCB substance. A Kow of approximately 1.5-1.6 was calculated based on certain assumptions about the structure.

Biodegradation

This substance was reported to biodegrade in less than 5 days. For the purposes of this assessment, this ethoxylated fatty acid ester will be considered to be inherently biodegradable.

Aquatic Toxicity

Following 10 hours of exposure, invertebrate lethality was noted at concentrations of 1-5%, and an EC_{50} in algae was reported to be 100 mg/L.

The 96-hour LC_{50} in fish was estimated to be 815 mg/L (ECOSAR); the 48-hr LC_{50} in daphnia was estimated to be 1,980 mg/L (ECOSAR); and the 96-hr EC_{50} in green algae based on general population growth was estimated to be 970 mg/L (ECOSAR).

Toxicity to Terrestrial Organisms

No data are available.

Determination of PNECs

Using the EC_{50} of 100 mg/L in algae and an assessment factor of 1,000, the $PNEC_{aquatic}$ is 0.1 mg/L.

Environmental Assessment

Ethoxylated Sorbitan Monooelate
Polysorbate 80
(CAS No. 9005-65-6)

Ethoxylated sorbitan monooleate or polysorbate 80 is a hydrophilic, non-ionic surfactant used in pharmaceutical preparations, and cosmetics as an emulsifier, dispersant, or stabilizer, and as a food additive. It is a mixture of oleic esters of sorbitan and its anhydrides copolymerized with approximately 20 mol of ethylene oxide (Sweetman, 2002). Thus, polysorbate 80 is considered a UVCB substance (substance of unknown or variable composition, complex reaction products or biological materials).

The water solubility of ethoxylated sorbitan monooleate has been reported to be 50-100 g/L at 23ºC (source unknown). This is consistent with the estimated water solubility of 25 g/L at 25ºC from the WATERNT program in EPISUITE.

There are no experimental data on the Kow for ethoxylated sorbitan monooleate. An estimated Kow is difficult to obtain since this polysorbate 80 is a UVCB substance. Carlsson et al. (2006) calculated a Kow of approximately 1.5-1.6 assuming a linear polyethylene glycol chain bound to sorbitan monooleate

Biodegradation

Polysorbate 80 was been reported to biodegrade in less than 5 days (Baleux and Caumette, 1974). In their environmental risk assessment, Carlsson et al. (2006) considered polysorbate 80 to be inherently biodegradable.

Aquatic Toxicity

Following 10 hours of exposure, invertebrate lethality was noted at concentrations of 1-5% (Saski *et al.*, 1971), and an EC_{50} in algae was reported to be 100 mg/L (Nyberg, 1998).

The 96-hr LC_{50} in fish was estimated to be 815 mg/L (ECOSAR); the 48-hr LC_{50} in daphnia was estimated to be 1,980 mg/L (ECOSAR); and the 96-hr EC_{50} in green algae based on general population growth was estimated to be 970 mg/L (ECOSAR).

Toxicity to Terrestrial Organisms

No data are available.

Determination of PNECs

Carlsson *et al.* (2006) calculated the following PNECs for ethoxylated sorbitan monooleate (polysorbate 80) using the acute algal EC_{50} of 100 mg/L, and assessment factors in accordance with the EU TGD. Using an assessment factor of 1,000, the $PNEC_{aquatic}$ is 0.1 mg/L.

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Environmental Assessment

Fatty Acid Ester

This fatty acid ester is a non-ionic surfactant-active agent that typically finds use as an emulsifier, stabilizer and thickener in foods, cosmetics, medical products, and lubricants, and other applications. It is approved by FDA as an indirect food additive.

Biodegradation

In an OECD 301C test, this fatty acid ester was degraded 62% in 28 days and did not meet the 10-day window. Thus, it is not readily biodegradable.

Aquatic Toxicity

This fatty acid ester caused no mortality in rainbow trout at nominal levels of 1,000 mg/L in an acute 96-hour fish toxicity study. The calculated water solubility of this fatty acid ester is 0.0191 mg/L. Thus, it appears that it would not be expected to cause acute toxicity at its water solubility limit.

The surrogate substance, has been evaluated in fish, daphnia and algae. The LC_{50} or EC_{50} value was reported to be greater than 1,000 mg/L [nominal loading concentrations in the water accommodated fraction (WAF) solutions tested] in all three aquatic species for this structurally analogous surrogate. The measured water solubility of the surrogate is <0.02 mg/L, which would suggest that this surrogate would not be expected to cause acute aquatic toxicity at its water solubility limit.

Toxicity to Terrestrial Organisms

No data are available.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available on the fatty acid ester and its surrogate for all three tropic levels. It was concluded that this fatty acid ester would not be expected to cause acute toxicity at its water solubility limit of 0.0191 mg/L. On the basis that the data consists of short-term results from three trophic level, an assessment factor of 1,000 has been applied to the water solubility limit of 0.0191 mg/L. The $PNEC_{aquatic}$ is 1.91×10^{-5} mg/L or 0.0191 µg/L.

Environmental Assessment

Guar Gum
(CAS No. 9000-30-0)

Guar gum (CAS No. 9000-30-0) is the milled endosperm of the leguminous plant *Cyanopsis tetragonolobus*. Structurally, it is a galactomannan (a polysaccharide) consisting of a main chain of D-mannose with a side chain of D-galactose at approximately every second mannose unit. The mannose units are β-(l-4) linked, and the single D-galactose units are joined to the main chain by α-(1-6) linkages. The estimated molecular weight of guar gum ranges from 200,000 to 300,000 daltons (Glickman, 1969).

Biodegradation

No information was found. Guar gum, being a polysaccharide composed of galactomannan, would be expected to be readily biodegradable.

Bioaccumulation

Not expected to bioaccumulate as a polysaccharide composed of galactomannans.

Aquatic Toxicity

The 48-hour LC_{50} for *Daphnia magna* was reported to be 42 mg/L (Biesinger *et al.*, 1976).

Toxicity to Terrestrial Organisms

No data were located.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for one trophic level. An acute LC_{50} value is available for the invertebrate Daphnia (42 mg/L). On the basis that the data consists of only one short-term result from one trophic level, an assessment factor of 1,000 has been applied to the reported effect concentration of 42 mg/L for Daphnia. The $PNEC_{aquatic}$ is 0.042 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The Kow and Koc of guar gum cannot be calculated using EPISUITE because the molecular weight of guar gum greatly exceeds the limit of 1,000. Thus, the equilibrium partition

method cannot be used to determine a $PNEC_{sediment}$ and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on soil organisms are available. The Kow and Koc of guar gum cannot be calculated using EPISUITE because the molecular weight of guar gum greatly exceeds the limit of 1,000. Thus, the equilibrium partition method cannot be used to determine a $PNEC_{soil}$ and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

No biodegradation was found on guar gum. However, guar gum is a naturally occurring polysaccharide which would be expected to readily biodegrade. Thus, it is not expected to meet the screening criteria for persistence.

The molecular weight of guar gum ranges from 200,000 to 300,000 daltons, and it is also water soluble. Thus, guar gum is not expected to meet the criteria for bioaccumulation.

The acute aquatic toxicity of guar gum is >0.1 mg/L. Thus, guar gum is not expected to meet the screening criteria for toxicity.

The overall conclusion is that guar gum is not a PBT substance.

References

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Environmental Assessment

Hydrocarbons, Terpene Processing By-products
(CAS No. 68956-56-9)

Terpenes and Terpenoids, Sweet Orange Oil
(CAS No. 68647-72-3)

CAS No. 68956-56-9 is a by-product of the manufacturing process in which high-quality gum turpentine oil or alpha pinene is synthesized into terpineol. It is largely composed of alpha terpinene, dl-limonene, cineol, gamma terpinene, terpinolene and other terpene hydrocarbons. The composition of CAS No. 68956-56-9 in the HPV Test Plan for Monoterpene Hydrocarbon Category is: 22-34% limonene, 22-33% terpinolene, 5-10% mycene, 18% limonene isomers, 10% other terpene hydrocarbons.

CAS No. 68647-72-3 is composed of 91-95% d-limonene, 1-3% beta-myrcene, and 1-2% alpha-pinene. (see HPV Test Plan for Monoterpene Hydrocarbon Category).

Biodegradation

Terpinolene was found to be biodegradable in two studies. In one study of inherent biodegradability, 80% biodegradation was reported using an OECD 302C guideline protocol after 28 and 31 days. In a study of ready biodegradability, 62.1% biodegradation was reported using an OECD 301B protocol after 28 days. One study of the ready biodegradability of terpinolene by OECD 301F reported it to be not readily biodegradable (51% after 28 days) but the authors concluded that the high vapor pressure and low water solubility of terpene hydrocarbons leads to volatilization in the upper parts of the test vessel, thereby, limiting aerobic biodegradation.

Limonene was readily biodegradable (41-98% degradation by biological oxygen demand in 14 days (OECD 301C).

Aquatic Toxicity

The 96-hour LC_{50}s in fathead minnows for limonene and terpinolene were reported to be 0.702 and 0.720 mg/L, respectively.

The 48-hour EC_{50} for limonene in *Daphnia pulex* was reported to be 69.6 mg/L. However, since the solubility of limonene is 13.8 mg/L at 25^{o}C, the actual test concentration is not known. The 96-hour LC_{50} value for limonene in *Daphnia magna* was reported to be 0.577 mg/L, while the 96-hour $EC_{50}$was 0.421 mg/L. When these tests were repeated using limonene from a different supplier, the 96-hour LC_{50} was 0.924 mg/L. The 48-hour LC_{50} for mycene in *Daphnia magna* was reported to be 31 mg/L and

is also considered unreliable given limits of solubility. For terpinolene, the 96-hour LC_{50} was reported to be 2.55 mg/L and the EC_{50} was reported to be 1.38 mg/L.

The 96-hour EC_{50}s for both limonene and terpinolene in green algae are >1.81 and >3.38 mg/L, respectively. Neither limonene nor terpinolene showed any significant inhibition at those test concentrations.

Toxicity to Terrestrial Organisms

The LC_{50} of *d*-limonene to earthworms (*Eisenia foetida* Savigny) is 6.0 ppm. The subacute dietary LC_{50} to Bobwhite quail (Colinus virginianus) is >5,620 ppm.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels for surrogates limonene and terpinolene. Acute $E(L)C_{50}$ values are available for fish (0.702 mg/L), Daphnia (0.421 mg/L), and algae (1.81 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 0.421 mg/L for Daphnia. The $PNEC_{aquatic}$ is 4.21×10^{-4} mg/L or 0.421 µg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$. The Koc was calculated using EPISUITE. Using a Koc of 6324 and a $PNEC_{aquatic}$ of 0.421 µg/L, the $PNEC_{sediment}$ was calculated to be 40 µg/kg (0.040 mg/kg).

$PNEC_{soil}$: Since there is limited experimental toxicity data on terrestrial organisms, the equilibrium partition method was used to determine a $PNEC_{soil}$. The Koc was calculated using EPISUITE. Using a Koc of 6324 and a $PNEC_{aquatic}$ of 0.421 µg/L, the $PNEC_{soil}$ was calculated to be 35 µg/kg (0.035 mg/kg).

PBT Assessment

This category of terpenes and terpenoids are considered to be readily biodegradable. Thus, terpenes and terpenoids do not meet the screening criteria for persistence.

The experimental log Kow values for d-limonene, terpinolene, beta-mycene and alpha-pinene are 4.38, 4.47, 4.44 and 4.17, respectively. The estimated BCF values using BCFFAF v. 3.01 for d-limonene, terpinolene, beta-mycene and alpha-pinene are 360.5, 413.3, 394.9, and 262 L/kg, respectively. Thus, this category of terpenes and terpenoids do not meet the screening criteria for bioaccumulation.

No chronic toxicity data exist terpenes and terpenoids; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, this category of terpenes and terpenoids do not meet the screening criteria for toxicity.

The overall conclusion is that this category of terpenes and terpenoids is not a PBT substance.

References

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Environmental Assessment

Hydrochloric acid
(CAS No. 7647-01-0)

Hydrochloric acid has been reviewed in the OECD-SIDS program (OECD, 202a,b).

Environmental Fate and Transport

Hydrochloric acid is readily dissociated in water into hydrated protons and chloride ions.

The increase in the concentration of hydrochloric acid in water decreases the pH in the aquatic ecosystem. Generally, the buffer capacity to maintain the pH in the aquatic ecosystem is important and the equilibrium between CO_2, HCO_3^- and CO_3^{2-} in the aquatic ecosystem is mainly responsible for the buffer capacity of receiving water.

$CO_2 + H_2O \leftrightarrow HCO_3^- + H^+$ ($pKa_1 = 6.35$)

$HCO_3^- \leftrightarrow CO_3^{2-} + H^+$ ($pKa_2 = 10.33$)

According to UNEP (1995), the mean, the 10th-percentile and the 90th-percentile of bicarbonate concentrations for 77 rivers in North-America, South-America, Asia, Africa, Europe and Oceania were 106, 20 and 195 mg/L, respectively. The buffering capacity for neutralization of receiving water with bicarbonate concentrations of 20, 106 and 195 mg/L is calculated to be 2.19, 11.60 and 21.3 mg/L, respectively.

Aquatic Toxicity

Several studies on the acute toxicity to fish have been published. The lowest 96-hour LC_{50} was reported to be 4.92 mg/L for *Cyprinus carpio* at pH 4.3 which was conducted according to OECD 203 guidelines (MLIT, 1999). The 96-hour LC_{50} for *Oncorhynchus mykiss* was 7.45 mg/L at pH 4.12 for hard water and 10.3 mg/L at pH 3.98 for soft water (Graham and Wood, 1981). The 96-hour LC_{50} in *Lepomis macrochirus* is 55.1 to 30.9 mg/L at pH 3.25 - 3.5; the low pH caused a reduction in the oxygen carrying capacity of hemoglobin and excessive secretion of mucus from the gills which in turn interfered with gas exchange (Ellgaard and Glimore, 1984).

Generally, the results of toxicity tests with acid or base depend on the buffer capacity of the test medium. Dechlorinated tap water was used as a test medium in the three tests described above. A 96-hour LC_{50} of 30.9 to 24.6 at pH 3.5-3.6 was obtained for *Lepomis macrochirus* using artificial water prepared from distilled water and analytical or reagent grade chemicals (Cairns and Scheier, 1959); other reported values are a 96-hour LC_{50} of 282 mg/L for *Gambusia affinis* (Wallen *et al.*, 1957) and a 16-hour LC_{100} value of 0.492 mg/L at pH 5.3 for the pike perch fry (*Lucioperca lucioperca*) conducted with pond water

(pH 6.0-8.2) are reported (Stangenberg, 1975). A 24-hr LC_{50} value of 60-80 mg/L for *Semotitus astromaculatus* with river water (pH 8.3) has also been reported. No long-term or chronic toxicity data on fish were located (Gillette *et al.*, 1952).

The 48-hour EC_{50} for *Daphnia magna* is 0.492 mg/L at pH 5.3 based on immobilization (MLIT, 1999). No long-term or chronic toxicity data on invertebrates have been reported. The 72-hour EC_{50} to *Selenastrum capriornutum* is 0.78 mg/L (pH 5.1) for biomass; 0.492 mg/L (pH 5.3) for growth rate; and the 72-hr-NOEC is 0.097 mg/L (pH 6.0) for biomass and growth rate (MLIT, 1999).

The hazard of hydrochloric acid for the environment is caused by the proton (pH effect). For this reason the effect of hydrochloric acid on the organisms depends on the buffer capacity of the aquatic ecosystem. Also, the variation in acute toxicity for aquatic organisms can be explained to a significant extent by the variation in buffer capacity of the test medium. For example, LC_{50} values of acute fish toxicity tests varied from 4.92 to 282 mg/L.

It is not considered useful to calculate a PNEC for hydrochloric acid because factors such as the buffer capacity, the natural pH, and the fluctuation of the pH are very specific for a certain ecosystem.

Toxicity to Terrestrial Organisms

No data are available.

Determination of PNECS

$PNEC_{aquatic}$: Based on the information above, a $PNEC_{aquatic}$ was not derived for hydrochloric acid.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Kow and Koc parameters do not readily apply to inorganics, such as hydrochloric acid. Thus;, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of hydrochloric acid to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. Sorption of hydrochloric acid should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Koc and Kow parameters do not readily apply to inorganics, such as hydrochloric acid. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, hydrochloric acid is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Hydrochloric acid is an organic salt that dissociates completely to hydrogen and chloride ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both hydrogen and chloride ions are also ubiquitous and are present in most water, soil and sediment. Thus, the persistent criteria is not considered applicable to this inorganic salt.

Hydrogen and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, hydrochloric acid is not expected to bioaccumulate.

No chronic toxicity data exist on hydrochloric acid; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, hydrochloric acid does not meet the screening criteria for toxicity.

The overall conclusion is that hydrochloric acid is not a PBT substance.

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Environmental Assessment

Monoethanolamine borate
(CAS No. 26038-87-9)

Monoethanolamine borate is also known as orthoboric acid, compound with 2-aminoethanol. It is a UVCB substance with the chemical formula: $C_2H_7NO.xBH_3O_3$.

Environmental Transport

Monoethanolamine (MEA) Polyborate 1:1 and MEA Polyborate 1:3 do not significantly adsorb to soil. The experimental log Koc was determined to be approximately 1.26.

Biodegradation

MEA Polyborate 1:1 was considered readily biodegradable in a modified Sturm test (OECD 301B). Degradation was 73% after 28 days.

MEA Polyborate 1:3 was considered readily biodegradable in a modified Sturm test (OECD 301B). Degradation was 75% after 28 days.

Aquatic Toxicity

The 96-hour LC_{50} in Carp for MEA Polyborate 1:3 is 617 mg/L.

The 48-hour EC_{50}s in *Daphnia magna* for MEA Polyborate 1:3 and MEA Polyborate 1:1 are 496 and 423 mg/L, respectively.

The 72-hour ErC_{50} in fresh water algae species *Pseudokirchneriella subcapitata* for MEA Polyborate 1:1 is 26 mg/L. The 72-hr EyC_{50} (yield inhibition) is 13 mg/L. The NOEC for growth rate reduction and yield inhibition is 3.2 mg/L. The 72-hr ErC_{50} in fresh water algae species *Pseudokirchneriella subcapitata* for MEA Polyborate 1:3 is 67 mg/L.

Toxicity to Sediment Organisms

No data are available.

Toxicity to Terrestrial Organisms

No data are available.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (617 mg/L), Daphnia (423 mg/L), and algae (13 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 13 mg/L for algae. The $PNEC_{aquatic}$ is 0.013 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$. The Koc was experimentally determined to be approximately 18.20. Using a Koc of 18.20 and a $PNEC_{aquatic}$ of 0.013 mg/L, the $PNEC_{sediment}$ was calculated to be 0.012 mg/kg.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The equilibrium partition method was used to determine a $PNEC_{soil}$. The Koc was experimentally determined to be approximately 18.20. Using a Koc of 18.20 and a $PNEC_{aquatic}$ of 0.013 mg/L, the $PNEC_{soil}$ was calculated to be 0.003 mg/kg (3.1 μg/kg).

PBT Assessment

Monoethanolamine borate is readily biodegradable and thus it does not meet the screening criteria for persistence.

Monoethanolamine borate is a UVCB substance and a log Kow cannot be accurately determined. For monoethanolamine itself, the measured log Kow and estimated BCF from BCFBAF v.3.01 are -1.6122 and 3.16 L/kg, respectively. The borate salt of monoethanolamine would not be expected to meet the screening criteria for bioaccumulation.

No chronic aquatic toxicity studies are available for monoethanolamine borate. The acute toxicity studies in fish, invertebrates and algae are >0.1 mg/L. Thus, monoethanolamine borate does not meet the criteria for toxicity.

The overall conclusion is that monoethanolamine borate is not a PBT substance.

Reference

ECHA REACH database: http://apps.echa.europa.eu/registered/registered-sub.aspx

Environmental Assessment

PEG Oleate Ester
[Poly(oxy-1,2-ethanediyl), .alpha.-hydro-.omega.-hydroxy-, (9Z)-9-octadecenoate]
(CAS No. 56449-46-8)

PEG oleate ester or polyethylene glycol oleate ester is an ethoxylated ester of oleic acid (http://legacy.library.ucsf.edu/tid/izs03c00/pdf); it is an UVCB substance with no defined ethylene oxide (EO) chain length. No data could be located for this particular substance.

An MSDS was found for BASF Cremophor® EL Castor Oil, which is ethoxylated castor oil. Castor oil contains 85-95% ricinoleic acid, 2-6% oleic acid, 1-5% linoleic acid; other fatty acids are <1%. Ricinoleic acid, a monounsaturated, 18-carbon fatty acid, is unusual in that it has a hydroxyl functional group on the 12th carbon. This functional group causes ricinoleic acid (and castor oil) to be unusually polar.

Information was also obtained from EPISuite v.4.10 (U.S. EPA, 2011) using PEG 18 oleate as a surrogate.

Biodegradation

BASF Cremophor® EL Castor Oil showed 90-100% degradation after 21 days in an OECD 302B study. It is biodegradable, but not readily biodegradable by OECD criteria.

PEG 18 oleate is predicted to not biodegrade fast by BIOWIN.

Aquatic Toxicity

BASF Cremophor® EL Castor Oil: The 48-hour LC_{50} in golden orfe is 448 mg/L. The 48-hour EC_{50} in *Daphnia* is >100 mg/L. The 72-hour EC_{50} in green algae is >93 mg/L.

The toxicity values for ethoxylated castor oil are in close agreement with those predicted for PEG 18 oleate by ECOSAR. For PEG 18 oleate, the estimated 96-hour LC_{50} in fish is 89 mg/L; the estimated 48-hour LC_{50} in *Daphnia* is 174 mg/L; and the 96-hour EC_{50} in green algae is 71 mg/L.

Toxicity to Terrestrial Organisms

No data are available.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (448 mg/L), Daphnia (>100 mg/L), and algae (>93 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 93 mg/L for algae. The $PNEC_{aquatic}$ is 0.093 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$. The Koc was calculated using EPISUITE (log Kow method). Using a Koc of 13.5 and a $PNEC_{aquatic}$ of 0.093 mg/L, the $PNEC_{sediment}$ was calculated to be 0.077 mg/kg.

$PNEC_{soil}$: No adequate experimental toxicity data on terrestrial organisms are available. The equilibrium partition method was used to determine a $PNEC_{soil}$. The Koc was calculated using EPISUITE (log Kow Method). Using a Koc of 13.5 and a $PNEC_{aquatic}$ of 0.093 mg/L, the $PNEC_{soil}$ was calculated to be 0.017 mg/kg.

PBT Assessment

The results of BIOWIN for PEG 18 oleate are as follows: does not biodegrade fast (Biowin 2); recalcitrant (Biowin 3); and does not biodegrade fast (Biowin 6). Thus, using PEG 18 oleate as a surrogate, PEG oleate ester meets the screening criteria for persistence.

For PEG 18 oleate, the estimated log Kow is 2.3772 and the estimated BCF is 17.2. Thus, using PEG 18 oleate as a surrogate, PEG oleate ester does not meet the screening criteria for bioaccumulation.

No chronic toxicity studies could be located on ethoxylated castor oil or PEG 18 oleate; however, the acute toxicity data on ethoxylated castor oil show values of >1 mg/L. Thus, using ethoxylated castor oil and PEG 18 oleate as surrogates, PEG oleate ester does not meet the screening criteria for toxicity.

The overall conclusion is that PEG oleate ester is not a PBT substance.

References

MSDS for BASF Cremophor® EL Castor Oil

U.S. EPA (2011) EPISuite v. 4.10, United States Environmental Protection Agency, Office of Pollution Prevention and Toxics and Syracuse Research Corporation.

Environmental Assessment

Sodium hydroxide
(CAS No. 1310-73-2)

Sodium hydroxide (NaOH) has been reviewed in the OECD-SIDS program (OECD, 2002a,b).

Environmental Fate

The high water solubility and low vapor pressure indicate that sodium hydroxide (NaOH) will be found predominantly in the aquatic environment. NaOH is present in the environment as sodium (Na^+) and hydroxyl (OH^-) ions, which implies that it will not adsorb on particulate matter or surfaces and will not accumulate in living tissues.

Measured concentrations in aquatic ecosystems
The concentration of hydroxyl ions in the environment has been determined very extensively via pH measurements. The pH is a very important parameter of aquatic ecosystems and it is a standard parameter of water quality monitoring programs. The most important freshwater aquatic ecosystems of the world revealed average annual pH values between 6.5 and 8.3 but lower and higher values have been measured in other aquatic ecosystems (UNEP, 1995). In aquatic ecosystems with dissolved organic acids a pH of less than 4.0 has been measured, while in waters with a high chlorophyll content the bicarbonate assimilation can result in pH values of higher than 9.0 at midday (UNEP, 1995). The pH of an aquatic ecosystem is mainly determined by geochemical, hydrological and/or biological processes.

Also sodium has been measured extensively in aquatic ecosystems. For example UNEP (1995) reported the concentration for a total number of 75 rivers in North-America, South-America, Asia, Africa, Europe and Oceania. The 10th –percentile, mean and 90th-percentile were 1.5, 28 and 68 mg/l, respectively.

NaOH addition and buffer capacity
An addition of NaOH to an aquatic ecosystem may increase the pH depending on the buffer capacity of the receiving water. In general the buffer capacity is regulated by the equilibria between CO_2, HCO_3^- and CO_3^{2-}:

$CO_2 + H_2O \leftrightarrow HCO_3^- + H^+$ ($pKa_1 = 6.35$)
$HCO_3^- \leftrightarrow CO_3^{2-} + H^+$ ($pKa_2 = 10.33$)

If the pH is between 7 and 9 then the bicarbonate ion is the most important species responsible for the buffer capacity of aquatic ecosystems. UNEP (1995) reported the bicarbonate concentration for a total number of 77 rivers in North-America, South-America, Asia, Africa, Europe and Oceania. The 10th– percentile, mean and 90th-percentile were 20, 106 and 195 mg/l, respectively.

Aquatic Toxicity

At concentrations reported in publications and study reports, the toxicity has been assumed to be due to hydroxide only, because at these effect concentrations the concentration of sodium is too low to explain the effects. However, it should be realized that the results of toxicity tests with NaOH depend on the buffer capacity of the test medium. In a highly buffered test medium the hydroxyl ion will be neutralized and the observed toxicity will be low, while in a poorly buffered test medium the pH will increase rapidly and therefore the observed toxicity will be relatively high. Besides the direct effects (pH change) NaOH could also have indirect effects. The pH change could influence the speciation of other chemicals and therefore increase and/or decrease the toxicity *e.g.*, NH_3 is more toxic than NH_4^+.

The 24-hour LC_{50} to *Carassius auratus* (goldfish) is 160 mg/L . At 100 mg/L, which was equivalent to a pH of 9.8, no mortality was observed. The 48-hour LC_{50} to *Leuciscus idus melanotus*, is 189 mg/L. The 96-hour LC_{50} of *Gambusia affinis* (mosquitofish) is 125 mg/L. At 84 mg/L, no effects on the fish were observed. The pH was 9 at 100 mg/L. The 48-hour LC_{50} is 40 mg/L for *Ceriodaphnia* cf. *dubia*. The toxicity threshold concentration of NaOH for *Daphnia magna* was reported to range from 40 to 240 mg/L.

No data are available on the effects of NaOH on algae.

Toxicity to Terrestrial Organisms

Toxicity tests, which determined the effects of NaOH on terrestrial organisms, are not available. Significant exposure of the terrestrial environment is not expected and for this reason there is no need to perform toxicity test with terrestrial organisms. The results of terrestrial toxicity tests will depend strongly on the buffer capacity of the soil and can probably be predicted based on the buffer capacity of the soil.

Determination of PNECs

In many cases pH, buffer capacity and/or medium composition were not discussed in the publications, although this is essential information for toxicity tests with NaOH. This is the most important reason why most of the studies, mentioned above were considered invalid. Although valid acute ecotoxicity tests and chronic ecotoxicity tests with NaOH are not available there is no need for additional testing with NaOH. A significant number of acute toxicity tests are available and the results of the tests are more or less consistent. Altogether they give a sufficient indication about acute toxicity levels of sodium hydroxide.

Furthermore acute toxicity data cannot be used to derive a PNEC or a PNEC added for sodium hydroxide. Aquatic ecosystems are characterized by an alkalinity/pH and the organisms of the ecosystem are adapted to these specific natural conditions. Based on the natural alkalinity of waters, organisms will have different optimum pH conditions, ranging from poorly buffered waters with a pH of 6 or less to very hard waters with pH values up to 9. A lot of information is available about the relationship between pH and ecosystem structure and also natural variations in pH of aquatic ecosystems have been quantified and reported extensively in ecological publications and handbooks.

Normally a PNEC or a PNEC added has to be derived from the available ecotoxicity data. A PNEC added is a PNEC which is based on added concentrations of a chemical (added risk approach). Based on the available data it is not considered useful to derive a PNEC or a PNEC added for NaOH because:

- The natural pH of aquatic ecosystems can vary significantly between aquatic ecosystems,

- Also the sensitivity of the aquatic ecosystems to a change of the pH can vary significantly between aquatic ecosystems and

- The change in pH due to an anthropogenic NaOH addition is influenced significantly by the buffer capacity of the receiving water.

Although a PNEC or a PNEC added was not calculated for NaOH there is a need to assess the environmental effect of an NaOH (alkaline) discharge. Based on the pH and buffer capacity of effluent and receiving water and the dilution factor of the effluent, the pH of the receiving water after the discharge can be calculated. Of course the pH change can be measured also very easily via a laboratory experiment or by conducting field measurements. The change in pH should be compared with the natural variation in pH of the receiving water and based on this comparison it should be assessed if the pH change is acceptable.

$PNEC_{aquatic}$: Based on the information above, a PNEC was not derived for sodium hydroxide.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Sodium hydroxide dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc parameters do not readily apply to inorganics, such as sodium hydroxide. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of sodium hydroxide to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The environmental distribution of sodium hydroxide is dominated by its water solubility.

Sorption of sodium hydroxide should probably be regarded as a reversible situation, i.e., the substance is not tightly nor permanently bound. Koc and Kow parameters do not readily apply to inorganics, such as sodium hydroxide Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, sodium hydroxide is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Sodium hydroxide is an organic salt that dissociates completely to sodium and hydroxide ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both sodium and hydroxide ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria is not considered applicable to this inorganic salt.

Sodium and hydroxide ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, sodium hydroxide is not expected to bioaccumulate.

No chronic toxicity data exist on sodium hydroxide; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, sodium hydroxide does not meet the screening criteria for toxicity.

The overall conclusion is that sodium hydroxide is not a PBT substance.

References

OECD (2002a). IUCLID Data Set for Sodium hydroxide (CAS No. 1310-73-2), UNEP Publications.

OECD (2002b). Screening Information Dataset (SIDS) Initial Assessment Report for Sodium hydroxide (CAS No. 1310-73-2), UNEP Publications.

Environmental Assessment

Sodium sulfate
(CAS No. 7757-82-6)

Sodium sulfate has been reviewed in the OECD-SIDS program (2005a,b).

Environmental Fate

Sodium sulfate is a solid inorganic salt that is highly soluble in water (161-190 g/L at 20^{o} C); with a melting point of 884^{o} C; and density of 2.7 g/cm^{3}. Sodium sulfate fully dissociates to sodium and sulfate ions in water.

Sulfates are not expected to bioaccumulate in the soil or in aqueous solution. Sodium and sulfate ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. However, some plants (*e.g.* corn and *Kochia Scoparia*), are capable of accumulating sulfate to concentrations that are potentially toxic to ruminants.

In anaerobic environments sulfate is biologically reduced to (hydrogen) sulfide by sulfate reducing bacteria, or incorporated into living organisms as source of sulfur, and thereby included in the sulfur cycle.

Aquatic Toxicity

Algae were shown to be the most sensitive to sodium sulfate: the 120-hour EC_{50} is 1,900 mg/L. For invertebrates *(Daphnia magna)*, the 48-hour EC_{50} is 4,580 mg/L and fish appeared to be the least sensitive with a 96-hour LC_{50} of 7,960 mg/L for *Pimephales promelas*.

No data were found for chronic toxicity.

Toxicity to Sediment Organisms

The 96-hour LC_{50} of 660 mg/L was reported for *Trycorythus sp*.

Toxicity to Terrestrial Organisms

Sodium sulfate is not very toxic to terrestrial plants. *Picea banksiana* was the most sensitive species, an effect was seen at 1.4 g/L.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (7,960 mg/L), Daphnia (4,580 mg/L), and algae (1,900 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 1,900 mg/L for Daphnia. The $PNEC_{aquatic}$ is 1.9 mg/L.

$PNEC_{sediment}$: No reliable experimental toxicity data on sediment organisms are available. Sodium sulfate dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc parameters do not readily apply to inorganics, such as sodium sulfate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of sodium sulfate to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No reliable experimental toxicity data on terrestrial organisms are available. The environmental distribution of sodium sulfate is dominated by its water solubility. Sorption of sodium sulfate should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Koc and Kow parameters do not readily apply to inorganics, such as sodium sulfate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, sodium sulfate is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Sodium sulfate is an organic salt that dissociates completely to sodium and sulfate ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both sodium and sulfate ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria is not considered applicable to this inorganic salt.

Sodium and sulfate ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, sodium sulfate is not expected to bioaccumulate.

No chronic toxicity data exist on sodium sulfate; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, sodium sulfate does not meet the screening criteria for toxicity.

The overall conclusion is that sodium sulfate is not a PBT substance.

References

OECD (2005a). IUCLID Data Set for Sodium sulfate (CAS No. 7757-82-6), UNEP Publications.

OECD (2005b). Screening Information Dataset (SIDS) Initial Assessment Report for Sodium sulfate (CAS No. 7757-82-6), UNEP Publications.

Environmental Assessment

Sodium sulfite
(CASRN 7757-83-7)

Sodium sulfite has been reviewed in the OECD-SIDS program (OECD, 2008a,b).

Environmental Fate

Sodium sulfite completely dissociates into the sodium and sulfite ions in aqueous solutions.

Sodium sulfite is a salt of sulfurous acid (H_2SO_3). Sulfurous acid dissociates in aqueous solutions (pKa_1 = 1.8; pKa_2 = 7.0 at 25°C). At neutral pH, a mixture of 50% sulfite (SO_3^{2-}) and 50% bisulfite (HSO_3^-) is present. At concentrations above 1M, bisulfite anions will dimerize with the elimination of water to form metabisulfite ($S_2O_5^{2-}$). At low concentrations, metabisulfite will hydrolyze to form bisulfite.

In surface waters, sulfite is oxidized to sulfate either catalytically by air oxygen or by microbial action. The half-life in deionized water was determined to be 77 hours. The presence of cations like iron, copper or manganese in the environment accelerates the oxidation rate significantly.

Aquatic Toxicity

For the interpretation of the test results the instability of the test solutions has to be considered. Sulfite is rapidly oxidized to sulfate, the reaction is accompanied with consumption of dissolved oxygen. Therefore, the observed effects can be caused either by sulfite toxicity or by lack of oxygen. The available results indicate that algae represent the most sensitive trophic level, followed by daphnids and fish.

Species	**Test Substance**	**96-hour LC_{50}***
Leuciscus idus	Sodium sulfite	215-464
Danio rerio	Dipotassium disulfite	570-1100**
Oncorhynchus mykiss	Sodium hydrogensulfite	>1,200
Oncorhynchus mykiss	Disodium disulfite	200-290
Leuciscus idus	Potassium sulfite	170-370

*Results are expressed as sodium sulfite.

**The referred concentrations are the sum of measured sulfite and sulfate concentrations. Assuming that the toxicity is caused exclusively by sulfite, the LC_{50} would be 12-220 mg/L (based on measurements after 96 h).

The 48-hour EC_{50} of sodium disulfite in *Daphnia magna* is 118 mg/L (expressed as Na_2SO_3) was obtained after 48 hours of exposure.

Species	Test Substance	Results	Endpoint
Chlamydomonas reinhardtii	Sodium sulfite	NOEC = 37.8 mg/L EC_{50} = 63-126 mg/L	Growth
Chlorella vulgaris	Sodium sulfite	NOEC = 37.8-63 mg/L EC_{50} = 63-126 mg/L	Growth
Scenedesmus basiliensis	Sodium sulfite	NOEC = 37.8-50.4 mg/L EC_{50} = 63-126 mg/L	Growth
Scenedesmus subspicatus	Sodium sulfite	EC_{20} = 52 mg/L EC_{50} = 77 mg/L	Growth

A long-term test on *Daphnia magna* was conducted using sodium disulfite as test substance. After 21 days of exposure, no effects were observed at all concentrations at either 1.3 or 13 mg/L (expressed as sodium sulfite). The NOEC is >13 mg/L.

Toxicity to Terrestrial Plants

In a study in which the effect of sulfite on the root growth of barley grains (*Hordeum vulgare*) was investigated, the roots were exposed to eight concentrations between 0.1 and 30 mM (pH 7) for 120 hours. At 0.1 mM slight stimulation of growth was observed, while at 0.5 mM root length decreased to ca. 6.1 cm (control ca. 6.7 cm, values taken from a graphic). 50% inhibition was reached at concentrations between 10 and 15 mM.

In another study, slices from leaves of *Vicia faba* in solutions containing various sodium sulfite concentrations (0.001-10 mM) was investigated. The oxygen uptake was stimulated at concentrations equal or lower than 0.1 mM (12.6 mg Na_2SO_3), higher concentrations had a dramatic inhibiting effect. The evolution of oxygen was inhibited by 20% at 0.01 mM (1.26 mg Na_2SO_3) and by 100% at 0.5 mM (63 mg Na_2SO_3).

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (170 mg/L), Daphnia (118 mg/L), and algae (63 mg/L). Long-term results are available for Daphnia (21-day NOEC: >13 mg/L) and algae (EC_{20} = 52 mg/L). On the basis that the data consists of long-term results from two trophic levels, an assessment factor of 50 has been applied to the lowest reported NOEC concentration of 13 mg/L for Daphnia. The $PNEC_{aquatic}$ is 0.26 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Sodium sulfite dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc parameters do not readily apply to inorganics, such as sodium sulfite. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of sodium sulfite to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No reliable experimental toxicity data on terrestrial organisms are available. The environmental distribution of sodium sulfite is dominated by its water solubility. Sorption of sodium sulfite should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Koc and Kow parameters do not readily apply to inorganics, such as sodium sulfite. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, sodium sulfite is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Sodium sulfite is an organic salt that dissociates completely to sodium and sulfite ions in aqueous solutions. Sulfite is also naturally present in the environment, formed from the release of sulfur dioxide by natural and anthropogenic sources. Sulfite is rapidly oxidized to sulfate in water. Biodegradation is not applicable to these inorganic ions; sodium and sulfate ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria is not considered applicable to this inorganic salt.

The sulfite ion is rapidly oxidized to sulfate in water. Both sodium and sulfate ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, sodium sulfite is not expected to bioaccumulate.

No chronic toxicity data exist on sodium sulfite; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, sodium sulfite does not meet the screening criteria for toxicity.

The overall conclusion is that sodium sulfite is not a PBT substance.

References

OECD (2008a). IUCLID Data Set for Sodium sulfite (CAS No. 7757-83-7).

OECD (2008b). Screening Information Dataset (SIDS) Initial Assessment Report for Sodium sulfite (CAS No. 7757-83-7).

Environmental Assessment

Sodium thiosulfate
(CAS No. 7772-98-7)

Environmental Fate

Ammonium thiosulfate is an inorganic compound that dissociates completely in water. Thiosulfate is a metastable, moderately reducing oxyanion of sulfur. Chemical reactions (redox reactions) of thiosulfate generate chemical species of sulfur that differ in their oxidation state. The thiosulfate anion is only stable in neutral or alkaline media. It is unstable in acid media. In aqueous media, thiosulfate irreversibly disproportionates to sulfide and sulfate. The chemistry of sulfur in soils (and in water) is complex because of its many oxidation states. The terminal, thermodynamically-favored reaction product of thiosulfate is sulfate, except in highly reduced soils (U.S. EPA, 2007).

Aquatic Toxicity

No data are available for sodium thiosulfate. However, studies have been conducted on ammonium thiosulfate, which will be used as read-across to sodium thiosulfate.

The 96-hour LC_{50} of ammonium thiosulfate is 510 mg/L in *Lepomis macrochirus* and 770 mg/L in *Salmo gairdneri*. The 48-hour EC_{50} of ammonium thiosulfate in *Daphnia magna* is 230 mg/L. The 72-hour EC_{50} of ammonium thiosulfate in algae *Pseudokirchneriella subcapitata* is >100 mg/L (NOEC: 100 mg/L).

Toxicity to Terrestrial Plants

Seeds of corn were germinated on ammonium thiosulfate-spiked soil, and effects on germination, root growth and shoot growth were monitored for a 7-day exposure period. Root growth was the most sensitive endpoint, and resulted in a NOEC of 100 mg ATS/kg dry wt. Expressed as thiosulfate, this value becomes 75.7 mg thiosulfate/kg soil.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (510 mg/L), Daphnia (230 mg/L), and algae (100 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 100 mg/L for algae. The $PNEC_{aquatic}$ is 0.1 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Sodium thiosulfate dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc parameters do not readily apply to inorganics, such as sodium thiosulfate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of sodium thiosulfate to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No reliable experimental toxicity data on terrestrial organisms are available. The environmental distribution of sodium thiosulfate is dominated by its water solubility. Sorption of sodium thiosulfate should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Koc and Kow parameters do not readily apply to inorganics, such as sodium thiosulfate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, sodium thiosulfate is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Sodium thiosulfate is an organic salt that dissociates completely to sodium and thiosulfate ions in aqueous solutions. Thiosulfate irreversibly disproportionates to sulfide and sulfate in aqueous media, with the terminal, thermodynamically-favored reaction product of thiosulfate being sulfate, except in highly reduced soils. Biodegradation is not applicable to these inorganic ions; sodium and sulfate ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria is not considered applicable to this inorganic salt.

Both sodium and sulfate ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, sodium thiosulfate is not expected to bioaccumulate.

No chronic toxicity data exist on sodium thiosulfate; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, sodium thiosulfate does not meet the screening criteria for toxicity.

The overall conclusion is that sodium thiosulfate is not a PBT substance.

Reference

ECHA REACH database, http://apps.echa.europa.eu/registered/registered-sub.aspx

U.S. EPA (2007). Reregistration Elibility Decision (RED) for Ammonium Thiosulfate, Office of Prevention, Pesticides an Toxic Substances, EPA 738-R-07-001, December 20, 2007.

Environmental Assessment

Sorbitan Monooelate
(CAS No. 1338-43-8)

Sorbitan fatty acid esters are non-ionic surfactant-active agents that typically find use as emulsifiers, stabilizers and thickeners in foods, cosmetics, medical products, lubricants and other applications (Andersen, 2002; Eisenhard, 1999). Sorbitan monooleate is approved by FDA as an indirect food additive.

The information in this toxicity profile was obtained from the U.S. EPA HPV Test Plan for Sorbitan Esters Category of the Aliphatic Esters Chemicals, November 26, 2003.

Biodegradation

In an OECD 301C test, sorbitan monooleate was degraded 62% in 28 days and did not meet the 10-day window. Thus, it is not readily biodegradable.

Aquatic Toxicity

Sorbitan monooleate caused no mortality in rainbow trout at nominal levels of 1,000 mg/L in an acute 96-hour fish toxicity study. The calculated water solubility of sorbitan monooleate is 0.0191 mg/L. Thus, it appears that sorbitan monooleate would not be expected to cause acute toxicity at its water solubility limit.

The surrogate substance, sorbitan fatty acid C6-10 tetraester (CAS NO. 228573-47-5) has been evaluated in fish, daphnia and algae. The LC_{50} or EC_{50} value was reported to be greater than 1,000 mg/L [nominal loading concentrations in the water accommodated fraction (WAF) solutions tested] in all three aquatic species for this structurally analogous surrogate. The measured water solubility of sorbitan fatty acid C6-10 tetraester is <0.02 mg/L, which would suggest that this surrogate sorbitan ester would not be expected to cause acute aquatic toxicity at its water solubility limit.

Toxicity to Terrestrial Organisms

No data are available.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available on either sorbitan monoleate or its surrogate sorbitan fatty acid C6-C10 tetraester for all three tropic levels. It was

concluded that sorbitan monooleate would not be expected to cause acute toxicity at its water solubility limit of 0.0191 mg/L. On the basis that the data consists of short-term results from three trophic level, an assessment factor of 1,000 has been applied to the water solubility limit of 0.0191 mg/L. The $PNEC_{aquatic}$ is 1.91×10^{-5} mg/L or 0.0191 μg/L.

References

Andersen, F.A. (2002). Final report on the safety assessment of sorbitan caprylate, sorbitan cocoate, sorbitan diisostearate, sorbitan dioleate, sorbitan distearate, sorbitan isostearate, sorbitan olivate, sorbitan sesquiisostearate, sorbitan sesquistearate, and sorbitan triisostearate. Int. J. Toxicol. 21 (Suppl. 1): 93-112.

Eisenhard, W.C. (1999). Esterification *in* Fatty Acids in Industry: Process, Properties, Derivatives, Applications. Johnson RW, Fritz E (eds.), Marcel Dekker, New York, pp. 139-152.

U.S. EPA HPV Test Plan for Sorbitan Esters Category of the Aliphatic Esters Chemicals, November 26, 2003.

Environmental Assessment

Terpenes and Terpenoids
Terpenes and Terpenoids, Sweet Orange Oil
(CAS No. 68647-72-3)

The chemical category designated terpenes and terpenoids are hydrocarbons that can include C_{10} isomeric monocyclic terpene hydrocarbons (*d*-limonene, *dl*-limonene, and terpinolene) and two C_{10} acyclic terpene hydrocarbons (*beta*-myrcene and dihydromyrcene).

Terpenes and terpenoids, sweet orange oil (CAS No. 68647-72-3) is composed of 91-95% d-limonene, 1-3% beta-myrcene, and 1-2% alpha-pinene.

Biodegradation

Terpinolene was found to be biodegradable in two studies. In one study of inherent biodegradability, 80% biodegradation was reported using an OECD 302C guideline protocol after 28 and 31 days. In a study of ready biodegradability, 62.1% biodegradation was reported using an OECD 301B protocol after 28 days. One study of the ready biodegradability of terpinolene by OECD 301F reported it to be not readily biodegradable (51% after 28 days) but the authors concluded that the high vapor pressure and low water solubility of terpene hydrocarbons leads to volatilization in the upper parts of the test vessel, thereby, limiting aerobic biodegradation.

Limonene was readily biodegradable (41-98% degradation by biological oxygen demand in 14 days (OECD 301C).

Aquatic Toxicity

The 96-hour LC_{50}s in fathead minnows for limonene and terpinolene were reported to be 0.702 and 0.720 mg/L, respectively.

The 48-hour EC_{50} for limonene in *Daphnia pulex* was reported to be 69.6 mg/L. However, since the solubility of limonene is 13.8 mg/L at 25^{o}C, the actual test concentration is not known. The 96-hour LC_{50} value for limonene in *Daphnia magna* was reported to be 0.577 mg/L, while the 96-hour $EC_{50}$was 0.421 mg/L. When these tests were repeated using limonene from a different supplier, the 96-hour LC_{50} was 0.924 mg/L. The 48-hour LC_{50} for mycene in *Daphnia magna* was reported to be 31 mg/L and is also considered unreliable given limits of solubility. For terpinolene, the 96-hour LC_{50} was reported to be 2.55 mg/L and the EC_{50} was reported to be 1.38 mg/L.

The 96-hour EC_{50}s for both limonene and terpinolene in green algae are >1.81 and >3.38 mg/L, respectively. Neither limonene nor terpinolene showed any significant inhibition at those test concentrations.

Toxicity to Terrestrial Organisms

The LC_{50} of *d*-limonene to earthworms (*Eisenia foetida* Savigny) is 6.0 ppm. The subacute dietary LC_{50} to Bobwhite quail (Colinus virginianus) is >5,620 ppm.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels for surrogates limonene and terpinolene. Acute $E(L)C_{50}$ values are available for fish (0.702 mg/L), Daphnia (0.421 mg/L), and algae (1.81 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 0.421 mg/L for Daphnia. The $PNEC_{aquatic}$ is 4.21×10^{-4} mg/L or 0.421 µg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$. The Koc was calculated using EPISUITE. Using a Koc of 6324 and a $PNEC_{aquatic}$ of 0.421 µg/L, the $PNEC_{sediment}$ was calculated to be 40 µg/kg (0.040 mg/kg).

$PNEC_{soil}$: Since there is limited experimental toxicity data on terrestrial organisms, the equilibrium partition method was used to determine a $PNEC_{soil}$. The Koc was calculated using EPISUITE. Using a Koc of 6324 and a $PNEC_{aquatic}$ of 0.421 µg/L, the $PNEC_{soil}$ was calculated to be 35 µg/kg (0.035 mg/kg).

PBT Assessment

This category of terpenes and terpenoids are considered to be readily biodegradable. Thus, terpenes and terpenoids do not meet the screening criteria for persistence.

The experimental log Kow values for d-limonene, terpinolene, beta-mycene and alpha-pinene are 4.38, 4.47, 4.44 and 4.17, respectively. The estimated BCF values using BCFFAF v. 3.01 for d-limonene, terpinolene, beta-mycene and alpha-pinene are 360.5, 413.3, 394.9, and 262 L/kg, respectively. Thus, this category of terpenes and terpenoids do not meet the screening criteria for bioaccumulation.

No chronic toxicity data exist terpenes and terpenoids; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, this category of terpenes and terpenoids do not meet the screening criteria for toxicity.

The overall conclusion is that this category of terpenes and terpenoids is not a PBT substance.

References

NICNAS (2002). Limonene. Priority Existing Chemical Assessment Report No. 22, National Industrial Chemicals Notification and Assessment Scheme, Australia.

U.S. EPA HPVIS database, http://www.epa.gov/chemrtk/hpvis/index.html

Environmental Assessment

Tetrakis(hydroxymethyl)phosphonium sulfate
(CAS No. 55566-30-8))

Environmental Fate and Transport

Tetrakis(hydroxymethyl)phosphonium sulfate (THPS) has a high water solubility and very low volatility. Photodegradation and hydrolysis of THPS are significant abiotic degradation pathways in the environment. THPS binds poorly to environmental particulates and is, therefore, mobile.

THPS is inherently biodegradable. In an OECD 302B study, greater than 20% degradation occurred within a 28-day period (IPCS, 2000). Aquatic aerobic degradation of THPS was assessed in a soil/water system using U.S. EPA guidelines. The soil was dosed with THPS at 1 μg/g. Radiolabeled THPS was metabolized with 60% of applied radioactivity appearing as CO_2 within 7 days. Major metabolites were trihydroxymethyl phosphine oxide (THPO) and bishydroxymethyl phosphonic acid (BMPA), which were both found in the water; neither degradate reached a concentration of 10% of the applied dose (IPCS, 2000). A comparable study at the same initial concentration of THPS but under anaerobic conditions also showed 60% degradation within 30 days, and the same breakdown products were identified (IPCS, 2000).

Aquatic Toxicity

The acute 96-hour LC_{50} in *Oncorhynchus mykiss* (rainbow trout) is 119 mg/L (IPCS, 2000). The acute 96-hour LC_{50} in (*Lepomis macrochirus*) bluegill sunfish is 93 mg/L (IPCS, 2000). The acute 96-hour LC_{50} in (*Cyprinodon variegatus*) sheepshead minnow is 72 mg/L (IPCS, 2000).

The 48-hour LC_{50} in *Daphnia magna* is 19.4 mg/L (IPCS, 2000).

The 72-hour EC_{50}s in freshwater green algae *Selenastrum capricornutum* are 0.652 mg/L (growth rate) and 0.204 mg/L (biomass). The NOECs were 0.063 mg/L (IPCS, 2000).

Toxicity to Sediment Organisms

No data could be located for freshwater sediment organisms. A 10-day LC_{50} for *Corophium volutator* was reported to be 2,174 mg/kg dry sediment weight (IPCS, 2000).

Toxicity to Terrestrial Organisms

The LD_{50} to mallard duck (*Anas platyryncus*) is 311 mg/kg (IPCS, 2000). The dietary LC_{50}s to mallard ducks and bobwhite quail are 1,313 and 2,414 mg/kg diet, respectively (IPCS, 2000).

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (72 mg/L), Daphnia (19.4 mg/L), and algae (0.204 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 0.204 mg/L for fish. The $PNEC_{aquatic}$ is calculated to be 0.0002 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on freshwater sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$. The Koc was calculated to be 142.3. Using a Koc of 142.3 and a $PNEC_{aquatic}$ of 0.204 µg/L, the $PNEC_{sediment}$ was calculated to be 0.56 µg/kg.

$PNEC_{soil}$: No adequate experimental toxicity data on terrestrial organisms are available. The equilibrium partition method was used to determine a $PNEC_{soil}$. The Koc was calculated to be 142.3. Using a Koc of 142.3 and a $PNEC_{aquatic}$ of 0.204 µg/L, the $PNEC_{soil}$ was calculated to be 0.38 µg/kg.

PBT Assessment

The results of BIOWIN v4.10 for THPS are as follows: biodegrade fast (Biowin2); ultimate biodegradation timeframe is days-weeks (Biowin3); and biodegrades fast (Biowin 6). Thus, THPS does not meet the screening criteria for persistence.

The estimated log Kow for THPS using EPISUITE is -20.39. Hydrolysis is also indicated as a significant abiotic degradation process. Thus, THPS does not meet the screening criteria for bioaccumulation.

The NOEC from a 72-hour green algae study was reported to be 0.063 mg/L, which is <0.1 mg/L. Thus, THPS meets the criteria for toxicity.

The overall conclusion is that Tetrakis(hydroxylmethyl)phosphonium sulfate is not a PBT substance.

Reference

IPCS (2000). Flame Retardants: Tris(2-butoxyethyl)phosphate, Tris (2-ethylhexyl) phosphate and tetrakis (hydroxymethyl)phosphonium Salts, Environmental Health

Criteria 218, International Programme on Chemical Safety, United Nations Environment Programme, International Labour Organisation, World Health Organization.

COFFEE EXTRACT

This dossier on coffee extract does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of coffee extract in its use in hydraulic fracturing fluids. The information presented in this dossier was obtained from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBSTANCE IDENTIFICATION

Chemical Name: Coffee, bean, roasted, extract

CAS RN: 68916-18-7

Molecular formula: UVCB substance

Molecular weight: UVCB substance

Synonyms: Coffee extract; coffee, bean, roasted, extract

Table 1 shows all of the constituents found in roasted arabica and robusta coffees.

Table 1: Composition of Medium-Roasted Coffee (Clarke, 1987; IARC, 1991)

Components	**Typical average content (dry basis, %)**		**% extractable with water, 100°C[a]**
	Arabica	**Robusta**	
Alkaloids (caffeine)	1.3	2.4	75 - 100
Trigonelline (including roasted by-products)	1.0	0.7	85 - 100
Minerals (as oxide ash)	4.5	4.7	90
Acids			
Residual chlorogenic	2.5	3.8	100
Aquinic	0.8	1.0	100
Aliphatic	1.6	1.6	100
Sugars			
Sucrose	0.0	0.0	-
Reducing	0.3	0.3	100

Polysaccharides (unchanged from green)	33	37	10
Lignin	2.0	2.0	0
Pectins	3.0	3.0	-
Proteinaceous compounds			
Protein	10	10	15 – 20
Free amino acids	0.0	0.0	-
Lipids (coffee oil)	17	11	1
Caramelized or condensation products (*e.g.*, melanoidins) by difference	23	22.5	20-25
Volatile substances other than acids	0.1	0.1	40-80

[a]Maier (1981), for normal household brewing

II. PHYSICO-CHEMICAL PROPERTIES

Table 2: Overview of the Physico-chemical Properties of Coffee Extract

Property	**Value**	**Klimisch score**	**Reference**
Physical state at 20°C and 101.3 kPa	Viscous liquid	2	ECHA
Melting point	ca. -16.82 to -15.95°C	1	ECHA
Boiling point	>102.21°C	1	ECHA
Density	1.234 g/cm^3 @ 20°C	1	ECHA
Vapor pressure	21.8 Pa @ 20°C	1	ECHA
Partition coefficient (log K_{ow})	<0.36 @ 25°C	1	ECHA
Water solubility	2.85 mg/L @ 25°C	1	ECHA
Flash point	No flash to boiling.	1	ECHA
Auto flammability	>600°C	1	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Coffee extract is inherently biodegradable and is expected to have a low potential for bioaccumulation. The potential for adsorption is unknown; however, the low octanol water partition coefficient for coffee extract suggests that it is low. The acute toxicity by the oral and dermal routes is low.

B. Biodegradation

Coffee extract is inherently biodegradable. In an OECD 301D test, degradation was 50.2% after 28 days (ECHA) [Kl. score = 1].

C. Environmental Distribution

Adsorption/desorption

No experimental data are available for coffee extract. Coffee extract is an UVCB substance containing a wide range of different constituents (see Table 1); thus, a K_{oc} value cannot be calculated.

D. Bioaccumulation

No bioconcentration studies have been conducted on coffee extract. Coffee extract is not expected to bioaccumulate based on the experimental log K_{ow} of <0.36 (ECHA).

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

The information on the human health hazard for coffee extract includes primarily data on caffeine, the pharmacologically active constituent of coffee extract, as well as the extract itself. Coffee extract is not irritating to the skin or eyes. Caffeine consumption up to 400 mg caffeine/day in healthy adults is not associated with overt, adverse cardiovascular effects, behavioral effects, reproductive and developmental effects, acute effects, or bone status. Also, consumption up to 300 mg caffeine/day in healthy pregnant women is generally not associated with adverse reproductive and developmental effects.

B. Pharmacokinetics

Caffeine is rapidly and completely adsorbed in humans, with approximately 99% absorbed within 45 minutes of consumption (Carillo and Benitez, 2000). Plasma caffeine levels may be influenced by the diet or route of exposure, but peak plasma levels occur approximately 15 to 120 minutes after consumption (Mandel, 2002; Beach *et al.*, 1984; Bonati *et al.*, 1984; Collomp *et al.*,

1991). Caffeine is water soluble and is rapidly distributed throughout the body, detected in all bodily fluids, including saliva, breast milk, urine and semen (Beach *et al.*, 1984). Caffeine elimination follows first-order kinetics (Newton *et al.*, 1981), with the plasma half-life of caffeine at approximately 3 to 6 hours in healthy adults and does not accumulate in body fat or other tissues (Kaplan *et al.*, 1997; Nawrot *et al.*, 2003). Caffeine is rapidly metabolized and excreted (1-3 mg/kg/minute) in the urine (Kaplan *et al.*, 1997), and varies between species, with a slightly different metabolic route noted in rats (Nawrot *et al.*, 2003).

C. Acute Toxicity

Animal Studies

The oral LD_{50} value of an aqueous extract of roasted and ground beans of *Coffea canephora robusta* containing 7.5% caffeine was between 2,000 and 5,000 mg/kg (ECHA) [Kl. score = 1].

No acute inhalation studies are available on coffee extract. The 4-hour LC_{50} value of a caffeine aerosol in rats is 4.94 mg/L (ECHA) [Kl. score = 2].

No acute dermal studies are available on coffee extract. The dermal LD_{50} value of an aqueous solution of caffeine in rats is >2,000 mg/kg (ECHA) [Kl. score = 2].

Human Studies

Studies in human have focused on caffeine, the pharmacologically active component in coffee. The fatal acute oral dose is estimated at 10 and 14 g (approximately 160 to 230 mg/kg for a 60 kg person) (Hodgman, 1998). The serum caffeine concentration is the most reliable indicator of potential caffeine toxicity, with a serum caffeine concentration >100 μg/ml considered lethal in humans (Mrvos *et al.*, 1989). Human caffeine consumption at up to 10 g has caused convulsions and vomiting, with recovery in six hours (Dreisbach, 1974). An acute dose of one gram caffeine can cause adverse effects, progressing from restlessness, nervousness, and irritability to delirium, emesis, neuromuscular tremors and convulsions (IOM, 2004). However, caffeine consumption through the day at up to 900 mg has been reported without adverse effects (Nawrot *et al.*, 2003).

D. Irritation

Coffee silverskin extracts was not considered a skin irritant when tested in an *in vitro* reconstructed human epidermis test (ECHA) [Kl. score = 1].

Coffee, bean, roasted, extract was not considered an eye irritant when tested in a bovine corneal opacity and permeability test (ECHA) [Kl. score = 1].

E. Sensitization

No studies are available.

F. Repeated Dose Toxicity

<u>Oral</u>

Male and female rats were given in their drinking water 0, 25, 50, or 100% with either instant or brewed coffee for 91 days. The average daily intakes of caffeine were 0, 20, 40, or 80 mg/kg-day for the brewed coffee and slightly lower intakes for the instant coffee. At study termination, the kidneys of the 100% male coffee groups had enlarged kidneys based on both absolute and relative weights. In the females, liver and kidneys were enlarged in all rats given brewed coffee, although the relative weights were significantly higher only in the 100% group. In the ≥50% instant coffee groups, both absolute and relative liver and kidney weights were increased, although there was no clear dose-response pattern. Histopathologic examination showed no treatment-related effects. In the absence of corresponding histopathologic changes, the liver and kidney weight changes were considered to be adaptive changes and not adverse. The NOAEL for this study is 100% coffee in drinking water, which corresponds to 80 mg/kg-day (Nolen, 1981; ECHA) [Kl. score = 2].

In an NTP study, male and female F344 rats were dosed by oral gavage with 0, 188, 375, 750, 1,500, or 3,000 ppm caffeine for 90 days. The average daily intakes were: 0, 19.7, 42, 85.4, 151, or 272 mg/kg-day for males; and 0, 23, 51, 104, 174, or 287 mg/kg-day for females). Body weight gain was reduced in all treated groups but was only significant in the 3,000 ppm animals (26% and 20% for males and females, respectively). Water consumption was decreased in the 3,000 ppm animals; it was increased in the 375 and 750 ppm groups. The only treatment-related effects observed was cellular enlargement in the salivary gland, which was dose-dependent. This effect in the salivary gland was considered an adaptive response as a result of the pharmacological effect of caffeine (sympathomimetic) and not an adverse effect. The NOAEL for this study is 1,500 ppm, which corresponds to 151 and 174 mg/kg-day for males and females, respectively (ECHA) [Kl. score = 2].

Inhalation

No studies are available.

Dermal

No studies are available.

G. Genotoxicity

In Vitro Studies

Instant and home brew coffees (caffeinated and decaffeinated) were evaluated for genotoxicity in an in vitro chromosomal aberration test using human lymphocytes with or without metabolic activation (S9 mix). Chromosomal aberrations were increased with all coffee samples with or without S9, although there was less of an increase with S9. Pure caffeine tested with or without S9 at doses equivalent to the levels in the caffeine-containing coffees did not induce a statistically significant increase in chromosomal aberrations (Aeschbacher et al., 1985; ECHA) [Kl. score 2].

Instant and home brew coffees (caffeinated and decaffeinated) were evaluated for mutagenicity in an in vitro bacterial reverse mutation assay with or without metabolic activation (S9 mix). The *S. typhimurium* strains were TA 98, TA 100, TA1535, TA 1537, and TA 1538. A mutagenic response was observed with TA 100 in the absence of S9, but not with S9. None of the other

strains showed a mutagenic response with or without S9 (Aeschbacher and Würzner, 1980; ECHA) [Kl. score = 2].

Five Americano coffees from selected coffee chains were evaluated for mutagenicity in an in vitro bacterial reverse mutation assay with or without metabolic activation (S9 mix). The *S. typhimurium* strains were TA 98, TA 100, and TA 1535. There were no mutagenic responses with or without metabolic activation (Liu et al., 2017; ECHA) [Kl. score = 2].

In Vivo Studies

Male Swiss OF-1 mice were dosed by oral gavage with 0, 500, 1,000, 2,000, or 3,000 mg/kg instant coffee for five consecutive days. There was no treatment-related increase in the frequency of micronuclei in bone marrow cells (Aeschbacher et. al., 1984 ECHA) [Kl. score = 2].

H. Carcinogenicity

No carcinogenicity studies are available.

I. Reproductive/Developmental Toxicity

Animal Studies

A one-generation reproductive toxicity study was conducted in rats. Male and female rats were given in their drinking water 0, 25, 50, or 100% with either instant or brewed coffee. The average daily intakes were 0, 20, 40, or 8 mg/kg-day for the brewed coffee and slightly lower intakes for the instant coffee. Exposure of parental animals were for 91 days and during mating. Exposure continued through the first gestation period and through weaning. Ten days later, the females were mated the second time and were sacrificed on GD 13 or 21. There were no indications of reproductive or developmental toxicity (Nolen, 1981; ECHA) [Kl. score = 2].

Human Studies

Studies in human have focused on caffeine, the pharmacologically active component in coffee. Studies that evaluated the potential teratogenicity of caffeine have been discussed in a review (Christian and Brent, 2001). In animal studies, caffeine administration to pregnant animals has been found to induce teratogenicity and toxic effects on the development of the fetuses only at doses that also caused toxic effects in the dams (Christian and Brent, 2001). Christian and Brent (2001) concluded that studies reporting positive teratogenic effects were administering large doses of caffeine that were far greater than human consumption and were providing the caffeine via gavage, which results in much higher peak serum caffeine levels and therefore overstates toxicity potential. Neither rodents nor humans could attain such peak exposures by consuming solutions of caffeine over several hours, the usual mode of human caffeine consumption.

There have been questions raised on whether high intake of coffee or caffeine may increase the risk of miscarriage. Caffeine crosses the placenta and increases maternal catecholamine levels (Goldstein and Warren, 1962). The American College of Obstetricians and Gynecologists (2010) have concluded the following: “Moderate caffeine consumption (less than 200 mg per day) does not appear to be a major contributing factor in miscarriage or preterm birth. The relationship of

caffeine to growth restriction remains undetermined. A final conclusion cannot be made at this time as to whether there is a correlation between high caffeine intake and miscarriage."

The American College of Obstetricians and Gynecologists (2010) have concluded that moderate caffeine consumption (<200 mg/day) does not appear to be a major contributing factor in miscarriage or preterm birth.

A recent systematic review of the potential adverse effects of caffeine consumptions in humans concluded that consumption up to 400 mg caffeine/day in healthy adults is not associated with reproductive and developmental effects. Also, consumption up to 300 mg caffeine/day in healthy pregnant women is generally not associated with adverse reproductive and developmental effects (Wikoff et al., 2017).

J. Human Studies

Caffeine is a stimulant and has been studied for its physiological and behavioral effects. Caffeine increases heart rate and blood pressure, increases diuresis, increases locomotion and alertness, and decreases sleepiness. Clinical studies indicate that doses <450 mg do not increase the risk or severity of cardiac arrhythmia, while acute doses of 150 mg caffeine may decrease heart rate (James, 1991; Green *et al.*, 1996; Myer, 1998). Studies evaluating effects of caffeine on cardiovascular health or serum cholesterol levels have not provided a consistent adverse effect with caffeine consumption (Nawrot *et al.*, 2003).

Nawrot *et al.* (2003) concluded in their review of the effects of caffeine on human health that "for the healthy adult population, moderate daily caffeine intake at a dose level up to 400 mg/day (equivalent to 6 mg/kg body weight/day in a 65-kg person) is not associated with adverse effects such as general toxicity, cardiovascular effects, effects on bone status and calcium balance (with consumption of adequate calcium), changes in adult behavior, increased incidence of cancer and effects on male fertility." It was indicated that habitual daily use of caffeine at greater than 500-600 mg/day (8.3 - 10 mg/kg) (4-7 cups of coffee or 7-9 cups of tea) could be considered a health risk. For women, caffeine intake greater than 400 mg/day (6.7 mg/kg) "may increase the risk of detrusor instability (unstable bladder) development in women" (Nawrot *et al.*, 2003).

A recent systematic review of the potential adverse effects of caffeine consumptions in humans also concluded that consumption up to 400 mg caffeine/day in healthy adults is not associated with overt, adverse cardiovascular effects, behavioral effects, acute effects or bone status (Wikoff et al., 2017).

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for coffee extract follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

<u>Oral</u>

A 90-day drinking water study on brewed and instant coffee reported no adverse effects up to 80 mg/kg-day (Nolen, 1982). A NTP 90-day oral gavage toxicity study in rats showed no adverse effects up to 174 mg/kg-day (NTP).

In two separate reviews (Nawrot et al., 2003; Wikoff et al., 2017) with the most recent one conducted using a systematic review approach (Wikoff et al., 2003), caffeine consumption in healthy adults up to 400 mg/day is not associated with any adverse health effects. Based on the acceptable daily intake of caffeine in coffee extract, the acceptable daily intake of caffeine of 400 mg/day will be used to derive the oral reference dose and drinking water guidance value for coffee extract.

Oral Reference Dose (oral RfD)

For a 70 kg person, the oral reference dose is 400/70 = 6 mg/kg-day.

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (5.7 x 70 x 0.1)/2 = <u>20 mg/L</u>

B. Cancer

No studies are available. Thus, a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Coffee extract does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Coffee extract has a low acute toxicity concern for aquatic life.

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies conducted on coffee extract.

Table 3: Acute Aquatic Toxicity Studies on Coffee Extract

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Oncorhynchus mykiss	96-hr LL_{50}	>100 WAF	1	ECHA
Daphnia magna	48-hr EL_{50}	>100 WAF	1	ECHA
Pseudokirchneriella subcapitata	72-hr EL_{50}	>100 WAF (growth)	1	ECHA

Chronic Studies

No studies are available.

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for coffee extract follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)L_{50}$ values are available for fish (>100 mg/L WAF), invertebrates (>100 mg/L WAF), and algae (>100 mg/L WAF). On the basis that the data consist of short-term results from three trophic levels, an assessment factor of 100 has been applied to the acute $E(L)L_{50}$ value of 100 mg/L WAF from fish, invertebrates, and algae. The $PNEC_{water}$ is 1 mg/L.

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. The $PNEC_{sed}$ was not calculated using the equilibrium partitioning method because the K_{oc} value cannot be determined.

PNEC soil

There are no toxicity data for terrestrial or soil organisms. The $PNEC_{soil}$ was not calculated using the equilibrium partitioning method because the K_{oc} value cannot be determined.

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008). Coffee extract is not readily biodegradable, but it does appear to be inherently biodegradable; thus, it is not expected to meet the screening criteria for persistence.

Based on a measured log K_{ow} of <0.36, coffee extract does not meet the screening criteria for bioaccumulation.

There are no chronic aquatic toxicity studies on coffee extract. The acute $E(L)L_{50}$ values for coffee extract are >1 mg/L for fish, invertebrates, and algae. Thus, coffee extract does not meet the screening criteria for toxicity.

The overall conclusion is that coffee extract is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Not classified.

B. Labelling

No signal word.

C. Pictogram

None.

X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
In case of contact, immediately flush eyes with plenty of water. If easy to do, remove contact lenses.

Skin Contact
Take off contaminated clothing immediately. Wash thoroughly with soap and water. Get medical attention if irritation develops and persists.

Inhalation
If inhaled, remove from area to fresh air. Get medical attention.

Ingestion
Rinse mouth with water and then drink a glass of water. Get medical attention. Do not induce vomiting. Never give anything by mouth to an unconscious person.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: carbon monoxide, carbon oxides, nitrogen oxides.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Use personal protective clothing.

Environmental Precautions
Do not empty into drains.

Steps to be Taken if Material is Released or Spilled
For small amounts: Pick up with absorbent material. Dispose of contaminated material. For large amounts: pump off product.

D. STORAGE AND HANDLING

General Handling
No special measures necessary provided product is used correctly.

Storage
Keep container tightly closed and dry. Store in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards

Workplace Australia has not established an occupational exposure limit for coffee extract.

Engineering Controls
None

Personal Protection Equipment

Respiratory Protection: Respiratory protection not required.

Hand Protection: Wear chemical resistant protective gloves.

Skin Protection: Body protection must be chosen depending on activity and possible exposure.

Eye protection*:* Wear safety goggles with side shields.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Wearing of closed work clothing is recommended. Ensure that eyewash stations and safety showers are close to the workstation location.

F. TRANSPORT INFORMATION

Coffee extract is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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Santos

APPENDIX G.3 HALLIBURTON CLEANSTIMAU

Environmental Assessment

Aluminum sulfate
(CAS No. 10043-01-3)

This environmental assessment on aluminum sulfate has been extracted from the 2010 Priority Substances List Assessment Report. Follow-up to the State of the Science Report, 2000 for Aluminum Chloride, Aluminum Nitrate, Aluminum Sulphate, prepared by Environment Canada and Health Canada (Canada, 2010). The report can be downloaded from: http://www.ec.gc.ca/lcpe-cepa/default.asp?lang=En&n=491F0099-1

Aluminum sulfate, also know as alum, has the chemical formula is $Al_2(SO_4)_3$. It is often represented as $Al_2(SO_4)_3 \cdot 14H_2O$. It may be found in different hydrated forms. The commercial product, called cake alum or patent alum, is an octadecahydrate aluminum sulfate, $Al_2(SO_4)_3 \cdot 18H_2O$.

Aluminum sulfate is used primarily as a coagulant and flocculant in water and wastewater treatment.

Aluminum sulfate, which is highly soluble, will form various dissolved species on contact with water. A wide variety of environmental parameters will affect the speciation and solubility of aluminum. These parameters include pH, solution temperature, dissolved organic carbon (DOC) content, and the presence and concentrations of numerous ligands.

Aluminum in solution can be present in several different forms: as dissolved complexes, as "free" ions, in association with particles, as colloids or as solids in the process of precipitating. Two general types of ligands can form strong complexes with aluminum in solution: inorganic ligands such as sulfate, fluoride, phosphate, bicarbonate and hydroxide; and organic ligands such as oxalic, humic and fulvic acids. DOC will complex with aluminum in water, forming aluminum-organic complexes and reducing concentrations of monomeric forms of aluminum.

At low pH values, dissolved aluminum is present mainly in the "free" ion form (Al^{3+}). Hydrolysis occurs as pH rises, resulting in a series of less soluble hydroxide complexes (e.g., $Al(OH)^{2+}$, $Al(OH)_2^{+}$). Aluminum solubility is at a minimum near pH 6.5 at 20°C and then increases as the anion, $Al(OH)_4^-$, begins to form at higher pH (Driscoll and Schecher 1990; Witters et al. 1996). Thus, at 20°C and pH < 5.7, aluminum is present primarily in the forms Al^{3+} and $Al(OH)^{2+}$. In the pH range 5.7 to 6.7, aluminum hydroxide species dominate, including $Al(OH)^{2+}$ and $Al(OH)_2^{+}$, and then $Al(OH)_3$. Typically, at a pH of approximately 6.5, $Al(OH)_3$ predominates over all the other species. In this range, aluminum solubility is low, and availability to aquatic biota should also be low. At pH > 6.7, $Al(OH)_4^-$ becomes the dominant species.

For metals such as aluminum, the "free" or hydrated dissolved ions (i.e., Al^{3+}, $Al(OH)^{2+}$ and $Al(OH)_2^{+}$) are normally considered to be the principal bioavailable forms (Newman and Jagoe, 1994).

Bioaccumulation

Fish accumulate aluminum in and on the gill, and it has been suggested that the rate of transfer of aluminum into the body is either slow or negligible under natural environmental conditions (Spry and Wiener, 1991). The initial uptake of aluminum by fish occurs mainly on the gill mucous layer (Wilkinson and Campbell, 1993); both mucus and bound aluminum may be rapidly eliminated following exposure. Roy (1999) calculated the BCFs in fish to range from 400 to 1,365.

The BCF for *Daphnia magna* varied from 10,000 at pH 6.5 to 0 at pH 4.5, based on the results of Havas (1985). Most of the metal appears to be adsorbed to external surfaces and is not internalized (Havas 1985; Frick and Hermann 1990).

The accumulation of aluminum by the algae *Chlorella pyrenoidosa* increased with the concentration of inorganic monomeric aluminum (Parent and Campbell, 1994). A comparison of assays performed at different pH values but at the same concentration of aluminum showed suppression of that aluminum accumulation at low pH.

Aquatic Toxicity

There are several comprehensive reviews of the aquatic toxicity of aluminum (ATSDR, 2008; Bélanger *et al.*, 1999; Roy 1999). Below is a brief summary of the literature that is relevant for hydraulic fracturing fluids.

The primary target organ for aluminum in fish is the gills (Dussault *et al.*, 2001). Aluminum binds to the gill surface, causing swelling and fusion of the lamellae and increased diffusion distance for gas exchange (Karlsson-Norrgren *et al.*, 1986; Tietge *et al.*, 1988). The resulting damage leads to loss of membrane permeability, reduced ion uptake, loss of plasma ions, and changes in blood parameters relating to respiration. Fish death may result from ionoregulatory or respiratory failure, or a combination of both, depending upon the pH of the water and concentration of waterborne aluminum (Neville 1985; Booth *et al.*, 1988; Gensemer and Playle, 1999). Aluminum exposure may also disrupt ionic balance and osmoregulation in aquatic invertebrates (Otto and Svensson 1983).

Most aquatic toxicity studies involving aluminum have been conducted under conditions of low pH, and a number of these accounted for the solubility of the metal in the experimental design. The general conclusion of these studies is that aluminum toxicity is related to the concentration of dissolved inorganic monomeric aluminum (Roy 1999). At pH 6.0 to 6.5, there are few studies that provide effects estimates in terms of inorganic

monomeric aluminum. At pH6.0, a LOEC of 8µg/L (inorganic monomeric aluminum) for growth of the alga *C. pyrenoidosa* can be estimated from the data of Parent and Campbell (1994). Growth of the alga was reduced at this single exposure concentration in media without phosphate. This LOEC is, however, well within the likely range of natural concentrations of inorganic monomeric aluminum in surface water. In comparison, Neville (1985) observed that 75 µg Al/L (as inorganic monomeric aluminum) caused physiological distress to rainbow trout (*Oncorhynchus mykiss*) at pH 6.1 but not at pH 6.5.

At pH 6.5 to 8.0, there are also few effects data available. At neutral or near-neutral pH, aluminum has a tendency to precipitate, and the chemistry of these solutions is difficult to control. While the toxicity of alum in neutral-pH waters has been the subject of many studies, the results are unreliable, due to extreme variation between replicates of the same exposure concentration and between duplicate experiments. However, a No-Observed-Effect Concentration (NOEC) for respiratory activity at pH 6.5 is provided by the results of the study by Neville (1985), who found that rainbow trout tolerated 75 µg Al/L (as inorganic monomeric aluminum) during exposures at this pH. Wold *et al.* (2005) reported a LOEC of 0.05 mg/L Al for reduced survival and reproduction in *Daphnia pulex* exposed for 21 days to concentrations ranging from 0.05 to 0.50 mg Al/L (nominal) as aluminum sulfate. The test water was maintained at a pH of 7 ± 1, suggesting that the observed effects were due to the presence of aluminum hydroxide rather than the dissolved inorganic monomeric aluminum that is usually associated with toxicity.

At pH > 8.0, LOECs for survival of rainbow trout are ≥ 1.5 mg/L as total aluminum (Freeman and Everhart, 1971). In a more recent study, Gundersen *et al.* (1994) reported LC_{50}s for exposures of rainbow trout in the pH range 8.0–8.6. The LC_{50}s at all pHs were approximately the same value, ~ 0.6 mg/L (range: 0.36–0.79 mg/L) as dissolved aluminum (*i.e.*, filterable through a 0.4-µm filter), and were similar in both acute (96-hour) and longer- term (16-day) exposures at hardness levels ranging from 20 to 100 mg/L (as calcium carbonate). A NOEC for mortality of 0.06 mg dissolved Al/L can be derived from data given for one of the 16-day exposures conducted at 20 mg/L hardness and pH 8.0. Although these concentrations were measured as dissolved aluminum, it is probable that the monomeric aluminate ion, AlO_4^- predominated at this pH.

PNEC calculations

Dissolved inorganic monomeric aluminum is considered to have the highest bioavailability to aquatic species and to present the greatest risk of adverse effects to pelagic organisms.

The data from Neville (1985) provides a NOEC of 0.075 mg/L as inorganic monomeric aluminum, based on the absence of deleterious effects on ventilation and respiratory activity of rainbow trout at pH 6.5. This chronic toxicity value is considered valid for the pH range 6.5–8.0.

A second chronic toxicity value for alkaline conditions (pH > 8.0) is based on the work of Gundersen *et al.* (1994), who determined similar LC_{50}s (~0.6 mg dissolved Al/L) during several experiments in the pH range 8.0–8.6 and water hardness range 20 to 100 mg/L (as calcium carbonate). A NOEC for mortality of 0.06 mg dissolved Al/L can be derived for rainbow trout from data given for one of the 16-day exposures at 20 mg/L hardness and pH 8.0. The chemical concentrations in Gundersen *et al.* (1994) are expressed as "total" and "dissolved" aluminum; there was no attempt to identify the forms of dissolved aluminum present. At the experimental pH, it is probable that a good proportion of the dissolved aluminum was the monomeric aluminate ion as the predominant species.

It is possible that effects may be elicited at concentrations below that of the selected chronic toxicity value of 0.06 mg/L Wold *et al.* (2005) reported a 21-day LOEC for reduced survival and reproduction in *Daphnia pulex* at a lowest test concentration of 0.05 mg/L. Testing was conducted at a pH of 7 ± 1, suggesting that the observed effects were due to the presence of aluminum hydroxide rather than the dissolved inorganic monomeric aluminum that is usually associated with toxicity.

In determining Predicted No-Effect Concentrations (PNECs) for aluminum, the nature of the biological response was considered, since some organisms respond to a narrow aluminum concentration range. This results in an abrupt "threshold" where an evident biological response occurs, with no observable effects at slightly lower concentrations (Hutchinson *et al.* 1987; Roy and Campbell 1995). Consequently, since the chronic toxicity value chosen is a NOEC, the application factor used to derive a PNEC from the chronic toxicity value was 1.

The $PNEC_{aquatic}$ for Al is 0.06 mg/L.

PBT Assessment

Aluminum sulfate is an organic salt that dissociates in water to form sulfate ions and various species of dissolved aluminum. Biodegradation is not applicable to aluminum sulfate. Both sulfate and aluminum can be found naturally in the environment. For the purposes of this PBT assessment, the persistent criteria is not considered applicable to this inorganic salt.

Fish accumulate aluminum in and on the gill, and it has been suggested that the rate of transfer of aluminum into the body is either slow or negligible under natural environmental conditions. Sulfate ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, aluminum sulfate (or its dissolved species) is not expected to bioaccumulate.

The chronic NOEC value in fish for aluminum is <0.1 mg/L; thus, the dissolved aluminum from aluminum sulfate meets the screening criteria for toxicity.

The overall conclusion is that aluminum sulfate is not a PBT substance.

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Environmental Assessment

Cellulase
(CAS No. 9012-54-8)

Enzymes are catalytic proteins or polypeptides and consist of amino acid residues coupled via peptide bonds. They are primarily characterized by their biocatalytic or enzymatic activity. There is a broad range of detergent cellulases used both from fungal as well as from bacterial origin; all are characterized by ß-1,4-endoglucanase activity.

Biodegradation

Three different cellulase enzymes were considered readily biodegradable based on the results of OECD 301C and 301E tests (HERA, 2005). In an OECD 301E test, there was 84% DOC removal of the enzyme Carezyme after 28 days. In another OECD 301E test, there was 92% DOC removal of the enzyme Clazinase® after 28 days. In an OECD 301C test, BOD/COD was 78% after 28 days.

Aquatic Toxicity

The 96-hour LC_{50} of an alkaline cellulase to zebrafish (*Brachydanio rerio*) is 330 mg aep/L (HERA, 2005). The 48-hour EC_{50} of the same alkaline cellulase to *Daphnia magna* was reported to be >1,000 mg aep/L (HERA, 2005). The same alkaline cellulase was also tested in algae (*Scenedesmus subspicatus*), with a 72-hour EC_{50} of >1000 mg aep/L (HERA, 2005).

The 24- and 48-hour EC_{50} values of an alkaline cellulase (SP 227, Celluzyme) to *Daphnia magna* were reported to be >1,000 mg aep/L and approximately 1,000 mg aep/L respectively (HERA, 2005).

Two additional acute fish toxicity studies showed findings with LC_{50} values of >100 mg aep/L, but no references were provided (HERA, 2005).

Toxicity to Sediment Organisms

No data could be located.

Toxicity to Terrestrial Organisms

No data could be located.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (330 mg aep/L), Daphnia (>1,000 mg aep/L), and algae (1,000 mg aep/L). Although the HERA report provides information on two acute fish studies with LC_{50} values of >100 mg aep/L, no references were provided and were therefore excluded from the determination of PNECs. On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 330 mg aep/L for fish. The $PNEC_{aquatic}$ is 0.33 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$. A calculated Koc of <1.3 was reported in the HERA report, calculated according to the TGD. Using a Koc of 1.3 and a $PNEC_{aquatic}$ of 0.33 mg aep/L, the $PNEC_{sediment}$ was calculated to be 0.21 mg aeg/kg.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The equilibrium partition method was used to determine a $PNEC_{soil}$. A calculated Koc of <1.3 was reported in the HERA report, calculated according to the TGD. Using a Koc of 1.3 and a $PNEC_{aquatic}$ of 0.33 mg aep/L, the $PNEC_{soil}$ was calculated to be 0.006 mg aeg/kg.

PBT Assessment

Cellulase is readily biodegradable and thus does not meet the screening criteria for persistence.

Cellulase has a high molecular weight (20 to 80 kD), has hydrophilic properties (high water solubility, log Kow <0), and is readily metabolized in organisms by proteolytic enzymes or proteases. Thus, it does not meet the screening criteria for bioaccumulation.

The acute $EC(L)_{50}$ of cellulase is >0.1 mg/L in fish, invertebrates and algae. Thus, it does not meet the screening criteria for toxicity.

The overall conclusion is that cellulase is not a PBT substance.

Reference

Human and Environmental Risk Assessment (HERA) on Ingredients of Household Cleaning Products: α-amylase, CAS No. 9000-90-2; Cellulase (β-(1,4)-glucanase), CAS No. 9012-54-8; Lipase, 9001-62-1, 2005. http://www.heraproject.com

Environmental Assessment

Lactose
(CAS No. 63-42-3)

Lactose is a disaccharide sugar composed of galactose and glucose. It is naturally synthesized in the mammary gland of virtually all mammals, occurring in milk at levels between 1 and 7%. Commercially, lactose is extracted from the whey of cow's milk (whey is the residual liquid of milk following cheese and casein production) and is purified extensively to remove fats, proteins, vitamins and minerals (Baldrick and Bamford, 1997; Goodhart, 1994).

Biodegradation

No biodegradation studies were found on lactose. The QSAR model BIOWIN estimates that the biodegradation of lactose would be fast, with primary degradation in hours-days and ultimate degradation in days-weeks (U.S. EPA, 2011).

Aquatic Toxicity

No aquatic toxicity studies were found on lactose.

Using ECOSAR, the 96-hour LC_{50} in fish was estimated to be 81,045 mg/L; the 48-hour LC_{50} in *Daphnia* was estimated to be 3,460,000 mg/L; and the 96-hour EC_{50} in green algae was estimated to be 583,000 mg/L (U.S. EPA, 2011).

Toxicity to Sediment Organisms

No data could be located.

Toxicity to Terrestrial Organisms

No data could be located.

Determination of PNECs

$PNEC_{aquatic}$: No experimental results are available for lactose. Acute $E(L)C_{50}$ estimates using the QSAR model ECOSAR are: fish (81,045 mg/L), Daphnia (3,460,000 mg/L), and algae (583,000 mg/L). On the basis that the data consists of short-term results from

three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 81,045 mg/L for fish. The $PNEC_{aquatic}$ is 81 mg/L.

PBT Assessment

No experimental biodegradation data are available on lactose. The QSAR model BIOWIN predict that lactose will biodegrade fast, with primary degradation in hours-days and ultimate degradation in days-weeks. Thus, lactose does not meet the screening criteria for persistence.

The estimated log K_{ow} and BCF for lactose is -5.03 and 3.162, respectively (U.S. EPA, 2011). Thus, lactose does not meet the screening criteria for bioaccumulation.

The estimated acute $EC(L)_{50}$ values of lactose indicate that it is non-toxic to fish, invertebrates and algae. Thus, it does not meet the screening criteria for toxicity.

The overall conclusion is that lactose is not a PBT substance.

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Environmental Assessment

Maltodextrin
(CAS No. 9050-36-6)

Maltodextrin is a nonsweet nutritive saccharide polymer that consists of D-glucose units linked primarily by $\alpha,1\rightarrow4$ bonds and that has a dextrose equivalent (D.E.) of <20. Typical commercial maltodextrins contain as few as three and as many as nineteen linked dextrose units. It is prepared as a white powder or concentrated solution by partial hydrolysis of corn starch, potato starch, or rice starch with safe and suitable acids and enzymes.

Biodegradation

No specific biodegradation studies could be found on maltodextrin. However, it is biopolymer that is readily broken down in the gastrointestinal tract of mammals by bacteria. Thus, it is expected to be readily biodegradable in the environment.

Aquatic Toxicity

No aquatic toxicity studies were found on maltodextrin. However, some of the smaller polymeric chains have molecular weights of <1,000 and are thus bioavailable. D-glucose, the monomeric units of maltodextrin, are found naturally in aquatic organisms and play a beneficial role. Thus, maltodextrin is not expected to be toxic to aquatic organisms.

Determination of PNECs

No aquatic toxicity data could be found on maltodextrin. Thus, PNECs were not determined.

PBT Assessment

Maltodextrin is expected to be readily biodegradable and thus would not be expected to meet the screening criteria for persistence.

The molecular weights of maltodextrin can be <1,000 and are thus bioavailable to aquatic organisms. Maltodextrin is water-soluble and composed of D-glucose monomeric units; which are naturally occurring in the body. Thus, maltodextrin is not likely to meet the screening criteria for bioaccumulation.

No aquatic toxicity data could be found on maltodextrin. However, D-glucose, the monomeric units of maltodextrin, are found naturally in aquatic organisms and play a beneficial role. Thus, maltodextrin is not expected to meet the screening criteria for toxicity.

The overall conclusion is that maltodextrin is not a PBT substance.

Environmental Assessment

Potassium chloride
(CAS No. 7447-40-7)

Potassium chloride (KCl) has been reviewed in the OECD-SIDS program (OECD, 2001a,b).

Environmental Fate

KCl is a solid inorganic salt that is highly soluble in water (342 g/L at 20^{o} C). Potassium chloride fully dissociates in aqueous solutions to K^+ and Cl^- ions.

KCl, either as an inorganic salt or as K^+ and Cl^- ions, is ubiquitous in the environment. There is no potential for bioaccumulation or bioconcentration. Potassium and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated.

Aquatic Toxicity

In a guideline study, the 96-hour LC_{50} in *Pimephales promelas* was reported to be 880 mg/L (Mount *et al.*, 1997). The 48-hour LC_{50} values from two studies on *Lepomis macrochirus* (Patrick *et al.*, 1968; Trama, 1954), and one study each on *Oncorhyncus mykiss* and *Ictalurus punctatus* (Waller *et al.*, 1993) ranged from 720 to 2,010 mg/L.

In a guideline study, the 48-hour EC_{50}s in *Daphnia magna* and *Ceriodaphnia dubia* were 660 and 630 mg/L, respectively (Mount *et al.*, 1997; ECHA REACH database). The 48-hour EC_{50} in *Daphnia magna* in another study was also reported to be 177 mg/L (Biesinger and Christensen, 1972).

The toxicity of KCl has been investigated in one algae species (*Nitzschia linearis*), showing 120 hour-EC_{50} (growth rate) of 1,337 mg/L (Patrick *et al.*, 1968). The 72-hour EC_{50} to *Scenedesmus subspicatus* is >100 mg/L (growth rate), with a NOEC of $\geq$100 mg/L (ECHA REACH database).

In a fish early-life-stage test with the fathead minnow (*Pimephales promelas*), the 7-day NOEC is 500 mg/L (ECHA REACH database). A long term (21-day) study has been performed on *Daphnia magna* where effects on reproduction were investigated for several metals. A 16% impairment of reproduction (LOEC) was observed at a concentration of 53 mg/L of K +, equal to KCl concentration of 101 mg/L (Biesinger and Christensen, 1972).

Toxicity to Terrestrial Organisms

Potassium is one of the three major nutrients and chloride is an essential micronutrient for plants. No data could be located on the toxicity to terrestrial organisms.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (720 mg/L), Daphnia (177 mg/L), and algae (>100 mg/L). Although chronic studies has been conducted on fish and invertebrates, these tests are not valid for deriving PNECs (ECHA REACH database). On the basis of the short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 100 mg/L for algae. The $PNEC_{aquatic}$ is determined to be 0.1 mg/L.

$PNEC_{sediment}$: No reliable experimental toxicity data on sediment organisms are available. Potassium chloride dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc parameters do not readily apply to inorganics, such as potassium chloride. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of potassium chloride to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No reliable experimental toxicity data on terrestrial organisms are available. The environmental distribution of potassium chloride is dominated by its water solubility. Sorption of potassium chloride should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Koc and Kow parameters do not readily apply to inorganics, such as potassium chloride. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, potassium chloride is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Potassium chloride is an organic salt that dissociates completely to potassium and chloride ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both potassium and chloride ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria is not considered applicable to this inorganic salt.

Potassium and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, potassium chloride is not expected to bioaccumulate.

No chronic toxicity data exist on potassium chloride; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, potassium chloride does not meet the screening criteria for toxicity.

The overall conclusion is that potassium chloride is not a PBT substance.

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Environmental Assessment

Shellac, Ammonium salt
(CAS No. 68308-35-8)

Lac is the hardened resinous secretion of the insesct *Kerria lacca* (Douglas, 1971; CIR, 1986). The secreted lac or sticklac contains lac resin, erythrolaccin, wax, inset debris, wood materials, sand, dust and water-soluble impurities. The semirefined seedlac of commerce is the yellowish granular material obtained from the processing of sticklac (Douglas, 1971; Misra and Sengupta, 1970; CIR, 1986).

Unrefined shellac can contain shellac wax and erythrolaccin (the yellow material), which both comprise about 6% of Shellac (CIR, 1986). The removal of these constituents yields lac resin that has a soft (30%) and hard (70%) components (CIR, 1986). Mild alkaline hydrolysis of this resin results in a complex mixture of hydroxyaliphatic and alicyclic acids and their polyesters. The composition of the mixture varies with the lac source and the time of collection (CIR, 1986).

The major component of the aliphatic fraction is aleuritic acid. The alicyclic fraction consists of sesquiterpenic acids, primarily jalaric acid and its derivatives. The native form of the pure lac resin molecule has a molecular weight of 2,095, which contains four terpene acids (mostly jalaric acid) and four aleuritic acid units in repeating ester linkage (Singh *et al.*, 1974). The proposed structure for lac resin respresents an average situation since the molecule may not always be homogenous with respect to sequence or ratio of jalaric acid to other sesquiterpenic acid substitutes (Singh *et al.*, 1974). The sesquiterpenic acids in lac resin are jalaric acid, shellolic acid, epishellolic acid, laksholic acid, and epilaksholic acid.

Aqueous shellac solutions can be prepared by neutralization with ethanolamines, alkalies, or borax (CIR, 1986).

Biodegradation

No data were found. As a natural resin, it is expected to be resistant to biodegradation.

Aquatic Toxicity

No data were found. Given that the molecular weight of the pure lac resin molecule is on average ~2,000 and that it is insoluble in water at environmentally relevant pHs, it is not expected to be bioavailable; this resin is thus expected to be non-toxic to aquatic organisms.

Toxicity to Sediment Organisms

No data were found.

Toxicity to Terrestrial Organisms

No data were found.

Determination of PNECs

PNECs were not determined since no aquatic toxicity data are available.

PBT Assessment

Shellac, ammonium salt is a natural resin and is not expected to readily biodegradable. Thus, it meets the screening criteria for persistence.

Shellac, ammonium salt has a high molecular weight (~2,000) and is insoluble in water at environmentally relevant pHs. It is not expected to be bioavailable and thus, it does not meet the screening criteria for bioaccumulation.

There are no aquatic toxicity in which to evaluate the aquatic toxicity of shellac, ammonium salt. It has, however, a high molecular weight (~2,000) and is also insoluble in water at environmentally relevant pHs; it is not expected to be bioavailable. Thus, shellac, ammonium salt is not expected to meet the screening criteria for toxicity.

The overall conclusion is that shellac, ammonium salt is not a PBT substance.

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Environmental Assessment

Sodium Carboxymethyl Cellulose
(CAS No. 9004-32-4)

Sodium carboxycellulose is the sodium salt of carboxymethylcellulose. Carboxymethyl cellulose is a cellulose derivative with carboxymethyl groups (-CH_2COOH) bound to some of the hydroxyl groups of the glucopyranose monomers that make up the cellulose backbone.

Carboxymethyl cellulose (CMC) is a water-soluble semisynthetic polymer in which part of the hydroxyl groups of cellulose has been replaced at random by carboxymethyl groups. Carboxymethyl cellulose is therefore composed of eight different glucose units, namely one unsubstituted, three monosubstituted, three disubstituted, and one trisubstituted. The average number of carboxymethyl groups per glucose unit is denoted by the degree of substitution (DS). Carboxymethyl cellulose with a DS ranging from 0.4 to 1.3 has become the largest industrial cellulose ether because of its versatile applications in, for example, detergents and oil drilling. "

Biodegradation

Carboxymethyl cellulose (DS 0.7) showed 25% biodegradation after 28 days in a OECD 301A test. Thus, sodium carboxymethyl cellulose is not readily biodegradable. Other studies have also shown partial degradation of carboxymethyl cellulose in ready and inherent biodegradability tests.

Aquatic Toxicity

Carboxymethyl cellulose has been tested in several acute aquatic toxicity tests. The 96-hour LC_{50} for *Brachydanio rerio* is >2,500 mg/L; the 48-hour LC_{50} for *Daphnia magna* is >5,000 mg/L; and the 96-hrourEC_{50} for *Selenastrum capricornutum* is 500 mg/L.

Toxicity to Sediment Organisms

No data could be located.

Toxicity to Terrestial Organisms

No data could be located.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (>2,500 mg/L), Daphnia (>5,000 mg/L), and algae (>500 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 500 mg/L for algae. The $PNEC_{aquatic}$ is 0.5 mg/L.

PBT Assessment

Sodium carboxymethyl cellulose is a water-soluble semisynthetic polymer and is not readily biodegradable. Thus, it meets the screening criteria for persistence.

Sodium carboxymethyl cellulose is a water-soluble semisynthetic polymer and is expected to have a molecular weight of >1,000 which limits its bioavailability to aquatic organisms. Thus, it is not expected to bioaccumulate.

The acute $EC(L)_{50}$ of sodium carboxymethylcellulose is >0.1 mg/L in fish, invertebrates and algae. Thus, it does not meet the screening criteria for toxicity.

The overall conclusion is that sodium carboxymethylcellulose is not a PBT substance.

Reference

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Environmental Assessment

Sodium chloride
(CAS No. 7647-14-5)

Sodium chloride will dissociate in aqueous solutions to sodium and chloride ions.

Determination of PNECs

$PNEC_{aquatic}$: Not determined.

$PNEC_{sediment}$: Sodium chloride dissociates completely in water with its environmental distribution dominated by its high water solubility. Kow and Koc are parameters that do not readily apply to inorganics, such as sodium chloride. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on its properties, no adsorption of sodium chloride to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: Sodium chloride dissociates completely in water with its environmental distribution idominated by its high water solubility. Kow and Koc are parameters that do not readily apply to inorganics, such as sodium chloride. Based on its properties, no adsorption of sodium chloride to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Sodium chloride is an organic salt that dissociates completely to sodium and chloride ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both sodium and chloride ions are also ubiquitous and are present in most water, soil and sediment. The persistent criteria is not considered applicable to this inorganic salt.

Sodium and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, sodium chloride is not expected to bioaccumulate.

No chronic toxicity data exist on sodium chloride; the acute $EC(L)_{50}$s are expected to be >0.1 mg/L in fish, invertebrates and algae based on aquatic toxicity studies involving sodium and chloride ions. Thus, sodium chloride does not meet the screening criteria for toxicity.

The overall conclusion is that sodium chloride is not a PBT substance.

Environmental Assessment

Sodium Lauryl Sulfate
(CAS No. 151-21-3)

Sodium lauryl sulfate has been reviewed in the OECD-SIDS program (IUCLID, 2007; OECD, 2007).

Environmental Fate and Transport

Sodium lauryl sulfate exhibits moderate sorption potential to sediments. The experimentally derived sediment-water coefficient (K_d) and sorption coefficient (K_{oc} for sodium lauryl sulfate are 70.2 – 99.1 and 316 – 446, respectively (Marchesi *et al.*, 1991).

Biodegradation

Sodium lauryl sulfate is readily biodegradable in standard ready tests (OECD 301D) that show 94-97% (Henkel KGaA, 1996; OECD, 2007) and ~85% (Fischer and Gerike, 1975) removal after 28 and 30 days, respectively. The 10-window was fulfilled in both tests. Alkyl sulfates with a chain length between 8 and 14 degraded to 90-100% after 8 days in an OECD 301E test (Sanchez-Leal *et al.*, 1991).

Bioaccumulation

The bioaccumulation of sodium lauryl sulfate is considered to be low based on the results of several studies. The BCFs for freshwater fish *Cyprinus carpio* and *Carassius auratus* were 2.1-5.3 (Wakabayashi *et al.*, 1978, 1980, 1981) and ~1.5 (Tovell *et al.*, 1975), respectively.

Aquatic Toxicity

The 48-hour LC_{50}s for *Oryzias latipes* was reported as a nominal value of 46 mg/L (Kikuchi and Wakabayashi, 1984) and as a measured value of 51 mg/L (Kikuchi *et al.*, 1976). In chronic studies, the lowest value was a 42-day NOEC for *Pimephales promelas* of >1.36 mg/L (OECD, 2007; Belanger *et al.*, 1995.

There are no reliable acute invertebrate studies conducted on sodium lauryl sulfate. The 24-hour EC_{50} nominal value for *Daphnia magna* for sodium tridecyl sulfate is 42 mg/L (Lundahl and Cabridenc, 1978). In another study, the 24-hour EC_{50} for *Daphnia magna* for sodium tridecyl sulfate was determined to 4.2 mg/L (Cognis, 2006). In a chronic study on sodium lauryl sulfate, the 7-day NOEC to *Ceriodaphnia dubia* was determined to be 0.88 mg/L (Dyer *et al.*, 1997).

The 72-hour EC_{50} values to algae *Desmodesmus subspicatus* are >120 mg/L for growth and 53 mg/L for biomass; the NOEC is 30 mg/L (Henkel KGaA, 1994). The 96-hour EC_{50} value to algae *Pseudokirchneriella subcapitata* is 117 mg/L based on growth (Nyholm and Damgaard, 1990).

Toxicity to Sediment Organisms

Three valid studies (two static and one semistatic) are available on the toxicity of sodium lauryl sulphate to benthic organisms. However, these studies were conducted in seawater without sediment.

Toxicity to Terrestrial Organisms

There are no valid studies.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (46 mg/L), Daphnia (4.2 mg/L), and algae (53 mg/L). Results from chronic studies are also available for all three trophic levels, with the lowest NOEC being 0.88 mg/L for invertebrates. On the basis that the data consists of short-term and long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported long-term NOEC of 0.88 mg/L for invertebrates. The $PNEC_{aquatic}$ is 0.09 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The equilibrium partition method was used to determine a $PNEC_{soil}$.

PBT Assessment

Sodium lauryl sulfate is readily biodegradable and thus does not meet the screening criteria for persistence.

The experimental BCFs in freshwater fish are in the range of 1.5 to 5.3. Thus, sodium lauryl sulfate does not meet the criteria for bioaccumulation.

The lowest NOEC from a chronic invertebrate toxicity study is 0.88 mg/L. This value is >0.01 mg/L; thus, sodium lauryl sulfate does not meet the screening criteria for toxicity.

The overall conclusion is that sodium lauryl sulfate is not a PBT substance.

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Environmental Assessment

Sorbitan, monododecanoate poly(oxy-1,2-diethanediyl)
(CAS No. 9005-64-5)

Sorbitan, monododecanoate poly(oxy-1,2-diethanediyl) or PEG sorbitan monolaurate is a hydrophilic, nonionic surfactant that is also called Polysorbate 20 and Tweens 20. In this environmental assessment sorbitan, monododecanoate poly(oxy-1,2-diethanediyl) will be referred to as Polysorbate 20. Polysorbate 20 contains mainly the fatty acid lauric acid, but other fatty acids are also present. Thus, polysorbate 20 would be considered a UVCB substance (substance of unknown or variable composition, complex reaction products or biological materials).

Because no environmental fate and aquatic toxicity data were found on Polysorbate 20, information on Polysorbate 80 was used for this environmental assessment. QSAR modeling (EPISUITE) was also used based on the structural information on Polysorbate 20 provided in the Japanese Food Safety Commission Evaluation Report of Food Additives: Polysorbates (JFSC, 2007).

Biodegradation

Polysorbate 80 was been reported to biodegrade in less than 5 days (Baleux and Caumette, 1974). In their environmental risk assessment, Carlsson *et al.* (2006) considered Polysorbate 80 to be inherently biodegradable.

The QSAR model Biowin 2 predicts that Polysorbate 20 does not biodegrade fast, and Biowin 3 predicts that it is recalcitrant (U.S. EPA, 2011).

Bioaccumulation

Using QSAR modeling, the log K_{ow} of Polysorbate 20 was estimated to be -2.9 and the BCF is estimated to be 3.16 (U.S. EPA, 2011).

Aquatic Toxicity

No aquatic toxicity data was found for Polysorbate 20. For Polysorbate 80, invertebrate lethality was noted at concentrations of 1-5% following 10 hours of exposure (Saski *et al.*, 1971; cited in Carlsson *et al.*, 2006). An EC_{50} in algae was reported to be 100 mg/L for (Nyberg, 1998; cited in Carlsson *et al.*, 2006).

Toxicity to Terrestrial Organisms

No data are available.

Determination of PNECs

$PNEC_{aquatic}$: There are no experimental studies on Polysorbate 20. An acute $E(L)C_{50}$ value is available for algae (100 mg/L) on the structurally similar Polysorbate 80. On the basis that the only toxicity value is a short-term result from one trophic level, an assessment factor of 1,000 has been applied to the EC_{50} value of 100 mg/L for algae. The $PNEC_{aquatic}$ is 0.1 mg/L.

PBT Assessment

Using the QSAR model Biowin 2, Polysorbate 20 is predicted to not biodegrade fast; Biowin 3 predicts that Polysorbate 20 is recalcitrant. Thus, Polysorbate 20 meets the screening criteria for persistence.

Using QSAR modeling, the log K_{ow} of Polysorbate 20 was estimated to be -2.9 and the BCF is estimated to be 3.16. Thus, Polysorbate 20 is not expected to meet the screening criteria for bioaccumulation.

There are no toxicity data on Polysorbate 20; nor are there any chronic toxicity data on Polysorbate 80, which is structurally similar to Polysorbate 20. The acute algal EC_{50} value for Polysorbate 80 is >0.1 mg/L. Thus, Polysorbate 20 is not expected to meet the screening criteria for toxicity.

The overall conclusion is that Polysorbate 20 or sorbitan, monododecanoate poly(oxy-1,2-diethanediyl) is not a PBT substance.

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Environmental Assessment

Sulfuric acid
(CAS No. 7664-93-9)

Sulfuric acid has been reviewed in the OECD-SIDS program (OECD, 2001).

Environmental Fate

Sulfuric acid (H_2SO_4) will dissociate completely in aqueous media at environmentally relevant pH to H^+ and SO_4^{2-}. The pK_a of sulfuric acid is 1.92.

Sulfates are not expected to bioaccumulate in the soil or in aqueous solution (OECD, 2005). Sulfate ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. However, some plants (*e.g.*, corn and *Kochia Scoparia*), are capable of accumulating sulfate to concentrations that are potentially toxic to ruminants (OECD, 2005).

In anaerobic environments sulfate is biologically reduced to (hydrogen) sulfide by sulfate reducing bacteria, or incorporated into living organisms as source of sulfur, and thereby included in the sulfur cycle (OECD, 2005).

Aquatic Toxicity

A review of the acute and chronic aquatic toxicity studies can be found in the OECD SIAR for sulfuric acid (OECD, 2001). The 24-hour LC_{50} in zebrafish (*Brachydanio rerio*) is 82 mg/L. In another study, the 48-hour LC_{50} in Bluegill sunfish (*Lepomis macrochirus*) was reported to be 16-28 mg/L at pH 3.25 to 3.5.

In a chronic toxicity study, the NOEC values for brook trout (*Salvelinus fontinalis*) are: 0.31 mg/L (pH 5.2) for embryo survival; 0.15 mg/L (pH 5.5) for time hatching, and 0.13 mg/L (pH 5.56) for weight of young fish.

The lowest 24-hour LC_{50} in *Daphnia magna* was reported to be 29 mg/L. In a chronic toxicity study, the 35-day NOEC for the midge *Tanytarsus dissimilis* is 0.15 mg/L (pH 5.5).

No standard algae growth studies could be found.

Toxicity to Sediment Organisms

No data are available.

Toxicity to Terrestrial Organisms

No data are available.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for two trophic levels. Acute $E(L)C_{50}$ values are available for fish (16 mg/L) and Daphnia (29 mg/L). Chronic toxicity studies are also available for fish and invertebrates, with comparable NOECs. On the basis that the data consists of short-term and long-term results from two trophic levels, an assessment factor of 50 has been applied to the lowest reported NOEC of 0.13 mg/L for fish. The $PNEC_{aquatic}$ value is 0.0026 mg/L (2.6 µg/L).

$PNEC_{sediment}$: No reliable experimental toxicity data on sediment organisms are available. Sulfuric acid dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc parameters do not readily apply to inorganics, such as sulfuric acid. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of sulfuric acid to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No reliable experimental toxicity data on terrestrial organisms are available. The environmental distribution of sulfuric acid is dominated by its water solubility. Sorption of sulfuric acid should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Koc and Kow parameters do not readily apply to inorganics, such as sulfuric acid. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, sulfuric acid is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Sulfuric acid is an organic salt that dissociates completely to hydrogen and sulfate ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both hydrogen and sulfate ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria is not considered applicable to this inorganic salt.

Hydrogen and sulfate ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, sulfuric acid is not expected to bioaccumulate.

Chronic toxicity studies have been conducted on sulfuric acid. The lowest NOEC was reported to be 0.13 mg/L in fish; this value is ~0.1 mg/L and thus meets the screening criteria for toxicity.

The overall conclusion is that sulfuric acid is not a PBT substance.

References

OECD (2001). Screening Information Dataset (SIDS) Initial Assessment Report for Sulfuric acid (CAS No. 7664-93-9), UNEP Publications.

OECD (2005). Screening Information Dataset (SIDS) Initial Assessment Report for Sodium sulfate (CAS No. 7757-82-6), UNEP Publications.

Environmental Assessment

Talc
(CAS No. 61789-40-0)

Talc is a mineral composed of hydrated magnesium silicate with the chemical formula $Mg_3Si4O_{10}(OH)_2$ or $H_2Mg_3(SiO_3)_4$. Talc is not soluble in water.

Biodegradation

As a mineral, talc does not biodegrade.

Aquatic Toxicity

No data were found. As an insoluble mineral, talc is not expected to be bioavailable; therefore, it is not expected to toxic to aquatic organisms.

Toxicity to Sediment Organisms

No data were found. As an insoluble mineral, talc is not expected to be bioavailable; therefore, it is not expected to toxic to sediment organisms.

Toxicity to Terrestrial Organisms

No data were found.

Determination of PNECs

PNEC values for talc cannot be calculated.

PBT Assessment

Talc is an inorganic mineral that is insoluble in water. Talc is not expected to be bioavailable to aquatic organisms; thus, it is does not meet the criteria for bioaccumulation or toxicity. Talc does not biodegrade in the environment. It is a naturally-occurring mineral and is persistent in the environment. However, for the purposes of this PBT assessment, it does not meet the criteria for persistence.

Environmental Assessment

Tributyl Tetradecyl Phosphonium Chloride [TTPC]
(CAS No. 81741-28-8)

Limited toxicity information was located for this alkyl phosphonium salt.

Biodegradation

No data were found.

Aquatic Toxicity

Bellacide 350 MSDS: The 96-hour LC_{50}s in rainbow trout and Bluegill sunfish were reported to be 0.46 mg/L and 0.06 mg/L, respectively. The 48-hour EC_{50} in Daphnia was reported to be 0.025 mg/L.

U.S. EPA OPP Pesticide Ecotoxicity Database: The 96-hour LC_{50}s in rainbow trout are 0.49 and 0.2 mg/L. The 96-hour LC_{50}s in Bluegill sunfish and common carp (*Cyprinus carpio*) are 0.06 and 0.09 mg/L, respectively. The 48-hour EC_{50} in Daphnia is 0.025 mg/L.

Toxicity to Sediment Organisms

No data were found.

Toxicity to Terrestrial Organisms

U.S. EPA OPP Pesticide Ecotoxicity Database: The 8-day dietary LC_{50} in Bobwhite Quail is 4,215 ppm, with a NOEL of 1,980 ppm. The 8-day dietary LC_{50} in Mallard Duck is 3,663 ppm, with a NOEL of 1,780 ppm. The 14-day oral gavage LD_{50} in Mallard Duck is 232 mg/kg, with a NOEL of 178 mg/kg.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for two trophic levels. Acute $E(L)C_{50}$ values are available for fish (0.2 mg/L) and Daphnia (0.025 mg/L). On the basis that the data consists of short-term results from two trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 0.025 mg/L for Daphnia. The $PNEC_{aquatic}$ is calculated to be 2.5×10^{-5} mg/L (0.025 µg/L).

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The equilibrium partition method was used to determine a $PNEC_{soil}$.

PBT Assessment

No information is available on biodegradation.

No information is available on bioaccumulation.

No chronic toxicity data are available for TTPC. The lowest acute $EC(L)_{50}$ of TTPC is 0.025 mg/L in invertebrates. Since this value is <0.1 mg/L, TTPC does meet the screening criteria for toxicity.

References

Material Safety Data Sheet for Bellacide 350, BWA Water Additives, SDS No. 10794, Report Date: 10/03/2009.

National Information System of the Regional Integrated Pest Management (IPM) Centers, U.S. Department of Agriculture and National Institutes of Food and Agriculture (www.ipmcenters.org).

Santos

APPENDIX G.4 SCHLUMBERGER CLEARFRAC XT

Environmental Assessment

Acetic Acid
(CAS No. 64-19-7)

Acetic acid and its salts undergo dissociation in aqueous media into the acetate anion ($H_3C_2O_2^-$) and the respective cations (H^+, NH_4^+, Ca^{2+}, Mg^{2+}, Mn^{2+}, K^+, Na^+). The toxicity of each compound is driven by acetate, with the cations playing a minor role. The pH is 2.5 at 50 g/L and 20°C; and the pK_a is 4.76 at 20°C.

Environmental Transport

Level I fugacity modeling predicts that about 73% of any acetic acid released to the environment would partition to water, with the remainder partitioning into the air (U.S. HPVIS database).

Biodegradation

Acetic acid and its salts readily dissociate into their respective cations and the acetate anion; the anion acetate is readily biodegraded. In aerobic conditions using adapted wastewater from domestic sewage, degradation was 96% after 20 days (Price *et al.*, 1974). It was also shown to be readily biodegradable under anaerobic conditions using activated sludge (99% after 7 days) (Kameya *et al.*, 1995).

Aquatic Toxicity

The 96-hour LC_{50} in bluegill sunfish is 75 mg/L (Price *et al.*, 1974), and the 96-hour LC_{50} in mosquito fish is 251 mg/L (Wallen *et al.*, 1957). The 96-hour LC_{50} of 60% acetic acid in *Oncorhynchus mykiss* is 108 mg/L (64.8 mg acetic acid/L) (unpublished data, ECHA). In a chronic study with *Oncorhynchus mykiss*, the 21-day LC_{50} and NOEC for 60% acetic acid were 87 mg/L and 57.2 mg/L, respectively (unpublished data, ECHA). The 21-day LC_{50} and NOEC for 100% acetic acid were 52.2 mg/L and 34.3 mg/L, respectively (unpublished data, ECHA).

The 24-hour EC_{50} to Daphnia was reported to be 95 mg/L (un-neutralized) and 6,000 mg/L (neutralized to pH 8.0) (Bringmann and Kuehn, 1982). One other study showed the 48-hour EC_{50} to be 65 mg/L (Janssen *et al.*, 1993). In a chronic Daphnia study, the 21-day NOEC for reproduction was reported to be 22.7 mg/L for 100% acetic acid (unpublished data, ECHA). In another chronic Daphnia study, the 21-day NOEC for reproduction was 31.4 mg/L for 100% acetic acid (unpublished data, ECHA).

In an algae growth inhibition study, the reported nominal ErC_{50} to *Desmodesmus subspicatus* was 810.9 mg/L for 60% acetic acid (unpublished data, ECHA). The

reported nominal ErC_{50} was 486.5 mg/L for 100% acetic acid (unpublished data, ECHA). The toxicity threshold to algae after 8 days in a growth inhibition test was reported to be 4,000 mg/L (Bringmann and Kuehn, 1980).

Toxicity to Terrestrial Organisms

No data could be located.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (65 mg/L) and Daphnia (65 mg/L), and algae (487 mg/L). Long-term results are also available for fish (NOEC = 34 mg/L) and Daphnia (NOEC = 23 mg/L). On the basis that the data consists of short-term results from three trophic levels and two chronic study for fish and another chronic study for Daphnia, an assessment factor of 50 has been applied to the lowest NOEC of 23 mg/L for Daphnia. The $PNEC_{aquatic}$ was calculated to be 0.5 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Acetic acid dissociates completely in water with its environmental distribution dominated by its high water solubility. Since log Kow and Koc are only applicable to the non-ionized forms of a substance, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Thus, the determination of the $PNEC_{sediment}$ is not possible. Based on its properties, no adsorption of acetic acid to sediment is to be expected and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. Acetic acid dissociates completely in water with its environmental distribution dominated by its high water solubility. Since log Kow and Koc are only applicable to the non-ionized forms of a substance, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Thus, the determination of the $PNEC_{soil}$ is not possible. Based on its properties, no adsorption of acetic acid to soil is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

The acetate ion of acetic acid is readily biodegradable and thus it does not meet the screening criteria for persistence.

The log Kow for acetic acid is reported to be -0.17 (Verschueren, 1966). Acetate is also found in the body and is metabolized as part of the body's biochemical pathways. Thus,

acetic acid (specifically, the acetate ion) does not meet the screening criteria for bioaccumulation.

The NOECs from the chronic aquatic toxicity data on acetic acid are >0.01 mg/L. Thus, acetic acid does not meet the criteria for toxicity.

The overall conclusion is that acetic acid is not a PBT substance.

References

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Environmental Assessment

Reaction mass of 5-chloro-2-methyl-4-isothiazolin-3-one and 2-methyl-2H-isothiazolin-3-one [3:1]
(CAS No. 55965-84-9)

Environmental Fate

5-Chloro-2-methyl-4-isothiazolin-3-one and 2-methyl-4-isothiazolin-3-one, the active ingredients in DOW™ CMIT/MIT antimicrobial products, have a low bioconcentration potential (tendency to accumulate in the food chain) and a high potential for mobility in soil. They are completely soluble in water. In the environment these compounds would tend to partition into water where they would rapidly biodegrade to non-persistent substances which are several orders of magnitude less toxic than parent compound. They would also be removed by common biological wastewater treatment facilities.

Biodegradation

The primary aerobic biodegradability of MIT has been examined in a river sediment-water system by use of a ^{14}C-labelled model compound. During the 7-day experiment ^{14}C-labelled MIT was rapidly metabolized as only 12.6% of the initial MIT was present after 24 hours of incubation at 25 The calculated half-life for the parent compound was 9.1 hours (Reynolds, 1994a). MIT was metabolized to several unidentified metabolites. One of the major metabolites reached a level corresponding to 18.2% of the ^{14}C added after 24 hours of incubation. This metabolite decreased to 6.8% after 7 days which indicates further transformation. Other metabolites tended to increase during the 7-day experiment. At the end of the experiment metabolites that were bound in the sediment corresponded to 55%, whereas $^{14}CO_2$ attained 9% of the added ^{14}C. Most of the formed metabolites have shorter chromatographic retention times than MI which indicates that they are polar compounds. On the basis of the identification of metabolites from transformation of 4,5-dichloro-2-(n-octyl)-4-isothiazolin-3-one, it has been proposed that MI is transformed via N-methyl malonamic acid, N-methyl acetamide, and malonic acid (Madsen, 2000).

The primary biodegradability of CMIT has been examined with the same type of sediment and water as described for MIT. The ^{14}C-labelled CMIT was rapidly metabolized as only 30% of the initial CMI remained after 24 hours of incubation at 25 The calculated half-life for the intact CMIT was 17.3 hours (Reynolds, 1994b). At the end of the 7-day experiment, the sediment bound metabolites corresponded to 57.1% of the added ^{14}C, whereas 2.8% of the added ^{14}C was released as $^{14}CO_2$. Due to the structural similarities of MI and CMIT, it is suggested that the major metabolites for the transformation of CMIT are the same as described for MIT.

MIT was tested in an OECD 301B test modified for low concentrations of ^{14}C-labelled

compounds. The accumulated $^{14}CO_2$ attained 54.1%, 55.8%, and 47.6% in the respective concentrations (0.1, 0.03 and 0.01 mg/l) after 29 days. During the 10-day window, 37%, 30% and 30%, respectively, of the initial MIT was mineralized to $^{14}CO_2$ (Bashir, 1998a).

CMIT was tested in an OECD 301B modified for low concentrations of ^{14}C-labelled compounds. The accumulated $^{14}CO_2$ attained 38.8%, 55.3%, and 62% in the respective concentrations (0.3, 0.1, and 0.03 mg/l) after 29 days. During the 10- day window, 25%, 40%, and 48%, respectively, of the initial CMIT was mineralized to $^{14}CO_2$. The ultimate biodegradability of CMIT exceeded the 60%-pass level for ready biodegradability at the lowest test concentration of 0.03 mg/L, but the pass level was not reached within the 10-day window Bashir, 1998b).

From Dow Chemicals MSDS for ROCIMA GT:
Biodegradation (aquatic metabolism): 5-Chloro-2-methyl-4-isothiazolin-3-one (CMIT): t ½ anaerobic = 0.2 day, t ½ aerobic = 0.38 – 1.3 days; 2-Methyl-4-isothiazolin-3-one (MIT): t ½ aerobic = 0.38 – 1.4 days.

Bioaccumulation

The bioaccumulation of CMIT in bluegill sunfish *(Lepomis macrochirus)* resulted in BCF values of 102, 114, and 67 at nominal concentrations of 0.02, 0.12, and 0.8 mg/L (Erikson *et al*. 1995). These BCF values are based on total accumulated ^{14}C and include both the parent compound and metabolites. The BCF for MIT has been determined to 2.3 at a nominal concentration of 0.12 mg/L (Erikson *et al*. 1995).

Aquatic Toxicity

From Dow Chemicals MSDS for ROCIMA GT:
The 96-hour LC_{50} for Bluegill sunfish (*Lepomis macrochirus*) is 0.28 mg/L, and the 96-hour LC_{50} for Rainbow trout (*Oncorhynchus mykiss*) is 0.188 mg/L. The 48-hour EC_{50} for *Daphnia magna* is 0.126 mg/L. The 72-hour ErC_{50} for algae (*Selenastrum capricornutum*) is 0.027 mg/L.

Toxicity to Terrestrial Organisms

No data were located.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (0.188 mg/L), Daphnia (0.126 mg/L), and algae (0.027 mg/L). On the basis that the data consists of short-term results from three trophic levels,

an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 0.027 mg/L for Daphnia. The $PNEC_{aquatic}$ is 2.7×10^{-5} mg/L or 0.027 µg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$. The Koc was calculated using EPISUITE (MCI Method). CMIT: Using a Koc of 19.38 and a $PNEC_{aquatic}$ of 0.027 µg/L, the $PNEC_{sediment}$ was calculated to be 0.025 µg/kg. MIT: Using a Koc of 12.08 and a $PNEC_{aquatic}$ of 0.027 µg/L, the $PNEC_{sediment}$ was calculated to be 0.022 µg/kg.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The equilibrium partition method was used to determine a $PNEC_{soil}$. The Koc was calculated using EPISUITE (MCI Method). CMIT: Using a Koc of 19.38 and a $PNEC_{aquatic}$ of 0.027 µg/L, the $PNEC_{soil}$ was calculated to be 0.007 µg/kg. MIT: Using a Koc of 12.08 and a $PNEC_{aquatic}$ of 0.027 µg/L, the $PNEC_{soil}$ was calculated to be 0.0043 µg/kg.

PBT Assessment

The half-lives of CMIT and MIT is a river water-sediment system were 17.3 hours and 9.1 hours, respectively. Thus, CMIT/MIT do not meet the criteria for persistence.

The experimental BCF for CMIT is 67-114 in bluefish sunfish, and the BCF for MIT was determined to be 2.3. Thus, CMIT/MIT do not meet the criteria for bioaccumulation.

No chronic toxicity data are available for CMIT/MIT; however, the acute $E(L)C_{50}$ values for algae are >0.01 but <0.1 mg/L. Thus, CMIT/MIT meet the screening criteria for toxicity.

The overall conclusion is that CMIT/MIT mixture is not PBT substances.

References

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Dow Chemicals MSDS for ROCIMA 625

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Environmental Assessment

Choline chloride
Cholinium chloride
(CAS No. 67-48-1)

Choline chloride, also known as cholinium chloride, is quaternary amine salt. It dissociates in water into the corresponding positively charged quaternary hydroxyl alkylammonium ion and the negatively charged chloride ion.

Choline chloride has been reviewed in the OECD-SIDS program (OECD, 2004).

Environmental Fate and Transport

Results from Mackay Level I modeling indicate that choline chloride will be distributed completely into water (BASF AG, 2004).

Biodegradation

Choline chloride is readily biodegradable (93% within 14 days) in a MITI I-test (MITI, 1992). In another MITI-I test, biodegradation was $\geq$60%, indicating ready biodegradation (Tunkel *et al.*, 2000). A $BOD_5/ThOD_5$ ratio of 75% was obtained in a BOD_5 test performed according to DIN 38409 part 43 (BASF AG, 1984).

Bioaccumulation

No measured data on bioaccumulation of choline chloride are available. The experimental octanol-water partition coefficient (log K_{ow}) was determined to be -3.77. The estimated BCF using the equation log BCF = 0.85*logK_{ow} – 0.70 is 0.59. Therefore, bioaccumulation is not expected in aquatic organisms.

Aquatic Toxicity

The 96-hour fish LC_{50} value is >100 mg/L (nominal and measured) in *Oryzias latipes* (MOE Japan, 1999a), and the 48-hour in vertebrate EC_{50} is 349 mg/L (nominal and measured) in *Daphnia magna* (MOE Japan, 1999b). The 72-hour EC_{50} to *Pseudokirchneriella subcapitata* is >1,000 mg/L (nominal and measured) based on growth rate; the 72-hour NOEC is 32 mg/L (MOE Japan, 1999c).

In a 21-day *Daphnia magna* reproduction test, the nominal and measured NOEC was reported to be 30.2 mg/L (MOE Japan, 1999d).

Toxicity to Terrestrial Plants

No data are available.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (>100 mg/L), invertebrates (349 mg/L), and algae (>1,000 mg/L). Results from chronic studies are available for invertebrates (21-day NOEC = 30.2 mg/L) and algae (72-hour NOEC = 32 mg/L). On the basis that the data consists of chronic studies on two trophic level (albeit not on the species with the lowest $E(L)C_{50}$), an assessment factor of 50 has been applied to the lowest reported NOEC of 30 mg/L for Daphnia. The $PNEC_{aquatic}$ is 0.6 mg/L.

PBT Assessment

Choline chloride is readily biodegradable and thus it does not meet the screening criteria for persistence.

Based on a measured log Kow of -3.77 and a calculated BCF of 0.59, choline chloride does not meet the screening criteria for bioaccumulation.

The chronic toxicity data on choline chloride show NOECs of >0.01 mg/L. Thus, choline chloride does not meet the screening criteria for toxicity.

The overall conclusion is that choline chloride is not a PBT substance.

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Environmental Assessment

Crystalline Silica, Quartz
(CAS No. 14808-60-7)

Crystalline Silica, Cristobalite
(CAS No. 14464-46-1)

Silica is an off-white granule that occurs naturally in various crystalline and amorphous or other non-crystalline forms. Crystalline silica is characterized by silicon dioxide (SiO_2) molecules oriented in fixed, periodic patterns to form stable crystals. The primary crystalline form of silica is quartz. Other crystalline forms of silica include cristobalite, tripoli and tridymite.

Crystalline silica, quartz and crystalline silica, cristobalite are naturally occurring minerals that are insoluble in water.

They are persistent in the environment.

Crystalline silica, quartz, and crystalline silica, cristobalite as minerals, are not expected to bioaccumulate or be toxic to aquatic organisms because of their water insolubility and lack of bioavailability.

Crystalline silica, quartz and crystalline silica, cristobalite are not considered to be PBT substances.

Environmental Assessment

Erucic amidopropyl dimethylbetaine
(CAS No. 149879-98-1)

No data were located on environmental fate/transport or aquatic toxicity. The QSAR models in EPI Suite™ (U.S. EPA, 2012) were used to estimate values for the environmental assessment.

Environmental Fate

A MacKay Level III fugacity model predicts a distribution of 51.8% to soil; 44.2% to sediment; 4.0% to water; and 0.0005% to air (U.S. EPA, 2012).

Biodegradation

Erucic amidopropyldimethyl betaine is predicted to biodegrade fast (Biowin 2) and in the timeframe of weeks-months (Biowin 3) (U.S. EPA, 2012).

Bioaccumulation

The estimated log K_{ow} of erucic amidopropyldimethyl betaine is estimated to be 5.38 (U.S. EPA, 2012). The BCF is estimated to be 70.8 (U.S. EPA, 2012).

Aquatic Toxicity

Using the QSAR model ECOSAR (neutral organic SAR), the 96-hour LC_{50} to fish is estimated to be 0.362 mg/L; the 48-hour LC_{50} to Daphnid is estimated to be 0.281 mg/L; and the 96-hour EC_{50} for algae is estimated to be 0.762 mg/L (U.S. EPA, 2012).

These values exceed the water solubility for erucic amidopropyldimethyl betaine, which is estimated to be 0.02368 mg/L (U.S. EPA, 2012).

Determination of PNECs

$PNEC_{aquatic}$: There are no experimental data on erucic amidopropyldimethyl betaine. Estimated acute $E(L)C_{50}$ values using the QSAR model ECOSAR (neutral organic SAR) are: fish (0.362 mg/L), Daphnia (0.281 mg/L), and algae (0.762 mg/L). These values exceed the water solubility for erucic amidopropyl betaine, which is estimated to be 0.02368 mg/L. Thus, the water solubility value will be used as the basis for the

$PNEC_{aquatic}$. Using as assessment factor of 1,000 since there are no experimental chronic data, the $PNEC_{aquatic}$ is 2.4×10^{-5} mg/L.

PBT Assessment

Erucic amidopropyldimethyl betaine is predicted to biodegrade fast (Biowin 2) and in the timeframe of weeks-months (Biowin 3). Thus, it does not meet the screening criteria for persistence.

The estimated log K_{ow} of erucic amidopropyldimethyl betaine is estimated to be 5.38. The BCF is calculated to be 70.8. Furthermore, erucic amidopropyldimethyl betaine is predicted to undergo biotransformation in aquatic organisms. Thus, erucic amidopropyldimethyl betaine does not meet the screening criteria for bioaccumulation.

No acute or chronic experimental aquatic toxicity was available for erucic amidopropyldimethyl betaine. Based on the QSAR model ECOSAR, the acute $E(L)C_{50}$ values are greater than the water solubility of erucic amidopropyldimethyl betaine, which is 0.02368 mg/L. Thus, chronic toxicity with a NOEC of <0.01 mg/L cannot be excluded. The ECOSAR model estimates ChVs of 0.051 and 0.065 for fish and daphnid, respectively. Since these values are >0.1 mg/L, erucic amidopropyldimethyl betaine meets the criteria for toxicity.

The overall conclusion is that erucic amidopropyldimethyl betaine is not a PBT substance.

Reference

U.S. EPA (2012) EPI Suite™ Version 4.11, United States Environmental Protection Agency, Office of Pollution Prevention and Toxics and Syracuse Research Corporation.

Environmental Assessment

Hydrochloric acid
(CAS No. 7647-01-0)

Hydrochloric acid has been reviewed in the OECD-SIDS program (OECD, 202a,b).

Environmental Fate and Transport

Hydrochloric acid is readily dissociated in water into hydrated protons and chloride ions.

The increase in the concentration of hydrochloric acid in water decreases the pH in the aquatic ecosystem. Generally, the buffer capacity to maintain the pH in the aquatic ecosystem is important and the equilibrium between CO_2, HCO_3^- and CO_3^{2-} in the aquatic ecosystem is mainly responsible for the buffer capacity of receiving water.

$CO_2 + H_2O \leftrightarrow HCO_3^- + H^+$ ($pKa_1 = 6.35$)

$HCO_3^- \leftrightarrow CO_3^{2-} + H^+$ ($pKa_2 = 10.33$)

According to UNEP (1995), the mean, the 10th-percentile and the 90th-percentile of bicarbonate concentrations for 77 rivers in North-America, South-America, Asia, Africa, Europe and Oceania were 106, 20 and 195 mg/L, respectively. The buffering capacity for neutralization of receiving water with bicarbonate concentrations of 20, 106 and 195 mg/L is calculated to be 2.19, 11.60 and 21.3 mg/L, respectively.

Aquatic Toxicity

Several studies on the acute toxicity to fish have been published. The lowest 96-hour LC_{50} was reported to be 4.92 mg/L for *Cyprinus carpio* at pH 4.3 which was conducted according to OECD 203 guidelines (MLIT, 1999). The 96-hour LC_{50} for *Oncorhynchus mykiss* was 7.45 mg/L at pH 4.12 for hard water and 10.3 mg/L at pH 3.98 for soft water (Graham and Wood, 1981). The 96-hour LC_{50} in *Lepomis macrochirus* is 55.1 to 30.9 mg/L at pH 3.25 - 3.5; the low pH caused a reduction in the oxygen carrying capacity of hemoglobin and excessive secretion of mucus from the gills which in turn interfered with gas exchange (Ellgaard and Glimore, 1984).

Generally, the results of toxicity tests with acid or base depend on the buffer capacity of the test medium. Dechlorinated tap water was used as a test medium in the three tests described above. A 96-hour LC_{50} of 30.9 to 24.6 at pH 3.5-3.6 was obtained for *Lepomis macrochirus* using artificial water prepared from distilled water and analytical or reagent grade chemicals (Cairns and Scheier, 1959); other reported values are a 96-hour LC_{50} of 282 mg/L for *Gambusia affinis* (Wallen *et al.*, 1957) and a 16-hour LC_{100} value of 0.492 mg/L at pH 5.3 for the pike perch fry (*Lucioperca lucioperca*) conducted with pond water

(pH 6.0-8.2) are reported (Stangenberg, 1975). A 24-hr LC_{50} value of 60-80 mg/L for *Semotitus astromaculatus* with river water (pH 8.3) has also been reported. No long-term or chronic toxicity data on fish were located (Gillette *et al.*, 1952).

The 48-hour EC_{50} for *Daphnia magna* is 0.492 mg/L at pH 5.3 based on immobilization (MLIT, 1999). No long-term or chronic toxicity data on invertebrates have been reported. The 72-hour EC_{50} to *Selenastrum capriornutum* is 0.78 mg/L (pH 5.1) for biomass; 0.492 mg/L (pH 5.3) for growth rate; and the 72-hr-NOEC is 0.097 mg/L (pH 6.0) for biomass and growth rate (MLIT, 1999).

The hazard of hydrochloric acid for the environment is caused by the proton (pH effect). For this reason the effect of hydrochloric acid on the organisms depends on the buffer capacity of the aquatic ecosystem. Also, the variation in acute toxicity for aquatic organisms can be explained to a significant extent by the variation in buffer capacity of the test medium. For example, LC_{50} values of acute fish toxicity tests varied from 4.92 to 282 mg/L.

It is not considered useful to calculate a PNEC for hydrochloric acid because factors such as the buffer capacity, the natural pH, and the fluctuation of the pH are very specific for a certain ecosystem.

Toxicity to Terrestrial Organisms

No data are available.

Determination of PNECS

$PNEC_{aquatic}$: Based on the information above, a $PNEC_{aquatic}$ was not derived for hydrochloric acid.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Kow and Koc parameters do not readily apply to inorganics, such as hydrochloric acid. Thus;, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of hydrochloric acid to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. Sorption of hydrochloric acid should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Koc and Kow parameters do not readily apply to inorganics, such as hydrochloric acid. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, hydrochloric acid is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Hydrochloric acid is an organic salt that dissociates completely to hydrogen and chloride ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both hydrogen and chloride ions are also ubiquitous and are present in most water, soil and sediment. Thus, the persistent criteria is not considered applicable to this inorganic salt.

Hydrogen and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, hydrochloric acid is not expected to bioaccumulate.

No chronic toxicity data exist on hydrochloric acid; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, hydrochloric acid does not meet the screening criteria for toxicity.

The overall conclusion is that hydrochloric acid is not a PBT substance.

References

Cairns, J., and Scheier, A. (1959). The relationship of bluegill sunfish body size to tolerance for some common chemicals. Proc. 13th Ind. Waste Conf., Purdue Univ. Eng. Bull. 96: 243-252.

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Environmental Assessment

2-Propanol or Isopropanol
(CAS No. 67-63-0)

2-Propanol or isopropanol has been reviewed in the OECD-SIDS program (OECD, 1997a,b).

Environmental Fate and Transport

Based on calculated results from a Level I fugacity model, isopropanol is expected to partition primarily to the aquatic compartment (77.7%) with the remainder to the air (22.3%) (OECD, 1977a,b).

Biodegradation

Aerobic biodegradation of isopropanol has been shown to occur rapidly under non-acclimated conditions, based on a result of 49% biodegradation from a 5-day BOD test (Bridie *et al.*, 1979). Additional biodegradation data developed using standardized test methods show that isopropanol is readily biodegradable in both freshwater and saltwater media (72 to 78% biodegradation in 20 days) (Price *et al.*, 1974).

Bioaccumulation

Bioconcentration of isopropanol in aquatic organisms is not expected to occur based on a measured log n-octanol/water partition coefficient (log Kow) of 0.05, a calculated bioconcentration factor of 1 for a freshwater fish, and the unlikelihood of constant, long-term exposures (OECD 1977a,b).

Aquatic Toxicity

The 96-hour LC_{50} in *Pimephales promelas* is 9,640 mg/L (Veith *et al.*, 1983). The 24-hour EC_{50} in *Daphnia magna* is >10,000 mg/L (Brinkmann and Kuehn, 1977). Chronic aquatic toxicity has also been shown to be of low concern, based on 16- and 21-day NOEC values of 141 and 30 mg/L, respectively, for the freshwater invertebrate *Daphnia magna* (Hermens *et al.*, 1985); OECD, 1977a,b). Toxicity of isopropanol to plants is expected to be low, based on a 7-day toxicity threshold value of 1,800 mg/L for a freshwater algae (Bringmann and Kuehn, 1980).

Toxicity to Terrestrial Plants

Toxicity of isopropanol to plants is expected to be low, based on an EC_{50} value of 2,100 mg/L from a lettuce seed germination test (Reynolds, 1977).

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (9,640 mg/L) and invertebrates (>10,000 mg/L). Results from chronic studies are available for invertebrates (16- and 21-day NOECs for Daphnia are 141 and 30 mg/L, respectively). On the basis that the data consists of a chronic study on one trophic level, an assessment factor of 100 has been applied to the lowest reported NOEC of 30 mg/L for Daphnia. The $PNEC_{aquatic}$ is 0.3 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$. The Koc was calculated using EPISUITE. Using a Koc of 1.53 and a $PNEC_{aquatic}$ of 0.3 mg/L, the $PNEC_{sediment}$ was calculated to be 0.19 mg/kg.

$PNEC_{soil}$: Insufficient experimental toxicity data on terrestrial organisms are available. The equilibrium partition method was used to determine a $PNEC_{soil}$. The Koc was calculated using EPISUITE. Using a Koc of 1.53 and a $PNEC_{aquatic}$ of 0.3 mg/L, the $PNEC_{soil}$ was calculated to be 0.0061 mg/kg.

PBT Assessment

Isopropanol is readily biodegradable and thus it does not meet the screening criteria for persistence.

Based on a measured log Kow of 0.05 and a calculated BCF of 1, isopropanol does not meet the screening criteria for bioaccumulation.

The chronic toxicity data on isopropanol show NOECs of >0.01 mg/L. Thus, isopropanol does not meet the screening criteria for toxicity.

The overall conclusion is that isopropanol is not a PBT substance.

References

Bridie, A.L., Wolff, C.J.M., and Winter, M. (1979). BOD and COD of some petrochemicals. Water Res. 13: 627-630.

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Environmental Assessment

Magnesium chloride
(CAS No. 7786-30-3)

Environmental Fate

Magnesium chloride dissociates completely in water to the Mg^{++} cation and the chloride anion (Cl^-).

Aquatic Toxicity

The 96-hour LC_{50} of magnesium chloride to *Pimephales promelas* is 541 mg of Mg/L (or 2,119.3 mg of $MgCl_2$/L).

The 48-hour LC_{50} for *Daphnia magna* is 140 mg Mg/L (or 548.4 mg of $MgCl_2$/L). In another study, the 48-hour LC_{50} to *Daphnia magna* and *Ceriodaphnia dubia* were 339 mg of Mg/L and 225 mg of Mg/L, respectively (or 1328 and 881.4 mg of $MgCl_2$/L, respectively).

The 72-hour EC_{50} of magnesium chloride for algae *Scenedesmus subspicatus* is >100 mg/L and the NOEC is 100 mg/L.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (2,119 mg/L as $MgCl_2$), Daphnia (548 mg/L as $MgCl_2$), and algae (100 mg/L $MgCl_2$). Even though a NOEC was obtained from the algae study, there were no chronic studies conducted on fish or Daphnia. On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 100 mg/L for algae. The $PNEC_{aquatic}$ was calculated to be 0.1 mg/L. The $PNEC_{aquatic}$ is 0.1 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Magnesium chloride dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc parameters do not readily apply to inorganics, such as magnesium chloride. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of magnesium chloride to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The environmental distribution of magnesium chloride is dominated by its water solubility.

Sorption of magnesium chloride should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Koc and Kow parameters do not readily apply to inorganics, such as magnesium chloride. Thus, the equilibrium partitioning methods cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, magnesium chloride is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Magnesium chloride is an organic salt that dissociates completely to magnesium and chloride ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both magnesium and chloride ions are also ubiquitous and are present in most water, soil and sediment. Thus, the persistent criteria is not considered applicable to this inorganic salt.

Magnesium and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, magnesium chloride is not expected to bioaccumulate.

No chronic toxicity data exist on magnesium chloride; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, maganesium chloride does not meet the screening criteria for toxicity.

The overall conclusion is that magnesium chloride is not a PBT substance.

Reference

ECHA REACH database: http://apps.echa.europa.eu/registered/registered-sub.aspx

Environmental Assessment

Magnesium nitrate (CAS No. 10377-60-3)

Environmental Fate

Magnesium nitrate dissociates completely in water to Mg^{++} and the nitrate anion (NO_3^-).

Determination of PNECs

$PNEC_{aquatic}$: The ANZECC water quality guideline (2000) uses acute and chronic laboratory toxicity data for the derivation of "trigger values" for nitrate. The guideline summary for freshwaters is: *"A freshwater moderate reliability trigger value for nitrate toxicity as NO_3 (nitrate) of 700 µg/L was calculated using the statistical distribution method 95% protection and the default ACR."*

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Magnesium nitrate dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc parameters do not readily apply to inorganics, such as magnesium nitrate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of magnesium nitrate to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The environmental distribution of magnesium nitrate is dominated by its water solubility. Sorption of magnesium nitrate should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Koc and Kow parameters do not readily apply to inorganics, such as magnesium nitrate. Thus, the equilibrium partitioning methods cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, magnesium nitrate is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Magnesium nitrate is an organic salt that dissociates completely to magnesium and nitrate ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both magnesium and nitrate ions are also ubiquitous and are present in most water, soil and sediment. Thus, the persistent criteria is not considered applicable to this inorganic salt.

Magnesium ions are essential to all living organisms and its intracellular and extracellular concentrations are actively regulated. Nitrates are ions that are very soluble in aqueous solutions. Thus, magnesium nitrate is not expected to bioaccumulate.

No chronic toxicity data exist on magnesium nitrate; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, maganesium nitrate does not meet the screening criteria for toxicity.

The overall conclusion is that magnesium nitrate is not a PBT substance.

Reference

ANZECC & ARMCANZ (2000). Australian and New Zealand guidelines for fresh and marine water quality. National Water Quality Management Strategy Paper No 4, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra, Australia.

Environmental Assessment

Benzenesulfonic acid, 4-ethyenyl-, sodium salt, homopolymer (CAS No. 25704-18-1)

Acetic acid ethenyl ester, polymer with ethanol (CAS No. 25213-24-5)

Vinylidene chloride/methacrylate copolymer (CAS No. 25038-72-6)

Polyvinyl acetate, partially hydrolyzed (CAS No. 30443-60-5) THIS IS NOT THE CORRECT CASRN

All of these substances are polymers. Aquatic toxicity data was located for only for acetic acid, ethenyl ester, polymer with ethanol (CAS No. 25213-24-5) on a supplier's MSDS. However, all of the polymers listed above are expected to exhibit similar environmental fate and aquatic toxicity (Boethling and Nabholz, 1997).

Biodegradation

Generally, polymers are considered to be essentially non-biodegradable.

Bioaccumulation

Polymers are not generally absorbed through biological membranes to bioaccumulate in tissues.

Aquatic Toxicity

These polymers are not very insoluble in water and are expected to be essentially non-toxic to aquatic organisms.

The MSDS for DuPont's product ELVANOL 60-30, a polyvinyl alcohol with CAS No. 25213-24-5 (>93%) reported that concentrations of "ELVANOL" up to 10,000 mg of liter of water showed no mortality or other effect when tested on bluegill sunfish.

Determination of PNECs

$PNEC_{aquatic}$: Not determined.

PBT Assessment

These polymers are not expected to biodegrade and thus meets the criteria for persistence.

Polymers are not generally absorbed through biological membranes to bioaccumulate in tissues. Thus, these polymers do not meet the criteria for bioaccumulation.

The acute aquatic toxicity to fish (LC_{50} of >10,000 mg/L) for CASRN 25213-24-5 indicates that these polymers do not meet the criteria for toxicity.

Thus, these polymers are not considered to be PBT substances.

References

Boethling, R.S. and Nabholz, J.V. (1997). Environmental Assessment of Polymers under the U.S. Toxic Substances Control Act. In: Ecological Assessment of Polymers Strategies for Product Stewardship and Regulatory Programs (Hamilton, J.D. and Sutcliffe, R. eds.), pp. 187-234, Van Nostrand Reinhold.

DuPont (2006) MSDS for “ELVANOL” 60-30, revised 27-Oct-2006.

Environmental Assessment

Sodium chloride
(CAS No. 7647-14-5)

Sodium chloride will dissociate in aqueous solutions to sodium and chloride ions.

Determination of PNECs

$PNEC_{aquatic}$: Not determined.

$PNEC_{sediment}$: Sodium chloride dissociates completely in water with its environmental distribution dominated by its high water solubility. Kow and Koc are parameters that do not readily apply to inorganics, such as sodium chloride. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on its properties, no adsorption of sodium chloride to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: Sodium chloride dissociates completely in water with its environmental distribution idominated by its high water solubility. Kow and Koc are parameters that do not readily apply to inorganics, such as sodium chloride. Based on its properties, no adsorption of sodium chloride to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Sodium chloride is an organic salt that dissociates completely to sodium and chloride ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both sodium and chloride ions are also ubiquitous and are present in most water, soil and sediment. The persistent criteria is not considered applicable to this inorganic salt.

Sodium and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, sodium chloride is not expected to bioaccumulate.

No chronic toxicity data exist on sodium chloride; the acute $EC(L)_{50}$s are expected to be >0.1 mg/L in fish, invertebrates and algae based on aquatic toxicity studies involving sodium and chloride ions. Thus, sodium chloride does not meet the screening criteria for toxicity.

The overall conclusion is that sodium chloride is not a PBT substance.

Environmental Assessment

Sodium chloroacetate
(CAS No. 3926-62-3)

Sodium chloroacetate has been reviewed in the OECD-SIDS program (OECD, 1994).

Biodegradation

In an OECD 301 C test, there was 91% degradation after 5.5 or 9 days with or without adaptation, respectively, indicating ready biodegradation (Solyom, 1981). In an OECD 302B test, there was 80% and 90% degradation after 5 and 6 days, respectively, indicating ready biodegradation (Hoechst AG, 1992).

Bioaccumulation

The calculated log P_{ow} is <0.2 (OECD, 1994).

Aquatic Toxicity

The 96-hour LC_{50} for Harlequin fish (*Rasbora heteromorpha*) is 1,400 mg/L (Martin, 1973), and the 48-hour LC_{50} for rainbow trout (*Oncorhynchus mykiss*) is 900 mg/L (U.S. EPA, 1993).

The 24-hour LC_{50} values for *Daphnia magna* are 800 mg/L (Bouonnet, 1988) and 427 mg/L (Hoechst AG, 1992).

The 72-hour EC_{50} for green algae (*Scenedesmus subspicatus*) is 0.033 mg/L based on biomass (Hoechst AG, 1992).

Toxicity to Terrestrial Organisms

The LD_{50} for bird (Hen) was reported to be 81 mg/kg (Hoechst AG, 1992). Administration of 50 mg/kg of sodium chloroacetate by stomach tube was not lethal to two geese; but 75 mg/kg, one week later, caused death within 46 hours in both birds. Symptoms, first occurring at 3 hours with 1,000 mg/kg included incoordination and convulsions. Death occurred withn 8.5 hours. Damage to the throat and gastrointestinal tract was seen at autopsy (Christiansen *et al.*, 1961).

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (900 mg/L), Daphnia (427 mg/L), and algae (0.033 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 0.033 mg/L for algae. The $PNEC_{aquatic}$ was calculated to be 3.3×10^{-5} mg/L or 0.033 µg/L.

PBT Assessment

Sodium chloroacetate is readily biodegradable and thus it does not meet the screening criteria for persistence.

The estimated log Kow value for sodium chloroacetate is <0.2. Thus, it does not meet the screening criteria for bioaccumulation.

No chronic toxicity data exist for sodium chloroacetate. The lowest acute $E(L)C_{50}$ is 0.033 mg/L is greater than 0.01 mg/L but less than 0.1 mg/L. Thus, sodium chloroacetate meets the screening criteria for toxicity.

The overall conclusion is that sodium chloroacetate is not a PBT substance.

References

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U.S. EPA AQUIRE (Aquatic Toxicity Information Retrieval Data Base), 1993; in OECD (1994).

Environmental Assessment

Talc
(CAS No. 61789-40-0)

Talc is a mineral composed of hydrated magnesium silicate with the chemical formula $Mg_3Si4O_{10}(OH)_2$ or $H_2Mg_3(SiO_3)_4$. Talc is not soluble in water.

Biodegradation

As a mineral, talc does not biodegrade.

Aquatic Toxicity

No data were found. As an insoluble mineral, talc is not expected to be bioavailable; therefore, it is not expected to toxic to aquatic organisms.

Toxicity to Sediment Organisms

No data were found. As an insoluble mineral, talc is not expected to be bioavailable; therefore, it is not expected to toxic to sediment organisms.

Toxicity to Terrestrial Organisms

No data were found.

Determination of PNECs

PNEC values for talc cannot be calculated.

PBT Assessment

Talc is an inorganic mineral that is insoluble in water. Talc is not expected to be bioavailable to aquatic organisms; thus, it is does not meet the criteria for bioaccumulation or toxicity. Talc does not biodegrade in the environment. It is a naturally-occurring mineral and is persistent in the environment. However, for the purposes of this PBT assessment, it does not meet the criteria for persistence.

Environmental Assessment

Tetramethylammonium chloride
(CAS No. 75-57-0)

Environmental Fate

No measured data could be located on tetramethylammonium chloride.

The following information was obtained from EPISUITE v. 4.11 for this assessment (U.S. EPA, 2012). The water solubility was calculated to be 1 x 10^6 mg/L at 25^{o}C, and the octanol-water partition coefficient (log K_{ow}) was estimated to be -4.1817. A Mackay Level III model predicts that tetramethylammonim chloride will distribute 68.4% to soil, 31.6% to water, and 0.07% to sediment. Tetramethylammonium chloride is expected to biodegrade fast based on the Biowin 2 model and with an ultimate biodegradation timeframe of weeks based on the Biowin 3 model.

Bioaccumulation

No measured data could be located on tetramethylammonium chloride. The BCF was calculated to be 3.162, indicating a low bioaccumulation potential.

Aquatic Toxicity

A 96-hour LC_{50} for tetramethylammonium chloride xxxxxin fathead minnows has been reported to be 462 mg/L (ECOTOX).

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for one trophic level. The acute 96-hour LC_{50} value for fish is 462 mg/L. Using an assessment factor of 1,000, the $PNEC_{aquatic}$ is 0.5 mg/L.

References

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Santos

APPENDIX G.5 HALLIBURTON ALTERNATIVE FLUID SYSTEM

Environmental Assessment

Acetic Acid
(CAS No. 64-19-7)

Acetic acid and its salts undergo dissociation in aqueous media into the acetate anion ($H_3C_2O_2^-$) and the respective cations (H^+, NH_4^+, Ca^{2+}, Mg^{2+}, Mn^{2+}, K^+, Na^+). The toxicity of each compound is driven by acetate, with the cations playing a minor role. The pH is 2.5 at 50 g/L and 20°C; and the pK_a is 4.76 at 20°C.

Environmental Transport

Level I fugacity modeling predicts that about 73% of any acetic acid released to the environment would partition to water, with the remainder partitioning into the air (U.S. HPVIS database).

Biodegradation

Acetic acid and its salts readily dissociate into their respective cations and the acetate anion; the anion acetate is readily biodegraded. In aerobic conditions using adapted wastewater from domestic sewage, degradation was 96% after 20 days (Price *et al.*, 1974). It was also shown to be readily biodegradable under anaerobic conditions using activated sludge (99% after 7 days) (Kameya *et al.*, 1995).

Aquatic Toxicity

The 96-hour LC_{50} in bluegill sunfish is 75 mg/L (Price *et al.*, 1974), and the 96-hour LC_{50} in mosquito fish is 251 mg/L (Wallen *et al.*, 1957). The 96-hour LC_{50} of 60% acetic acid in *Oncorhynchus mykiss* is 108 mg/L (64.8 mg acetic acid/L) (unpublished data, ECHA). In a chronic study with *Oncorhynchus mykiss*, the 21-day LC_{50} and NOEC for 60% acetic acid were 87 mg/L and 57.2 mg/L, respectively (unpublished data, ECHA). The 21-day LC_{50} and NOEC for 100% acetic acid were 52.2 mg/L and 34.3 mg/L, respectively (unpublished data, ECHA).

The 24-hour EC_{50} to Daphnia was reported to be 95 mg/L (un-neutralized) and 6,000 mg/L (neutralized to pH 8.0) (Bringmann and Kuehn, 1982). One other study showed the 48-hour EC_{50} to be 65 mg/L (Janssen *et al.*, 1993). In a chronic Daphnia study, the 21-day NOEC for reproduction was reported to be 22.7 mg/L for 100% acetic acid (unpublished data, ECHA). In another chronic Daphnia study, the 21-day NOEC for reproduction was 31.4 mg/L for 100% acetic acid (unpublished data, ECHA).

In an algae growth inhibition study, the reported nominal ErC_{50} to *Desmodesmus subspicatus* was 810.9 mg/L for 60% acetic acid (unpublished data, ECHA). The

reported nominal ErC_{50} was 486.5 mg/L for 100% acetic acid (unpublished data, ECHA). The toxicity threshold to algae after 8 days in a growth inhibition test was reported to be 4,000 mg/L (Bringmann and Kuehn, 1980).

Toxicity to Terrestrial Organisms

No data could be located.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (65 mg/L) and Daphnia (65 mg/L), and algae (487 mg/L). Long-term results are also available for fish (NOEC = 34 mg/L) and Daphnia (NOEC = 23 mg/L). On the basis that the data consists of short-term results from three trophic levels and two chronic study for fish and another chronic study for Daphnia, an assessment factor of 50 has been applied to the lowest NOEC of 23 mg/L for Daphnia. The $PNEC_{aquatic}$ was calculated to be 0.5 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Acetic acid dissociates completely in water with its environmental distribution dominated by its high water solubility. Since log Kow and Koc are only applicable to the non-ionized forms of a substance, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Thus, the determination of the $PNEC_{sediment}$ is not possible. Based on its properties, no adsorption of acetic acid to sediment is to be expected and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. Acetic acid dissociates completely in water with its environmental distribution dominated by its high water solubility. Since log Kow and Koc are only applicable to the non-ionized forms of a substance, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Thus, the determination of the $PNEC_{soil}$ is not possible. Based on its properties, no adsorption of acetic acid to soil is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

The acetate ion of acetic acid is readily biodegradable and thus it does not meet the screening criteria for persistence.

The log Kow for acetic acid is reported to be -0.17 (Verschueren, 1966). Acetate is also found in the body and is metabolized as part of the body's biochemical pathways. Thus,

acetic acid (specifically, the acetate ion) does not meet the screening criteria for bioaccumulation.

The NOECs from the chronic aquatic toxicity data on acetic acid are >0.01 mg/L. Thus, acetic acid does not meet the criteria for toxicity.

The overall conclusion is that acetic acid is not a PBT substance.

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Environmental Assessment

Alcohols, C6-C12, Ethoxylated Propoxylated
(CAS No. 68937-66-6)

No toxicity information could located on alcohols, C6-C12, ethoxylated propoxylated (CAS No. 68937-66-6). Toxicity information is available on alcohol ethoxylates. Alcohols, C6-C12, ethoxylated propoxylated is produced by the use of propylene oxide (PO) in addition to ethylene oxide (EO) during the alkoxylation of the alcohol(s). the PO is either incorporated randomly by alkoxylation within the epoxide mixture, or in a block by sequencing the addition of EO and PO to the reactor. Because of the similarity in structures, the toxicity data on the alcohol ethoxylates were used to read-across to alcohols, C6-C12, ethoxylated propoxylated.

Alcohol ethoxylates (AE) are a class of non-ionic surfactants that have the basic structure $C_{x-y}AE_n$. The subscript (x-y) following the 'C' indicates the range of carbon chain units. AEs with carbon unit range between C8 to C18 are most commonly used in household detergent products. The hydrocarbon chain can be either linear or branched. AEs also contain an ethylene oxide (E) chain attached to the alcohol. The degree of ethylene oxide polymerization is indicated by the subscript (n) which indicates the average number of ethylene oxide units. In household products the average ethylene oxide chain length commonly ranges between 3 and 12 units.

The toxicity profile has been developed from a risk assessment report on alcohol ethoxylates ranging from C8 to C18 prepared by the household cleaning product and chemical industry (HERA, 2009).

Biodegradation

AE homologues with hydrocarbon chain lengths ranging from 8 to 18 and with 2 to >20 ethylene oxide units are readily biodegradable.

As a class, AE undergo rapid primary and ultimate biodegradation under both laboratory and field conditions. The biodegradability of the different AE homologues used in HERA applications is relatively unaffected by the alkyl carbon chain length and the number of EO units.

Proposed half-lives in river water at 12^{o}C: 4 to 24 hours (based on experimental data).

AE are also anaerobically biodegradable.

Bioaccumulation

The AE homologues used for domestic cleaning applications are very likely to have a log Kow value greater than 3.

The Danish EPA report on surfactants (Danish EPA, 2001) found that bioaccumulation of alkyl ethoxylates in aquatic organisms had been determined only for fish. The majority of the limited data were based on studies with 14C-labelled compounds that do not allow the distinction between the parent compound and metabolites, or material incorporated into the cells during growth. Because alcohol ethoxylates are metabolized in aquatic organisms (Danish EPA, 2001), the bioconcentration factor for the parent compound may well be overestimated in experiments in which 14C-labelled model surfactants are used. Tolls *et al.* (2000a,b) combined 14C-techniques and chemical analysis to determine the amount of AE actually present as the parent molecule in the fish. This showed that the parent AE (e.g. C13 EO8) was rapidly eliminated by transformation into metabolites, which were eliminated at a slower rate. The Danish EPA concluded that the data indicate that the more hydrophobic AE (e.g. C13 EO4, C14 EO4, and C16 EO8) have a moderate bioaccumulation potential (Danish EPA 2001). They also note that in the study by Tolls (1998) the BCF values ranged from < 5 to 387.5, whereas the uptake rates ($k1$) varied from 330 to 1660 (l x kg x d-1) and the elimination rates ($k2$) varied from 3.3 to 59 (d-1). The time to steady state and the BCF for AE increase with decreasing length of the ethoxylate chain (e.g., t95 for C13 EO8 = 2.4 h and BCF = 30-55, and t95 for C13 EO4 = 17.1 h and BCF = 233) (Danish EPA 2001).

Tolls *et al.* (2000a,b) concluded that the high values of the elimination rate constants suggest that fathead minnows efficiently biotransform AE, thereby preventing AE from attaining high concentrations in fish. They note that estimates of the bioconcentration potential of AE mixtures in influents and effluents of several wastewater treatment plants were similar to each other, implying that the bioconcentration potential was not significantly altered by the processes involved in wastewater treatment. These estimates of the bioconcentration potential were conservative and ranged around 140 L/kg.

Environment Canada and Health Canada (2006) has established that the degree of bioaccumulation expected from AE is well below the Canadian bioconcentration criterion of 5000. The sixteen measured BCF values for 15 AE homologues showed the lack of a linear relationship between alkyl or ethoxylate chain length and BCF, with the highest measured BCF value being under 800. Environment Canada (2006) concluded that it is evident that the AE metabolism rates prevent any significant accumulation. The data indicated that there may be an optimal structural combination of ethoxylate and alkyl chain lengths, at or around C14EO7, where BCF is maximized, but even the measured BCF for this chemical is well below the criterion of 5000. Thus Environment Canada (2006) concluded that ethoxylated aliphatic alcohols are not bioaccumulative.

Aquatic Toxicity

Acute aquatic effects data is presented in the HERA report only to establish that the essentially linear and branched AE used in household detergents are not more toxic than

the linear AE which have the same uses. The toxicity mechanism for AE is accepted to be non-polar narcosis, in which the AE homologues with longer hydrocarbon chains and higher log K_{ow} are more efficient at penetration of the cell membrane, and thus more toxic. However, the AE homologues must be sufficiently soluble in water to allow a toxic concentration to reach the target organism. For the long chain alcohols, generally the least soluble and the most toxic of the AE homologues, the long chain alcohol OECD-Screening Information Assessment Report (SIAR) (SIAR 2006) shows that the toxicity is restricted by solubility considerations at hydrocarbon chain lengths of 15 and above. Although the addition of ethylene oxide groups makes the other AE homologues more soluble, solubility considerations may reduce the toxicity of several higher hydrocarbon chain length and lower EO chain length AE. The available acute toxicity data follows this generally accepted pattern, and also indicates that the linear, essentially linear and branches AE are of similar toxicity.

Toxicity to Terrestrial Organisms

Acute soil toxicity measurements for both plants and soil invertebrates are available from standard tests carried out on commercial AE mixtures, which contain differing distributions of AE homologues. The available data are reviewed in the HERA report.

A range of chronic soil tests has been carried out for two pure AE homologues, C12EO4 and C16EO4. The two AE homologues chosen for the chronic tests span the hydrocarbon chain length range of high tonnage AE, and have an EO chain length value at which the toxicity is expected to be in the high range for each hydrocarbon chain length. The chronic tests, to assess the survival and reproduction of earthworms (*Eisenia fetida fetida)*, springtails (*Folsomia candida*), and nematodes (*Caenorhabditas elegans*), were carried out using a natural sandy loam soil, with an organic carbon content of 1.3%, which could be assumed to be free of pesticide. If an application factor of 10 were applied to the lowest chronic NOEC value to determine a PNEC, a PNEC of 22 mg/kg would result for C12EO4 and a PNEC of 46 mg/kg would result for the C16EO4 AE homologue. Comparison of the acute test data with the equilibrium partition soil PNEC values show very similar values. Thus, the chronic soil toxicity results for C12EO4 and C16EO4 support the validity of the PNEC values determined by equilibrium partitioning.

Information showing the relatively small difference between acute and chronic toxicity for soil organisms means that available single homologue acute data also supports the PNEC calculated by equilibrium partitioning from aquatic monitoring data. In addition, available data for AE mixtures is consistent with the equilibrium partitioning PNEC values.

Determination of $PNEC_{aquatic}$

The chronic *Daphnia magna* QSAR developed by Boeije *et al.* (2006) can be used, with an appropriate application factor, to determine the PNEC for each AE homologue. Of the three trophic level QSARs discussed here, the chronic *Daphnia magna* QSAR is the most

robust. The algal QSAR work by Wind and Belanger (2006) has shown that AE toxicity to algae, daphnia, and fish are of similar magnitude, while the chronic AE toxicity data given indicates that *Daphnia magna* are among the most sensitive invertebrates.

The PNEC values determined for each AE homologue using both the chronic *Daphnia magna* QSAR with an application factor of 10 given in Table 4.38 of the HERA report. For the *Daphnia magna* QSAR, the application factor of 10 is used as three chronic QSARs are available for AE homologues. The *Daphnia magna* QSAR has been chosen as it is the most robust of these three chronic QSARs, and has the most sensitive endpoint over much of the range of AE homologues.

The composition of alcohols, C6-C12, ethoxylated propoxylated (CAS No. 68937-66-6). For a comparable C6-C12 alcohol ethoxylate, a mean PNEC was calculated as follows: for each hydrocarbon number, the PNEC value AE for EO units 1 to 20 were average together, providing a mean value that covers the range of PNECs calculated for that hydrocarbon number. Each of these mean PNECs were then averaged together to cover all of the hydrocarbon chain lengths that may be included in alcohols, C6-C12, ethoxylated propoxylated, *i.e.* C6 to C12. It should be noted that the HERA document does not cover hydrocarbon numbers less that C8 and therefore PNEC values were not calculated for the C6 and C7 alcohol ethoxylates. Without knowing the hydrocarbon distribution in the supplier product, it is unclear how the limited data will influence the overall PNEC value for this substance.

$PNEC_{aquatic}$: Chronic Daphnia magna QSAR and an Application Factor of 10

	C8 + C9 (mg/L)	**C10 (mg/L)**	**C11 (mg/L)**	**C12 (mg/L)**
Mean	3.54	1.71	0.979	0.513
Range	0.171 – 11.9	0.118 – 6.23	0.0652 – 3.26	0.0358 – 1.7

$PNEC_{aquatic}$ (freshwater) = (3.54 + 1.71 + 0.979 + 0.513)/4 = 1.69 mg/L

PBT Assessment

Based on the alcohol ethoxylates, the alcohols, C6-C12, ethoxylated propoxylated are expected to be readily biodegradable; thus, they not meet the screening criteria for persistence.

Based on the information provided in the bioaccumulation section above on the alcohol ethoxylates, the alcohols, C6-C12, ethoxylated propoxylated are not be expected to meet the criteria for bioaccumulation.

The chronic Daphnia NOEC value for the C8-C12 alcohol ethoxylates is >0.1 mg/L. Thus, the alcohols, C6-C12, alcohols, ethoxylated propoxylated are not expected to meet the criteria for toxicity.

The overall conclusion is that alcohols, C6-C12, ethoxylated propoxylated (CAS No. 68937-66-6) is not a PBT substance.

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Environmental Assessment

Alcohols, C10-C16, Ethoxylated Propoxylated
(CAS No. 69227-22-1)

No toxicity information could located on alcohols, C10-C16, ethoxylated propoxylated (CAS No. 69227-22-1). Toxicity information is available on alcohol ethoxylates. Alcohols, C10-C16, ethoxylated propoxylated is produced by the use of propylene oxide (PO) in addition to ethylene oxide (EO) during the alkoxylation of the alcohol(s). the PO is either incorporated randomly by alkoxylation within the epoxide mixture, or in a block by sequencing the addition of EO and PO to the reactor. Because of the similarity in structures, the toxicity data on the alcohol ethoxylates were used to read-across to alcohols, C10-C16, ethoxylated propoxylated.

Alcohol ethoxylates (AE) are a class of non-ionic surfactants that have the basic structure $C_{x\text{-}y}AE_n$. The subscript (x-y) following the 'C' indicates the range of carbon chain units. AEs with carbon unit range between C8 to C18 are most commonly used in household detergent products. The hydrocarbon chain can be either linear or branched. AEs also contain an ethylene oxide (E) chain attached to the alcohol. The degree of ethylene oxide polymerization is indicated by the subscript (n) which indicates the average number of ethylene oxide units. In household products the average ethylene oxide chain length commonly ranges between 3 and 12 units.

The toxicity profile has been developed from a risk assessment report on alcohol ethoxylates ranging from C8 to C18 prepared by the household cleaning product and chemical industry (HERA, 2009).

Biodegradation

AE homologues with hydrocarbon chain lengths ranging from 8 to 18 and with 2 to >20 ethylene oxide units are readily biodegradable.

As a class, AE undergo rapid primary and ultimate biodegradation under both laboratory and field conditions. The biodegradability of the different AE homologues used in HERA applications is relatively unaffected by the alkyl carbon chain length and the number of EO units.

Proposed half-lives in river water at 12^{o}C: 4 to 24 hours (based on experimental data).

AE are also anaerobically biodegradable.

Bioaccumulation

The AE homologues used for domestic cleaning applications are very likely to have a log Kow value greater than 3.

The Danish EPA report on surfactants (Danish EPA, 2001) found that bioaccumulation of alkyl ethoxylates in aquatic organisms had been determined only for fish. The majority of the limited data were based on studies with 14C-labelled compounds that do not allow the distinction between the parent compound and metabolites, or material incorporated into the cells during growth. Because alcohol ethoxylates are metabolized in aquatic organisms (Danish EPA, 2001), the bioconcentration factor for the parent compound may well be overestimated in experiments in which 14C-labelled model surfactants are used. Tolls *et al.* (2000a,b) combined 14C-techniques and chemical analysis to determine the amount of AE actually present as the parent molecule in the fish. This showed that the parent AE (e.g. C13 EO8) was rapidly eliminated by transformation into metabolites, which were eliminated at a slower rate. The Danish EPA concluded that the data indicate that the more hydrophobic AE (e.g. C13 EO4, C14 EO4, and C16 EO8) have a moderate bioaccumulation potential (Danish EPA 2001). They also note that in the study by Tolls (1998) the BCF values ranged from < 5 to 387.5, whereas the uptake rates ($k1$) varied from 330 to 1660 (l x kg x d-1) and the elimination rates ($k2$) varied from 3.3 to 59 (d-1). The time to steady state and the BCF for AE increase with decreasing length of the ethoxylate chain (e.g., t95 for C13 EO8 = 2.4 h and BCF = 30-55, and t95 for C13 EO4 = 17.1 h and BCF = 233) (Danish EPA 2001).

Tolls *et al.* (2000a,b) concluded that the high values of the elimination rate constants suggest that fathead minnows efficiently biotransform AE, thereby preventing AE from attaining high concentrations in fish. They note that estimates of the bioconcentration potential of AE mixtures in influents and effluents of several wastewater treatment plants were similar to each other, implying that the bioconcentration potential was not significantly altered by the processes involved in wastewater treatment. These estimates of the bioconcentration potential were conservative and ranged around 140 L/kg.

Environment Canada and Health Canada (2006) has established that the degree of bioaccumulation expected from AE is well below the Canadian bioconcentration criterion of 5000. The sixteen measured BCF values for 15 AE homologues showed the lack of a linear relationship between alkyl or ethoxylate chain length and BCF, with the highest measured BCF value being under 800. Environment Canada (2006) concluded that it is evident that the AE metabolism rates prevent any significant accumulation. The data indicated that there may be an optimal structural combination of ethoxylate and alkyl chain lengths, at or around C14EO7, where BCF is maximized, but even the measured BCF for this chemical is well below the criterion of 5000. Thus Environment Canada (2006) concluded that ethoxylated aliphatic alcohols are not bioaccumulative.

Aquatic Toxicity

Acute aquatic effects data is presented in the HERA report only to establish that the essentially linear and branched AE used in household detergents are not more toxic than

the linear AE which have the same uses. The toxicity mechanism for AE is accepted to be non-polar narcosis, in which the AE homologues with longer hydrocarbon chains and higher log K_{ow} are more efficient at penetration of the cell membrane, and thus more toxic. However, the AE homologues must be sufficiently soluble in water to allow a toxic concentration to reach the target organism. For the long chain alcohols, generally the least soluble and the most toxic of the AE homologues, the long chain alcohol OECD-Screening Information Assessment Report (SIAR) (SIAR 2006) shows that the toxicity is restricted by solubility considerations at hydrocarbon chain lengths of 15 and above. Although the addition of ethylene oxide groups makes the other AE homologues more soluble, solubility considerations may reduce the toxicity of several higher hydrocarbon chain length and lower EO chain length AE. The available acute toxicity data follows this generally accepted pattern, and also indicates that the linear, essentially linear and branches AE are of similar toxicity.

Toxicity to Terrestrial Organisms

Acute soil toxicity measurements for both plants and soil invertebrates are available from standard tests carried out on commercial AE mixtures, which contain differing distributions of AE homologues. The available data are reviewed in the HERA report.

A range of chronic soil tests has been carried out for two pure AE homologues, C12EO4 and C16EO4. The two AE homologues chosen for the chronic tests span the hydrocarbon chain length range of high tonnage AE, and have an EO chain length value at which the toxicity is expected to be in the high range for each hydrocarbon chain length. The chronic tests, to assess the survival and reproduction of earthworms (*Eisenia fetida fetida)*, springtails (*Folsomia candida*), and nematodes (*Caenorhabditas elegans*), were carried out using a natural sandy loam soil, with an organic carbon content of 1.3%, which could be assumed to be free of pesticide. If an application factor of 10 were applied to the lowest chronic NOEC value to determine a PNEC, a PNEC of 22 mg/kg would result for C12EO4 and a PNEC of 46 mg/kg would result for the C16EO4 AE homologue. Comparison of the acute test data with the equilibrium partition soil PNEC values show very similar values. Thus, the chronic soil toxicity results for C12EO4 and C16EO4 support the validity of the PNEC values determined by equilibrium partitioning.

Information showing the relatively small difference between acute and chronic toxicity for soil organisms means that available single homologue acute data also supports the PNEC calculated by equilibrium partitioning from aquatic monitoring data. In addition, available data for AE mixtures is consistent with the equilibrium partitioning PNEC values.

Determination of $PNEC_{aquatic}$

The chronic *Daphnia magna* QSAR developed by Boeije *et al.* (2006) can be used, with an appropriate application factor, to determine the PNEC for each AE homologue. Of the three trophic level QSARs discussed here, the chronic *Daphnia magna* QSAR is the most

robust. The algal QSAR work by Wind and Belanger (2006) has shown that AE toxicity to algae, daphnia, and fish are of similar magnitude, while the chronic AE toxicity data given indicates that *Daphnia magna* are among the most sensitive invertebrates.

The PNEC values determined for each AE homologue using both the chronic *Daphnia magna* QSAR with an application factor of 10 given in Table 4.38 of the HERA report. For the *Daphnia magna* QSAR, the application factor of 10 is used as three chronic QSARs are available for AE homologues. The *Daphnia magna* QSAR has been chosen as it is the most robust of these three chronic QSARs, and has the most sensitive endpoint over much of the range of AE homologues.

The composition of alcohols, C6-C12, ethoxylated propoxylated (CAS No. 68937-66-6). For a comparable C6-C12 alcohol ethoxylate, a mean PNEC was calculated as follows: for each hydrocarbon number, the PNEC value AE for EO units 1 to 20 were average together, providing a mean value that covers the range of PNECs calculated for that hydrocarbon number. Each of these mean PNECs were then averaged together to cover all of the hydrocarbon chain lengths that may be included in alcohols, C6-C12, ethoxylated propoxylated, *i.e.* C6 to C12. It should be noted that the HERA document does not cover hydrocarbon numbers less that C8 and therefore PNEC values were not calculated for the C6 and C7 alcohol ethoxylates. Without knowing the hydrocarbon distribution in the supplier product, it is unclear how the limited data will influence the overall PNEC value for this substance.

$PNEC_{aquatic}$: Chronic Daphnia magna QSAR and an Application Factor of 10

	C10 (mg/L)	**C11 (mg/L)**	**C12 (mg/L)**	**C13 (mg/L)**	**C14 (mg/L)**	**C15 (mg/L)**	**C16 (mg/L)**
Mean	1.71	0.979	0.513	0.308	0.142	0.074	0.042
Range	0.118 – 6.23	0.0652 – 3.26	0.0358 – 1.7	0.0196 – 0.89	0.0107 – 0.465	0.00583 – 0.243	0.00316 – 0.127

$PNEC_{aquatic}$ (freshwater) = (1.71 + 0.979 + 0.513 + 0.308 + 0.142 + 0.074 + 0.042)/7 = 0.538 mg/L

PBT Assessment

Based on the alcohol ethoxylates, the alcohols, C10-C16, ethoxylated propoxylated are expected to be readily biodegradable; thus, they not meet the screening criteria for persistence.

Based on the information provided in the bioaccumulation section above on the alcohol ethoxylates, the alcohols, C10-C16, ethoxylated propoxylated are not be expected to meet the criteria for bioaccumulation.

The chronic Daphnia NOEC value for the C10-C16 alcohol ethoxylates is >0.1 mg/L. Thus, the alcohols, C10-C16, alcohols, ethoxylated propoxylated are not expected to meet the criteria for toxicity.

The overall conclusion is that alcohols, C10-C16, ethoxylated propoxylated (CAS No. 69227-22-1) is not a PBT substance.

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Boeije, G. M., Cano, M. L., Marshall, S. J., Belanger, S. E., Van Compernolle, R. , Dorn, P. B., Dorn, Gümbel, H., Toy, R., Wind, T. (2006). Ecotoxicity QSARs for alcohol ethoxylates based on the mixture toxicity concept. Ecotoxicol. and Environ. Safety 64: 75-84.

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Environmental Assessment

Choline chloride
Cholinium chloride
(CAS No. 67-48-1)

Choline chloride, also known as cholinium chloride, is quaternary amine salt. It dissociates in water into the corresponding positively charged quaternary hydroxyl alkylammonium ion and the negatively charged chloride ion.

Choline chloride has been reviewed in the OECD-SIDS program (OECD, 2004).

Environmental Fate and Transport

Results from Mackay Level I modeling indicate that choline chloride will be distributed completely into water (BASF AG, 2004).

Biodegradation

Choline chloride is readily biodegradable (93% within 14 days) in a MITI I-test (MITI, 1992). In another MITI-I test, biodegradation was $\geq$60%, indicating ready biodegradation (Tunkel *et al.*, 2000). A $BOD_5/ThOD_5$ ratio of 75% was obtained in a BOD_5 test performed according to DIN 38409 part 43 (BASF AG, 1984).

Bioaccumulation

No measured data on bioaccumulation of choline chloride are available. The experimental octanol-water partition coefficient (log K_{ow}) was determined to be -3.77. The estimated BCF using the equation log BCF = 0.85*logK_{ow} – 0.70 is 0.59. Therefore, bioaccumulation is not expected in aquatic organisms.

Aquatic Toxicity

The 96-hour fish LC_{50} value is >100 mg/L (nominal and measured) in *Oryzias latipes* (MOE Japan, 1999a), and the 48-hour in vertebrate EC_{50} is 349 mg/L (nominal and measured) in *Daphnia magna* (MOE Japan, 1999b). The 72-hour EC_{50} to *Pseudokirchneriella subcapitata* is >1,000 mg/L (nominal and measured) based on growth rate; the 72-hour NOEC is 32 mg/L (MOE Japan, 1999c).

In a 21-day *Daphnia magna* reproduction test, the nominal and measured NOEC was reported to be 30.2 mg/L (MOE Japan, 1999d).

Toxicity to Terrestrial Plants

No data are available.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (>100 mg/L), invertebrates (349 mg/L), and algae (>1,000 mg/L). Results from chronic studies are available for invertebrates (21-day NOEC = 30.2 mg/L) and algae (72-hour NOEC = 32 mg/L). On the basis that the data consists of chronic studies on two trophic level (albeit not on the species with the lowest $E(L)C_{50}$), an assessment factor of 50 has been applied to the lowest reported NOEC of 30 mg/L for Daphnia. The $PNEC_{aquatic}$ is 0.6 mg/L.

PBT Assessment

Choline chloride is readily biodegradable and thus it does not meet the screening criteria for persistence.

Based on a measured log Kow of -3.77 and a calculated BCF of 0.59, choline chloride does not meet the screening criteria for bioaccumulation.

The chronic toxicity data on choline chloride show NOECs of >0.01 mg/L. Thus, choline chloride does not meet the screening criteria for toxicity.

The overall conclusion is that choline chloride is not a PBT substance.

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Environmental Assessment

Cocoamidopropyl betaine
(CAS No. 61789-40-0)

Cocoamidopropyl betaine has been reviewed in the OECD-SIDS program (OECD, 2006).

Cocamidopropyl betaines are mainly a mixture of C_{12}-C_{18} fatty acids from hydrolysis of coconut oil. Coconut oil has a mixed fatty acid composition, which varies slightly, as it is a natural product. Lauric acid - resulting in lauramidopropyl betaine - is the major ingredient of coconut oil. As the physical chemical properties of cocamidopropyl betaine are not fully available as measured values, calculated values of lauramidopropyl betaine (RCOOH=lauric acid, C_{12} fatty acid) - as the main component in the cocamidopropyl betaine - are indicated instead. If possible the calculated ranges for the cocamidopropyl betaine (C_{12} – C_{18}) are given. In terms of the environmental exposure assessment, the relevant calculated values of the respective betaine derived from the C_{18} fatty acid – Stearamidopropylbetaine are indicated. The characteristics of the stearamidopropylbetaine are regarded as to represent the most hydrophobic properties of the cocamidopropyl betaine.

Environmental Transport

Based on the calculation for caprylamidopropyl betaine (C8 fatty acid derivative) and stearamidopropyl betaine (C18 fatty acid derivative), cocamidopropyl betaine will be mainly distributed to the hydrosphere (59 - 100 %), and to a lesser extent to soil and sediment (0 - 20 % each). The Henry's law constants for alkylamidopropyl betaines calculated for every single fatty acid chain length indicate a very low potential for volatilization from surface waters under environmentally relevant conditions. The soil sorption coefficients (K_{OC}) calculated for the alkylamidopropyl betaines indicate a low to very high potential for sorption to organic matter of soils and sediments. The low sorption potential is confirmed by experimentally obtained values for laurylamidopropyl betaine (C12 derivative) and tetradecylamidopropyl betaine (C14 derivative) from the screening HPLC-method according to OECD Test Guideline 121. A high potential for sorption applies only for the alkylamidopropyl betaines with the C16 and C18 fatty acid chain length.

Biodegradation

Cocamidopropyl betaine can be considered as being readily biodegradable under aerobic conditions. In guideline tests biodegradation rates of 86 – 100 % after 28 days (OECD 301A/B/D/E), 90 – 93 % after 35 days (OECD 301B) and 100 % after 20 days (Directive 84/449/EEC, C.5) were determined with cocamidopropyl betaine. Under anaerobic

conditions, 80 – 90 % mineralization after 60 days or 56% after 56 days were observed for cocamidopropyl betaine.

Bioaccumulation

A low potential for bioaccumulation is to be expected for cocoamidopropyl betaines based on the calculated BCFs between 3 (with C8 fatty acid) and 71 (with C10 – C18 fatty acids).

Aquatic Toxicity

For cocoamidopropyl betaine, the lowest acute LC/EC_{50} values for fish, *Daphnia*, and algae are all in the range of 1.3 – 2 mg active substance/L. One long-term test with fish (according to OECD 215), and several chronic tests with *Daphnia* and algae were conducted on cocoamidopropyl betaine. The lowest NOECs are 0.16 mg active substance/L for fish (*Oncorhynchus mykiss*), 0.03 mg active substance/L for *Daphnia magna*, and 0.09 mg active substance/L for green algae (*Desmodesmus subspicatus*). These values were derived with analytical monitoring (photometric) except for the algae test. However, the effect values within the same species (*e.g.*, *Desmodesmus subspicatus*, *Daphnia magna*) have shown a high variability. Recent guideline studies performed in accordance with OECD 211 and 201 using state-of-the-art analytical monitoring and a quality of cocamidopropyl betaine currently commercialized, resulted in a lower aquatic toxicity. In these studies the lowest NOEC for *Daphnia* was determined to be 0.932 mg active substance/L. The lowest NOEC (72 hour, based on growth rate) for algae was determined to be 3.55 mg active substance/L (72-hour ErC_{50} = 9.86 mg active substance/L). This latter NOEC for algae is further supported by the similar NOEC of 3.53 mg active substance/L calculated using the geometric mean of all valid tests with this algae species. Furthermore, for algae a potential for recovery from the effect up to a concentration of 96 mg active substance/L has been observed.

Toxicity to Terrestrial Organisms

Two studies (without analytical monitoring) of effects on earthworms and higher plants showed low toxicity (no data given in the OECD-SIDS SIAP). Taking additionally into account that the adsorption potential of the main components of cocamidopropyl betaine (the C8 to C14 derivatives) is low, a risk for the terrestrial compartment is not expected.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. A recent state-of-the-art chronic study is available for invertebrates (lowest NOEC for Daphnia is 0.932 mg/L). A recent state-of-the-art OECD 211 study is also available with the lowest

NOEC (72 hour, based on growth rate) for algae was determined to be 3.55 mg/L. On the basis that the data consists of two chronic studies (Daphnia and algae), an assessment factor of 50 has been applied to the lowest reported NOEC of 0.932 mg/L for Daphnia. The $PNEC_{aquatic}$ is 0.019 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$. The Koc was calculated using PCKOCWIN v. 1.66 using specific betaine with C8, C10, C12, C14, C16, and C18 fatty acids. Using a Koc values of 264.7 to 120600 and a $PNEC_{aquatic}$ of 0.0.019 mg/L, the $PNEC_{sediment}$ was calculated to be 0.085 to 33.7 mg/kg.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The equilibrium partition method was used to determine a $PNEC_{soil}$. The Koc was calculated using PCKOCWIN v. 1.66 using specific betaine with C8, C10, C12, C14, C16, and C18 fatty acids. Using a Koc values of 264.7 to 120,600 and a $PNEC_{aquatic}$ of 0.0.01 mg/L, the $PNEC_{soil}$ was calculated to be 0.066 to 29.8 mg/kg.

PBT Assessment

Cocoamidopropyl betaine is readily biodegradable and thus it does not meet the screening criteria for persistence.

The estimated log Kow values for cocoamidopropyl betaine (with C8 to C18 fatty acids) is -1.28 to 3.63, calculated using KOWWIN v1.67 (HERA, 2005). Thus, cocoamidopropyl betaine does not meet the screening criteria for bioaccumulation.

The lowest chronic NOEC for cocoamidopropyl betaine is >0.1 mg/L. Thus, cocoamidopropyl betaine does not meet the criteria for toxicity.

The overall conclusion is that cocoamidopropyl betaine is not a PBT substance.

References

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Environmental Assessment

Coffee Beans (Roasted and Ground)

The composition of a medium-roasted coffee (Clarke, 1987; IARC, 1991) is shown in the table below:

Components	Typical avg content (dry basis, %)		% extractable with water, 100°C[a]
	Arabica	Robusta	
Alkaloids (caffeine)	1.3	2.4	75 - 100
Trigonelline (including roasted by-products)	1.0	0.7	85 - 100
Minerals (as oxide ash)	4.5	4.7	90
Acids			
Residual chlorogenic	2.5	3.8	100
Aquinic	0.8	1.0	100
Aliphatic	1.6	1.6	100
Sugars			
Sucrose	0.0	0.0	-
Reducing	0.3	0.3	100
Polysaccharides (unchanged from green)	33	37	10
Lignin	2.0	2.0	0
Pectins	3.0	3.0	-
Proteinaceous compounds			
Protein	10	10	15 – 20
Free amino acids	0.0	0.0	-
Lipids (coffee oil)	17	11	1
Caramelized or condensation products (*e.g.*, melanoidins) by difference	23	22.5	20-25
Volatile substances other than acids	0.1	0.1	40-80

[a]Maier (1981), for normal household brewing

The environmental assessment will focus on caffeine.

Caffeine (CAS No. 58-08-2) is an alkaloid. The chemical names for caffeine are 1,3,7-trimethyl-2,6-dioxopurine; 1,3,7-trimethylxanthine; 2,7-dihydro-1,3,7-trimethyl-1H-purine-2,6-dione; and 7-methyltheophylline. Caffeine has been reviewed in the OECD-SIDS program (OECD, 2002a,b) and has been registered in the EU under the REACH legislation (ECHA REACH database).

Caffeine is soluble in water with a solubility limit of 20 g/L at 20°C. The measured octanol-water coefficient (log K_{ow}) is -0.091. A Mackay Level I fugacity model predicts that caffeine will distribute almost entirely into water (99.99%). One biodegradation study was found on caffeine, but findings have not been considered valid due to the large variability in the results (OECD, 2002a,b). The structural analogue of caffeine, theophylline (CAS No. 58-55-9) which differs from caffeine in the absence of a methyl group at the 7- position, has been tested for ready biodegradation in an OECD 301A test (OECD, 2002a,b). There was 90-100% degradation after 22 days, with >90% at the end of the 10-day window, indicating ready biodegradation. Thus, caffeine would be expected to biodegrade rapidly in the environment.

Acute toxicity guideline studies have been conducted in fish, invertebrates and algae (OECD, 2002a,b; ECHA REACH database). A 96-hour LC_{50} in *Leuciscus idus* was reported to be 87 mg/L; the 48-hour EC_{50} in *Daphnia magna* was reported to be 182 mg/L. and the ErC_{50} in *Scenedesmus subspicatus* was reported to be >100 mg/L. Based on the lowest acute toxicity value of 87 mg/L in fish, caffeine is considered to be harmful to aquatic organisms. Using an assessment factor of 1,000, a $PNEC_{aquatic}$ is determined to be 0.087 mg/L.

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Environmental Assessment

Crystalline Silica, Quartz
(CAS No. 14808-60-7)

Crystalline Silica, Cristobalite
(CAS No. 14464-46-1)

Silica is an off-white granule that occurs naturally in various crystalline and amorphous or other non-crystalline forms. Crystalline silica is characterized by silicon dioxide (SiO_2) molecules oriented in fixed, periodic patterns to form stable crystals. The primary crystalline form of silica is quartz. Other crystalline forms of silica include cristobalite, tripoli and tridymite.

Crystalline silica, quartz and crystalline silica, cristobalite are naturally occurring minerals that are insoluble in water.

They are persistent in the environment.

Crystalline silica, quartz, and crystalline silica, cristobalite as minerals, are not expected to bioaccumulate or be toxic to aquatic organisms because of their water insolubility and lack of bioavailability.

Crystalline silica, quartz and crystalline silica, cristobalite are not considered to be PBT substances.

Environmental Assessment

Ethylene glycol
(CAS No. 107-21-1)

Ethylene glycol has been reviewed in the OECD-SIDS program (OECD, 2004a,b)

Environmental Transport

A Mackay Level III fugacity model predicts that ethylene glycol will distribute 45.6% to water, 52.3% to soil, 2.02% to air, and <0.1% to sediment (OECD, 2004a,).

Biodegradation

Ethylene glycol is readily biodegradable both aerobically and anaerobically. There was 97% degradation after 20 days in a BOD test (OECD, 2004a,b), and 96% degradation after 28 days in an OECD 301D test (OECD, 2004a,b).

The aerobic degradation of ethylene glycol was measured from grab river water samples at 4, 8, and 20^{o}C (Evans and David, 1974). At 20^{o}C, ethylene glycol was completely degraded in three days in all river waters tested, and at 8^{o}C degradation was complete within 14 days. Degradation at 4^{o}C was substantially slower, with degradation of less than 20% after 14 days in river samples with limited suspended matter and a starting concentration of 10 mg/L.

Bioaccumulation

The log K_{ow} of ethylene glycol was measured as -1.36 (Hansch *et al.*, 1989). The BCF for ethylene glycol in golden ide (*Leuciscus idus melanotus*) after three days of exposure was determined to be 10 (Freitag *et al.*, 1985).

Aquatic Toxicity

The 96-hour LC_{50} values to fry, juvenile, and subadult fathead minnows (*Pimephales promelas*) are 53,000, 49,000 and 57,000 mg/L, respectively (Mayes *et al.*, 1983). The 96-hour LC_{50} values to fathead minnows (*Pimephales promelas*) was also reported to be 72,860 mg/L (Pillard, 1995). The 96-hour LC_{50} to rainbow trout (*Oncorhynchus mykiss*) is 22,810 mg/L (OECD, 2004b). In a 12-day chronic study, the NOEC to rainbow trout (*Oncorhynchus mykiss*) was reported to be 14,692 mg/L (OECD, 2004b).

The 48-hour LC_{50} to *Daphnia magna* is 46,300 mg/L (Gersich *et al.*, 1986). The 48-hour EC_{50} values to *Ceriodaphnia dubia-affinis* and *Daphnia magna* are 10,000 and 51,000 mg/L at 24^{o}C, respectively; and 25,800 and 46,300 mg/L at 24^{o}C, respectively (Cowgill

et al., 1985). The NOEC for a 7-day reproduction test to *Ceriodaphnia dubia* is 3,469 mg/L (OECD, 2004b).

The 96-hour EC_{50} to green algae (*Selenastrum capricornutum*) is 10,940 mg/L based on cell growth; the NOEC is 10,000 mg/L (Pillard and DuFresne, 1999).

Toxicity to Sediment Organisms

No data were located.

Toxicity to Terrestrial Organisms

A mallard duck receiving 1.1 mL/kg ethylene glycol recovered, but ducks (1/dose) receiving 2.3, 4.5, 8.9, 13.3, and 17.8 mL/kg died (Stowe *et al.*, 1981). Ethylene glycol (0.1 mL/chicken egg) significantly decreased hatchability relative to controls and significantly increased embryonic mortality during weeks 1 and 3 (Ameenuddin and Suude, 1984). Doses of 0, 0.05, 0.1, and 0.15 ml/egg resulted in hatchability of approximately 82, 75, 45 and 45%, respectively.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (22,810 mg/L), Daphnia (10,000 mg/L), and algae (10,940 mg/L). NOEC values are available for fish (14,692 mg/L), invertebrates (3,469 mg/L), and algae (10,000 mg/L). On the basis that the data consists of short-term and long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported NOEC of 3,469 mg/L for invertebrates. The $PNEC_{aquatic}$ is 347 mg/L.

PBT Assessment

Ethylene glycol is readily biodegradable and thus does not meet the screening criteria for persistence.

The octanol-water coefficient (log K_{ow}) for ethylene glycol is -1.36. The measured BCF in fish is 10. Thus, ethylene glycol does not meet the criteria for bioaccumulation.

The chronic toxicity data on ethylene glycol show NOECs of >0.01 mg/L. Thus, ethylene glycol does not meet the screening criteria for toxicity.

The overall conclusion is that ethylene glycol is not a PBT substance.

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Environmental Assessment

Guar Gum
(CAS No. 9000-30-0)

Guar gum (CAS No. 9000-30-0) is the milled endosperm of the leguminous plant *Cyanopsis tetragonolobus*. Structurally, it is a galactomannan (a polysaccharide) consisting of a main chain of D-mannose with a side chain of D-galactose at approximately every second mannose unit. The mannose units are β-(l-4) linked, and the single D-galactose units are joined to the main chain by α-(1-6) linkages. The estimated molecular weight of guar gum ranges from 200,000 to 300,000 daltons (Glickman, 1969).

Biodegradation

No information was found. Guar gum, being a polysaccharide composed of galactomannan, would be expected to be readily biodegradable.

Bioaccumulation

Not expected to bioaccumulate as a polysaccharide composed of galactomannans.

Aquatic Toxicity

The 48-hour LC_{50} for *Daphnia magna* was reported to be 42 mg/L (Biesinger *et al.*, 1976).

Toxicity to Terrestrial Organisms

No data were located.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for one trophic level. An acute LC_{50} value is available for the invertebrate Daphnia (42 mg/L). On the basis that the data consists of only one short-term result from one trophic level, an assessment factor of 1,000 has been applied to the reported effect concentration of 42 mg/L for Daphnia. The $PNEC_{aquatic}$ is 0.042 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The Kow and Koc of guar gum cannot be calculated using EPISUITE because the molecular weight of guar gum greatly exceeds the limit of 1,000. Thus, the equilibrium partition

method cannot be used to determine a $PNEC_{sediment}$ and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on soil organisms are available. The Kow and Koc of guar gum cannot be calculated using EPISUITE because the molecular weight of guar gum greatly exceeds the limit of 1,000. Thus, the equilibrium partition method cannot be used to determine a $PNEC_{soil}$ and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

No biodegradation was found on guar gum. However, guar gum is a naturally occurring polysaccharide which would be expected to readily biodegrade. Thus, it is not expected to meet the screening criteria for persistence.

The molecular weight of guar gum ranges from 200,000 to 300,000 daltons, and it is also water soluble. Thus, guar gum is not expected to meet the criteria for bioaccumulation.

The acute aquatic toxicity of guar gum is >0.1 mg/L. Thus, guar gum is not expected to meet the screening criteria for toxicity.

The overall conclusion is that guar gum is not a PBT substance.

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Environmental Assessment

Hemicellulase
(CAS No. 9025-56-3)

Hemicellulases are a group of enzymes that break down hemicellulose, which are polysaccharides that are present in cell walls of all terrestrial plants. These polysaccharides have a β-(1→4)-linked backbone and are composed of pentoses (xylose, arabinoses), hexoses (mannose, glucose, galactose), and sugar acids. Unlike cellulose which are polysaccharides consisting of linear chains of several hundred to over ten thousand β-(1→4) linked D-glucoses, hemicelluloses are not chemically homogeneous. The best characterized hemicellulases are the 1,4- β -D-xylanases and, in particular, those derived from fungal sources presumably because their substrates, xylans, constitute the largest proportion of hemicelluloses in pasture plants.

No toxicity information could be located on hemicellulases; however, mammalian toxicity information were found on the cellulase enzymes (HERA report, 2005). Cellulases cleave the ß-1,4-glycosidic bonds in cellulose, and are used in the pulp and paper industry, the textile industry, and in detergents to remove deposits and stains.

Enzymes are catalytic proteins or polypeptides and consist of amino acid residues coupled via peptide bonds. They are primarily characterized by their biocatalytic or enzymatic activity. There is a broad range of detergent cellulases used both from fungal as well as from bacterial origin; all are characterized by ß-1,4-endoglucanase activity. For the purposes of risk assessment, the structure of hemicellulases would be expected to be similar to that of cellulases, given that hemicellulases and cellulases are both enzyme families that hydrolyze polysaccharides, although differing in their substrates. Thus, the toxicity data on cellulases will be used as read-across to hemicellulases.

Biodegradation

Three different cellulase enzymes were considered readily biodegradable based on the results of OECD 301C and 301E tests (HERA, 2005). In an OECD 301E test, there was 84% DOC removal of the enzyme Carezyme after 28 days. In another OECD 301E test, there was 92% DOC removal of the enzyme Clazinase® after 28 days. In an OECD 301C test, BOD/COD was 78% after 28 days. Likewise, hemicellulase is expected to be readily biodegradable.

Aquatic Toxicity

The 96-hour LC_{50} of an alkaline cellulase to zebrafish (*Brachydanio rerio*) is 330 mg aep/L (HERA, 2005). The 48-hour EC_{50} of the same alkaline cellulase to *Daphnia magna* is >1,000 mg aep/L (HERA, 2005). The same alkaline cellulase was also tested in algae (*Scenedesmus subspicatus*), with a 72-hour EC_{50} of >1000 mg aep/L (HERA,

2005).

The 24- and 48-hour EC_{50} values of an alkaline cellulase (SP 227, Celluzyme) to *Daphnia magna* are >1,000 mg aep/L and approximately 1,000 mg aep/L respectively (HERA, 2005).

Two additional acute fish toxicity studies showed findings with LC_{50} values of >100 mg aep/L, but no references were provided (HERA, 2005).

Toxicity to Sediment Organisms

No data could be located.

Toxicity to Terrestial Organisms

No data could be located.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (330 mg aep/L), Daphnia (>1,000 mg aep/L), and algae (1,000 mg aep/L). Although the HERA report provides information on two acute fish studies with LC_{50} values of >100 mg aep/L, no references were provided and were therefore excluded from the determination of PNECs. On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 330 mg aep/L for fish. The $PNEC_{aquatic}$ is 0.33 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$. A calculated Koc of <1.3 was reported in the HERA report, calculated according to the TGD. Using a Koc of 1.3 and a $PNEC_{aquatic}$ of 0.33 mg aep/L, the $PNEC_{sediment}$ was calculated to be 0.21 mg aeg/kg.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The equilibrium partition method was used to determine a $PNEC_{soil}$. A calculated Koc of <1.3 was reported in the HERA report, calculated according to the TGD. Using a Koc of 1.3 and a $PNEC_{aquatic}$ of 0.33 mg aep/L, the $PNEC_{soil}$ was calculated to be 0.006 mg aeg/kg.

PBT Assessment

Hemicellulase is expected to be readily biodegradable based on read-across to cellulases. Thus, hemicellulase does not meet the screening criteria for persistence.

Based on the similarity to cellulase, hemicellulase has a high molecular weight (20 to 80 kD), has hydrophilic properties (high water solubility, log Kow <0), and is readily metabolized in organisms by proteolytic enzymes or proteases. Thus, hemicellulose does not meet the screening criteria for bioaccumulation.

The acute $EC(L)_{50}$ of hemicellulase is >0.1 mg/L in fish, invertebrates and algae. Thus, hemicellulase does not meet the screening criteria for toxicity.

The overall conclusion is that hemicellulase is not a PBT substance.

Reference

Human and Environmental Risk Assessment (HERA) on Ingredients of Household Cleaning Products: α-amylase, CAS No. 9000-90-2; Cellulase (β-(1,4)-glucanase), CAS No. 9012-54-8; Lipase, 9001-62-1, 2005. http://www.heraproject.com

Environmental Assessment

Maltodextrin
(CAS No. 9050-36-6)

Maltodextrin is a nonsweet nutritive saccharide polymer that consists of D-glucose units linked primarily by $\alpha,1\rightarrow4$ bonds and that has a dextrose equivalent (D.E.) of <20. Typical commercial maltodextrins contain as few as three and as many as nineteen linked dextrose units. It is prepared as a white powder or concentrated solution by partial hydrolysis of corn starch, potato starch, or rice starch with safe and suitable acids and enzymes.

Biodegradation

No specific biodegradation studies could be found on maltodextrin. However, it is biopolymer that is readily broken down in the gastrointestinal tract of mammals by bacteria. Thus, it is expected to be readily biodegradable in the environment.

Aquatic Toxicity

No aquatic toxicity studies were found on maltodextrin. However, some of the smaller polymeric chains have molecular weights of <1,000 and are thus bioavailable. D-glucose, the monomeric units of maltodextrin, are found naturally in aquatic organisms and play a beneficial role. Thus, maltodextrin is not expected to be toxic to aquatic organisms.

Determination of PNECs

No aquatic toxicity data could be found on maltodextrin. Thus, PNECs were not determined.

PBT Assessment

Maltodextrin is expected to be readily biodegradable and thus would not be expected to meet the screening criteria for persistence.

The molecular weights of maltodextrin can be <1,000 and are thus bioavailable to aquatic organisms. Maltodextrin is water-soluble and composed of D-glucose monomeric units; which are naturally occurring in the body. Thus, maltodextrin is not likely to meet the screening criteria for bioaccumulation.

No aquatic toxicity data could be found on maltodextrin. However, D-glucose, the monomeric units of maltodextrin, are found naturally in aquatic organisms and play a beneficial role. Thus, maltodextrin is not expected to meet the screening criteria for toxicity.

The overall conclusion is that maltodextrin is not a PBT substance.

Environmental Assessment

Polyethylene Glycol
(CAS No. 25322-68-3)

Polyethylene glycols (PEGs) are water-soluble linear polymers formed by the addition reaction of ethylene oxide to an ethylene glycol equivalent. The general formula for polyethylene glycol is: $H-(OCH_2CH_2)_n-OH$ where "n" is the average number of repeating oxyethylene groups. PEGs are available in average molecular weights ranging from 200 to 8000.

No information on the aquatic toxicity and environmental fate and transport could be located for the PEGs. There are, however, data available on tetraEG and pentaEG, both being major constituents of the low molecular weight PEG 200. PEG 200 is a mixture consisting of ethylene glycols with an average molecular weight of approximately 200; there is an average of 4 oxyethylene units, but the range is from 2 to 8 oxyethylene units. The approximate composition of PEG 200 is as follows: 3% diethylene glycol (DEG), 17% triethylene glycol (TEG), 29% tetraEG, 25% pentaEG, 16% hexaEG, 8% heptaEG, and 2% octaEG (Bailey and Koleske, 1966).

Environmental Fate and Transport

PEG is a water-soluble polymer with molecular weights ranging from 200 to 8,000. PEG 200 consists of approximately 29% tetraEG and 25% pentaEG. A Mackay III fugacity model predicts that tetraEG and pentaEG will essentially distribute to water (45.3%) to soil (54.6%) (OECD, 2004).

Biodegradation

Both tetraEG and pentaEG are inherently biodegradable. For tetraEG, there was 22% degradation after 20 days in a BOD test and 40% degradation after 28 days in an OECD 301D test (Waggy *et al.*, 1994). For pentaEG, there was 34% degradation after 20 days in a BOD test (OECD, 2004).

Bioaccumulation

The log K_{ow} values for the PEG polymers were not found. Log K_{ow} and BCF values were estimated for tetraEG and pentaEG, the major constituents of the low molecular weight PEG 200. The log K_{ow} values for tetraEG and pentaEG were estimated to be -2.0 and -2.3, respectively, using EPISUITE v.4.11. The BCF values were estimated to be 3.16 for both tetraEG and pentaEG.

Aquatic Toxicity

No aquatic toxicity data were found on the PEG polymers. However, data are available on tetraEG and pentaEG.

For tetraEG, the acute 96-hour LC_{50} to fathead minnows (*Pimephales promelas*) is >10,000 mg/L (OECD, 2004), and the acute 48-hour LC_{50} to *Daphnia magna* is 7,746 mg/L (OECD, 2004).

For pentaEG, the acute 96-hour LC_{50} to fathead minnows (*Pimephales promelas*) is >50,000 mg/L (OECD, 2004); the acute 48-hour LC_{50} to *Daphnia magna* is >20,000 mg/L (OECD, 2004); and the 72-hour EC_{50} to algae *Pseudokirchneriella subcapitata* is >100 mg/L; the NOEC is 100 mg/L (OECD, 2004).

A 7-day LC_{50} for triethylene glycol in guppies was reported to be 63,000 mg/L (Könemann, 1981).

Toxicity to Terrestrial Organisms

No data were located on either PEG 200 or on the higher ethylene glycols, such as tetraEG and pentaEG.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels for PEG 200 constituents tetraEG and pentaEG. Acute $E(L)C_{50}$ values are available for fish (>10,000 mg/L), Daphnia (7,746 mg/L), and algae (>100 mg/L). Chronic toxicity data on pentaEG are available for algae (NOEC = 100 mg/L); and a chronic fish toxicity study has been conducted on triethylene glycol (NOEC = 63,000 mg/L), which is also found in PEG 200 but at lower concentrations than either tetraEG or pentaEG. On the basis that the data consists of short-term results from three trophic levels and long-term results from two trophic levels, an assessment factor of 50 has been applied to the lowest reported short-term EC_{50} of 100 mg/L for algae. The $PNEC_{aquatic}$ was calculated to be 2.0 mg/L.

PBT Assessment

No biodegradation data could be found on the PEG polymers. PEG is a water-soluble polymer, with molecular weights ranging from 200 to 8,000. The high molecular weight PEGs would be expected to meet the screening criteria for persistence. TetraEG and pentaEG are major constituents of the low molecular weight PEG 200. Biowin 2 predicts that both tetraEG and pentaEG will not biodegrade fast and Biowin 3 predicts the ultimate biodegradation timeframe is in weeks. Thus, the low molecular weight PEGs do not meet the screening criteria for persistence.

No information on log K_{ow} or BCF could be found on the PEG polymers. The molecular weights of PEGs range from 200 to 8,000. The high molecular weight PEGs would not be expected to bioaccumulate due to limitations in bioavailability because of the size of the polymer. TetraEG and pentaEG are major constituents of the low molecular weight PEG 200. The log K_{ow} values for tetraEG and penta were estimated to be -2.0 and -2.3, respectively; the BCF values were estimated to be 3.16 for both tetraEG and pentaEG. Thus, the low molecular weight PEGs are also not expected to meet the criteria for bioaccumulation.

No aquatic toxicity data could be located for the PEG polymers. The molecular weights of PEGs range from 200 to 8,000. The high molecular PEGs are not expected to meet the screening criteria of toxicity because the molecular size would limit bioavailability. TetraEG and pentaEG are major constituents of the low molecular weight PEG 200. There are no chronic aquatic toxicity on tetraEG or pentaEG; however, the acute aquatic toxicity is >0.1 mg/L. Thus, the low molecular weight PEGs are also not expected to meet the screening criteria for toxicity.

The overall conclusion is that the polyethylene glycol polymers are not PBT substances.

References

Bailey, F.E., Jr., and Koleske, J.V. (1966). Chapter 23. Configuration and hydrodynamic properties of the polyoxyethylene chain in solution. In: Nonionic Surfactants. Edited by M.J. Schick, Marcel Dekker, Inc., New York.

Könemann, H. (1981). Quantitative structure-activity relationships in fish toxicity studies. Part 1: relationship for 50 industrial pollutants. Toxicology 19: 209-221.

OECD (2004). SIDS Initial Assessment Report on the Ethylene Glycol Category: Ethylene Glycol (CAS No. 107-21-1), Diethylene Glycol (CAS No. 111-46-6), Triethylene Glycol (CAS No. 112-27-6), Tetraethylene Glycol (CAS No. 112-60-7), Pentaethylene glycol (CAS No. 4792-15-8).

Waggy, G.T., Conway, R.A., Hansen, J.L., and Blessing, R.L. (1994). Comparison of 20-d BOD and OECD closed-bottle biodegradation tests. Environ. Toxicol. Chem. 13: 1277-1280.

Environmental Assessment

Sodium hydroxide
(CAS No. 1310-73-2)

Sodium hydroxide (NaOH) has been reviewed in the OECD-SIDS program (OECD, 2002a,b).

Environmental Fate

The high water solubility and low vapor pressure indicate that sodium hydroxide (NaOH) will be found predominantly in the aquatic environment. NaOH is present in the environment as sodium (Na^+) and hydroxyl (OH^-) ions, which implies that it will not adsorb on particulate matter or surfaces and will not accumulate in living tissues.

Measured concentrations in aquatic ecosystems
The concentration of hydroxyl ions in the environment has been determined very extensively via pH measurements. The pH is a very important parameter of aquatic ecosystems and it is a standard parameter of water quality monitoring programs. The most important freshwater aquatic ecosystems of the world revealed average annual pH values between 6.5 and 8.3 but lower and higher values have been measured in other aquatic ecosystems (UNEP, 1995). In aquatic ecosystems with dissolved organic acids a pH of less than 4.0 has been measured, while in waters with a high chlorophyll content the bicarbonate assimilation can result in pH values of higher than 9.0 at midday (UNEP, 1995). The pH of an aquatic ecosystem is mainly determined by geochemical, hydrological and/or biological processes.

Also sodium has been measured extensively in aquatic ecosystems. For example UNEP (1995) reported the concentration for a total number of 75 rivers in North-America, South-America, Asia, Africa, Europe and Oceania. The 10th –percentile, mean and 90th-percentile were 1.5, 28 and 68 mg/l, respectively.

NaOH addition and buffer capacity
An addition of NaOH to an aquatic ecosystem may increase the pH depending on the buffer capacity of the receiving water. In general the buffer capacity is regulated by the equilibria between CO_2, HCO_3^- and CO_3^{2-}:

$CO_2 + H_2O \leftrightarrow HCO_3^- + H^+$ ($pKa_1 = 6.35$)
$HCO_3^- \leftrightarrow CO_3^{2-} + H^+$ ($pKa_2 = 10.33$)

If the pH is between 7 and 9 then the bicarbonate ion is the most important species responsible for the buffer capacity of aquatic ecosystems. UNEP (1995) reported the bicarbonate concentration for a total number of 77 rivers in North-America, South-America, Asia, Africa, Europe and Oceania. The 10th– percentile, mean and 90th-percentile were 20, 106 and 195 mg/l, respectively.

Aquatic Toxicity

At concentrations reported in publications and study reports, the toxicity has been assumed to be due to hydroxide only, because at these effect concentrations the concentration of sodium is too low to explain the effects. However, it should be realized that the results of toxicity tests with NaOH depend on the buffer capacity of the test medium. In a highly buffered test medium the hydroxyl ion will be neutralized and the observed toxicity will be low, while in a poorly buffered test medium the pH will increase rapidly and therefore the observed toxicity will be relatively high. Besides the direct effects (pH change) NaOH could also have indirect effects. The pH change could influence the speciation of other chemicals and therefore increase and/or decrease the toxicity *e.g.*, NH_3 is more toxic than NH_4^+.

The 24-hour LC_{50} to *Carassius auratus* (goldfish) is 160 mg/L . At 100 mg/L, which was equivalent to a pH of 9.8, no mortality was observed. The 48-hour LC_{50} to *Leuciscus idus melanotus*, is 189 mg/L. The 96-hour LC_{50} of *Gambusia affinis* (mosquitofish) is 125 mg/L. At 84 mg/L, no effects on the fish were observed. The pH was 9 at 100 mg/L. The 48-hour LC_{50} is 40 mg/L for *Ceriodaphnia* cf. *dubia*. The toxicity threshold concentration of NaOH for *Daphnia magna* was reported to range from 40 to 240 mg/L.

No data are available on the effects of NaOH on algae.

Toxicity to Terrestrial Organisms

Toxicity tests, which determined the effects of NaOH on terrestrial organisms, are not available. Significant exposure of the terrestrial environment is not expected and for this reason there is no need to perform toxicity test with terrestrial organisms. The results of terrestrial toxicity tests will depend strongly on the buffer capacity of the soil and can probably be predicted based on the buffer capacity of the soil.

Determination of PNECs

In many cases pH, buffer capacity and/or medium composition were not discussed in the publications, although this is essential information for toxicity tests with NaOH. This is the most important reason why most of the studies, mentioned above were considered invalid. Although valid acute ecotoxicity tests and chronic ecotoxicity tests with NaOH are not available there is no need for additional testing with NaOH. A significant number of acute toxicity tests are available and the results of the tests are more or less consistent. Altogether they give a sufficient indication about acute toxicity levels of sodium hydroxide.

Furthermore acute toxicity data cannot be used to derive a PNEC or a PNEC added for sodium hydroxide. Aquatic ecosystems are characterized by an alkalinity/pH and the organisms of the ecosystem are adapted to these specific natural conditions. Based on the natural alkalinity of waters, organisms will have different optimum pH conditions, ranging from poorly buffered waters with a pH of 6 or less to very hard waters with pH values up to 9. A lot of information is available about the relationship between pH and ecosystem structure and also natural variations in pH of aquatic ecosystems have been quantified and reported extensively in ecological publications and handbooks.

Normally a PNEC or a PNEC added has to be derived from the available ecotoxicity data. A PNEC added is a PNEC which is based on added concentrations of a chemical (added risk approach). Based on the available data it is not considered useful to derive a PNEC or a PNEC added for NaOH because:

- The natural pH of aquatic ecosystems can vary significantly between aquatic ecosystems,

- Also the sensitivity of the aquatic ecosystems to a change of the pH can vary significantly between aquatic ecosystems and

- The change in pH due to an anthropogenic NaOH addition is influenced significantly by the buffer capacity of the receiving water.

Although a PNEC or a PNEC added was not calculated for NaOH there is a need to assess the environmental effect of an NaOH (alkaline) discharge. Based on the pH and buffer capacity of effluent and receiving water and the dilution factor of the effluent, the pH of the receiving water after the discharge can be calculated. Of course the pH change can be measured also very easily via a laboratory experiment or by conducting field measurements. The change in pH should be compared with the natural variation in pH of the receiving water and based on this comparison it should be assessed if the pH change is acceptable.

$PNEC_{aquatic}$: Based on the information above, a PNEC was not derived for sodium hydroxide.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Sodium hydroxide dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc parameters do not readily apply to inorganics, such as sodium hydroxide. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of sodium hydroxide to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The environmental distribution of sodium hydroxide is dominated by its water solubility.

Sorption of sodium hydroxide should probably be regarded as a reversible situation, i.e., the substance is not tightly nor permanently bound. Koc and Kow parameters do not readily apply to inorganics, such as sodium hydroxide Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, sodium hydroxide is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Sodium hydroxide is an organic salt that dissociates completely to sodium and hydroxide ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both sodium and hydroxide ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria is not considered applicable to this inorganic salt.

Sodium and hydroxide ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, sodium hydroxide is not expected to bioaccumulate.

No chronic toxicity data exist on sodium hydroxide; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, sodium hydroxide does not meet the screening criteria for toxicity.

The overall conclusion is that sodium hydroxide is not a PBT substance.

References

OECD (2002a). IUCLID Data Set for Sodium hydroxide (CAS No. 1310-73-2), UNEP Publications.

OECD (2002b). Screening Information Dataset (SIDS) Initial Assessment Report for Sodium hydroxide (CAS No. 1310-73-2), UNEP Publications.

Environmental Assessment

Tetrakis(hydroxymethyl)phosphonium sulfate
(CAS No. 55566-30-8))

Environmental Fate and Transport

Tetrakis(hydroxymethyl)phosphonium sulfate (THPS) has a high water solubility and very low volatility. Photodegradation and hydrolysis of THPS are significant abiotic degradation pathways in the environment. THPS binds poorly to environmental particulates and is, therefore, mobile.

THPS is inherently biodegradable. In an OECD 302B study, greater than 20% degradation occurred within a 28-day period (IPCS, 2000). Aquatic aerobic degradation of THPS was assessed in a soil/water system using U.S. EPA guidelines. The soil was dosed with THPS at 1 μg/g. Radiolabeled THPS was metabolized with 60% of applied radioactivity appearing as CO_2 within 7 days. Major metabolites were trihydroxymethyl phosphine oxide (THPO) and bishydroxymethyl phosphonic acid (BMPA), which were both found in the water; neither degradate reached a concentration of 10% of the applied dose (IPCS, 2000). A comparable study at the same initial concentration of THPS but under anaerobic conditions also showed 60% degradation within 30 days, and the same breakdown products were identified (IPCS, 2000).

Aquatic Toxicity

The acute 96-hour LC_{50} in *Oncorhynchus mykiss* (rainbow trout) is 119 mg/L (IPCS, 2000). The acute 96-hour LC_{50} in (*Lepomis macrochirus*) bluegill sunfish is 93 mg/L (IPCS, 2000). The acute 96-hour LC_{50} in (*Cyprinodon variegatus*) sheepshead minnow is 72 mg/L (IPCS, 2000).

The 48-hour LC_{50} in *Daphnia magna* is 19.4 mg/L (IPCS, 2000).

The 72-hour EC_{50}s in freshwater green algae *Selenastrum capricornutum* are 0.652 mg/L (growth rate) and 0.204 mg/L (biomass). The NOECs were 0.063 mg/L (IPCS, 2000).

Toxicity to Sediment Organisms

No data could be located for freshwater sediment organisms. A 10-day LC_{50} for *Corophium volutator* was reported to be 2,174 mg/kg dry sediment weight (IPCS, 2000).

Toxicity to Terrestrial Organisms

The LD_{50} to mallard duck (*Anas platyryncus*) is 311 mg/kg (IPCS, 2000). The dietary LC_{50}s to mallard ducks and bobwhite quail are 1,313 and 2,414 mg/kg diet, respectively (IPCS, 2000).

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (72 mg/L), Daphnia (19.4 mg/L), and algae (0.204 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 0.204 mg/L for fish. The $PNEC_{aquatic}$ is calculated to be 0.0002 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on freshwater sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$. The Koc was calculated to be 142.3. Using a Koc of 142.3 and a $PNEC_{aquatic}$ of 0.204 µg/L, the $PNEC_{sediment}$ was calculated to be 0.56 µg/kg.

$PNEC_{soil}$: No adequate experimental toxicity data on terrestrial organisms are available. The equilibrium partition method was used to determine a $PNEC_{soil}$. The Koc was calculated to be 142.3. Using a Koc of 142.3 and a $PNEC_{aquatic}$ of 0.204 µg/L, the $PNEC_{soil}$ was calculated to be 0.38 µg/kg.

PBT Assessment

The results of BIOWIN v4.10 for THPS are as follows: biodegrade fast (Biowin2); ultimate biodegradation timeframe is days-weeks (Biowin3); and biodegrades fast (Biowin 6). Thus, THPS does not meet the screening criteria for persistence.

The estimated log Kow for THPS using EPISUITE is -20.39. Hydrolysis is also indicated as a significant abiotic degradation process. Thus, THPS does not meet the screening criteria for bioaccumulation.

The NOEC from a 72-hour green algae study was reported to be 0.063 mg/L, which is <0.1 mg/L. Thus, THPS meets the criteria for toxicity.

The overall conclusion is that Tetrakis(hydroxylmethyl)phosphonium sulfate is not a PBT substance.

Reference

IPCS (2000). Flame Retardants: Tris(2-butoxyethyl)phosphate, Tris (2-ethylhexyl) phosphate and tetrakis (hydroxymethyl)phosphonium Salts, Environmental Health

Criteria 218, International Programme on Chemical Safety, United Nations Environment Programme, International Labour Organisation, World Health Organization.

Santos

APPENDIX G.6 SCHLUMBERGER YF120FLEX WITH J318 SYSTEM

Environmental Assessment

Reaction mass of 5-chloro-2-methyl-4-isothiazolin-3-one and 2-methyl-2H-isothiazolin-3-one [3:1]
(CAS No. 55965-84-9)

Environmental Fate

5-Chloro-2-methyl-4-isothiazolin-3-one and 2-methyl-4-isothiazolin-3-one, the active ingredients in DOW™ CMIT/MIT antimicrobial products, have a low bioconcentration potential (tendency to accumulate in the food chain) and a high potential for mobility in soil. They are completely soluble in water. In the environment these compounds would tend to partition into water where they would rapidly biodegrade to non-persistent substances which are several orders of magnitude less toxic than parent compound. They would also be removed by common biological wastewater treatment facilities.

Biodegradation

The primary aerobic biodegradability of MIT has been examined in a river sediment-water system by use of a ^{14}C-labelled model compound. During the 7-day experiment ^{14}C-labelled MIT was rapidly metabolized as only 12.6% of the initial MIT was present after 24 hours of incubation at 25□C. The calculated half-life for the parent compound was 9.1 hours (Reynolds, 1994a). MIT was metabolized to several unidentified metabolites. One of the major metabolites reached a level corresponding to 18.2% of the ^{14}C added after 24 hours of incubation. This metabolite decreased to 6.8% after 7 days which indicates further transformation. Other metabolites tended to increase during the 7-day experiment. At the end of the experiment metabolites that were bound in the sediment corresponded to 55%, whereas $^{14}CO_2$ attained 9% of the added ^{14}C. Most of the formed metabolites have shorter chromatographic retention times than MI which indicates that they are polar compounds. On the basis of the identification of metabolites from transformation of 4,5-dichloro-2-(n-octyl)-4-isothiazolin-3-one, it has been proposed that MI is transformed via N-methyl malonamic acid, N-methyl acetamide, and malonic acid (Madsen, 2000).

The primary biodegradability of CMIT has been examined with the same type of sediment and water as described for MIT. The ^{14}C-labelled CMIT was rapidly metabolized as only 30% of the initial CMI remained after 24 hours of incubation at 25□C. The calculated half-life for the intact CMIT was 17.3 hours (Reynolds, 1994b). At the end of the 7-day experiment, the sediment bound metabolites corresponded to 57.1% of the added ^{14}C, whereas 2.8% of the added ^{14}C was released as $^{14}CO_2$. Due to the structural similarities of MI and CMIT, it is suggested that the major metabolites for the transformation of CMIT are the same as described for MIT.

MIT was tested in an OECD 301B test modified for low concentrations of ^{14}C-labelled compounds. The accumulated $^{14}CO_2$ attained 54.1%, 55.8%, and 47.6% in the respective concentrations (0.1, 0.03 and 0.01 mg/l) after 29 days. During the 10-day window, 37%, 30% and 30%, respectively, of the initial MIT was mineralized to

$^{14}CO_2$ (Bashir, 1998a).

CMIT was tested in an OECD 301B modified for low concentrations of ^{14}C-labelled compounds. The accumulated $^{14}CO_2$ attained 38.8%, 55.3%, and 62% in the respective concentrations (0.3, 0.1, and 0.03 mg/l) after 29 days. During the 10- day window, 25%, 40%, and 48%, respectively, of the initial CMIT was mineralized to $^{14}CO_2$. The ultimate biodegradability of CMIT exceeded the 60%-pass level for ready biodegradability at the lowest test concentration of 0.03 mg/L, but the pass level was not reached within the 10-day window Bashir, 1998b).

From Dow Chemicals MSDS for ROCIMA GT:
Biodegradation (aquatic metabolism): 5-Chloro-2-methyl-4-isothiazolin-3-one (CMIT): t ½ anaerobic = 0.2 day, t ½ aerobic = 0.38 – 1.3 days; 2-Methyl-4-isothiazolin-3-one (MIT): t ½ aerobic = 0.38 – 1.4 days.

Bioaccumulation

The bioaccumulation of CMIT in bluegill sunfish *(Lepomis macrochirus)* resulted in BCF values of 102, 114, and 67 at nominal concentrations of 0.02, 0.12, and 0.8 mg/L (Erikson *et al*. 1995). These BCF values are based on total accumulated ^{14}C and include both the parent compound and metabolites. The BCF for MIT has been determined to 2.3 at a nominal concentration of 0.12 mg/L (Erikson *et al*. 1995).

Aquatic Toxicity

From Dow Chemicals MSDS for ROCIMA GT:
The 96-hour LC_{50} for Bluegill sunfish (*Lepomis macrochirus*) is 0.28 mg/L, and the 96-hour LC_{50} for Rainbow trout (*Oncorhynchus mykiss*) is 0.188 mg/L. The 48-hour EC_{50} for *Daphnia magna* is 0.126 mg/L. The 72-hour ErC_{50} for algae (*Selenastrum capricornutum*) is 0.027 mg/L.

Toxicity to Terrestrial Organisms

No data were located.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (0.188 mg/L), Daphnia (0.126 mg/L), and algae (0.027 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 0.027 mg/L for Daphnia. The $PNEC_{aquatic}$ is 2.7×10^{-5} mg/L or 0.027 µg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$. The Koc was

calculated using EPISUITE (MCI Method). CMIT: Using a Koc of 19.38 and a $PNEC_{aquatic}$ of 0.027 µg/L, the $PNEC_{sediment}$ was calculated to be 0.025 µg/kg. MIT: Using a Koc of 12.08 and a $PNEC_{aquatic}$ of 0.027 µg/L, the $PNEC_{sediment}$ was calculated to be 0.022 µg/kg.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The equilibrium partition method was used to determine a $PNEC_{soil}$. The Koc was calculated using EPISUITE (MCI Method). CMIT: Using a Koc of 19.38 and a $PNEC_{aquatic}$ of 0.027 µg/L, the $PNEC_{soil}$ was calculated to be 0.007 µg/kg. MIT: Using a Koc of 12.08 and a $PNEC_{aquatic}$ of 0.027 µg/L, the $PNEC_{soil}$ was calculated to be 0.0043 µg/kg.

PBT Assessment

The half-lives of CMIT and MIT is a river water-sediment system were 17.3 hours and 9.1 hours, respectively. Thus, CMIT/MIT do not meet the criteria for persistence.

The experimental BCF for CMIT is 67-114 in bluefish sunfish, and the BCF for MIT was determined to be 2.3. Thus, CMIT/MIT do not meet the criteria for bioaccumulation.

No chronic toxicity data are available for CMIT/MIT; however, the acute $E(L)C_{50}$ values are <0.1 mg/L. Thus, CMIT/MIT meet the screening criteria for toxicity.

The overall conclusion is that the CMIT/MIT mixture is not a PBT substance.

References

Bashir, M. (1998a). Ready biodegradability of 14C-RH-573: Modified Sturm Test . Covance Laboratories Inc., Madison, WI. Rohm and Haas Technical Report No. TR-97-076.

Bashir, M. (1998b). Ready biodegradability of 14C-RH-651: Modified Sturm Test . Covance Laboratories Inc., Madison, WI. Rohm and Haas Technical Report No. TR-97-15.

Dow Chemicals MSDS for ROCIMA GT

Dow Chemicals MSDS for ROCIMA 625

Dow Product Safety Assessment for DOW™ Methylisothiazoline (MIT) AntiMicrobial Products. DOW™ 5-Chloro-2-Methyl-2H-Isothiazol-3-one/2-Methyl-2H- Isothiazol-3-one (CMIT/MIT)-Based Antimicrobial Products (www.dow.com/productsafety/finder/)

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Environmental Assessment

Amorphous/Non-crystalline Silica
(CAS No. 7631-86-9[1])

Silica Gel
(CAS No. 112926-00-8)

Amorphous Silica and silica gel have been reviewed in the OECD-SIDS program (OECD, 2004a,b).

The CAS No. 7631-86-9 is the general CAS registry number for silicon dioxide which includes all forms of silicas (*e.g.*, also crystalline and natural forms). Only the silica sub-classes, the synthetic amorphous silicas, are subject of this assessment.

Synthetic amorphous silica and silicates are in powder form which have a low water solubility, based on the sum of soluble SiO_2 and cations (water-soluble fraction): ≤70 mg/l (SAS), approx. 70 – 80 mg/l (NAS), and approx. 260 mg/l (CS) at 20 °C.

Environmental Fate and Transport

Silicon oxides are the most abundant compounds in the earth's crust mass. Synthetic amorphous silica and silicates are released into the environment are expected to be distributed mainly into soils and sediments, weakly into water and probably not at all in the air due to their physico-chemical properties, particularly low water solubility and very low vapor pressure.

Synthetic amorphous silica and silicates released into the environment are expected to combine indistinguishably with the soil or sediment due to their similarity with inorganic soil/sediment matter and will be subjected to natural processes under environmental conditions (cation exchange, dissolution, sedimentation).

Biodegradation is not applicable to these inorganic substances. The bioavailable form of synthetic amorphous silica and silicates is the dissolved form which exists exclusively as monosilicic $[Si(OH)_4]$ acid under environmental pH. In analogy to the general chemical reaction of weak acids and salts of weak acids with water, the water-soluble fraction of silica acts as a weak acid and, therefore, will tend to lower the pH value, while that of a silicate acts as a base tending to bind protons and, thus, raise the pH value by forming hydroxyl ions. But pH shifts which are measurable at high loadings under laboratory conditions are not expected to occur from the anthropogenic deposition in the aquatic environment of synthetic amorphous silicas due to low aquatic releases and sufficient natural buffer capacities. Finally, these materials are supposed to combine indistinguishably with the soil layer or sediment due to their chemical similarity with inorganic soil matter.

Dissolved silica can be actively assimilated by some marine and terrestrial organisms as normal natural processes mainly related to structural function.

Aquatic Toxicity

Studies on fish, Daphnia and algae using excess loadings of SAS or NAS showed no acute toxicity, although physical effects on Daphnia were observed in tests using unfiltered test medium. Test results, based on loading rates, are as follows: 96-hour LL_0 *(Brachydanio rerio)* is 10,000 mg/L for SAS and NAS; 24-hour EL_{50} *(Daphnia magna)* >10,000 mg/L for SAS; 72-hour NOEL *(Scenedesmus subspicatus)* is 10,000 mg/L for NAS.

There are no chronic aquatic toxicity data, but due to the known inherent physico-chemical properties, absence of acute toxic effects as well as the ubiquitous presence of silica/silicates in the environment, there is no evidence of harmful long-term effects arising from exposure to synthetic amorphous silica/silicates.

Toxicity to Terrestrial Organisms

No data are available.

PBT Assessment

Noncrystalline silica (silica gel) is silicon dioxide, an inorganic compound which is ubiquitous in the environment. For the purposes of this PBT assessment, the persistent criteria is not considered applicable to this inorganic salt.

A log Kow is not applicable to noncrystalline silica. Noncrystalline silica (silica gel), as a stable crystalline solid, is expected to have negligible uptake through the gill or gut of aquatic organisms. Thus, noncrystalline silica (silica gel) is not expected to bioaccumulate.

No chronic toxicity data exist on noncrystalline silica or silica gel; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, noncrystalline silica (silica gel) does not meet the screening criteria for toxicity.

The overall conclusion is that noncrystalline silica (silica gel) is not a PBT substance.

References

OECD (2004a). IUCLID Data Set for Synthetic Amorphous Silica and Silicates: Silicon Dioxide (CAS No. 7631-86-9, 112945-52-5, 112926-00-8; Silicic Acid, Aluminum Sodium Salt (CAS No. 1344-00-9); Silicic Acid, Calcium Salt (CAS No. 1344-95-2), UNEP Publications.

OECD (2004b). Screening Information Dataset (SIDS) Initial Assessment Report for Synthetic Amorphous Silica and Silicates: Silicon Dioxide (CAS No. 7631-86-9, 112945-52-5, 112926-00-8; Silicic Acid, Aluminum Sodium Salt (CAS No. 1344-00-9); Silicic Acid, Calcium Salt (CAS No. 1344-95-2), UNEP Publications.

Environmental Assessment

Choline chloride
Cholinium chloride
(CAS No. 67-48-1)

Choline chloride, also known as cholinium chloride, is a quaternary amine salt. It dissociates in water into the corresponding positively charged quaternary hydroxyl alkylammonium ion and the negatively charged chloride ion.

Choline chloride has been reviewed in the OECD-SIDS program (OECD, 2004).

Environmental Fate and Transport

Results from Mackay Level I modeling indicate that choline chloride will be distributed completely into water (BASF AG, 2004).

Biodegradation

Choline chloride is readily biodegradable (93% within 14 days) in a MITI I-test (MITI, 1992). In another MITI-I test, biodegradation was $\geq$60%, indicating ready biodegradation (Tunkel *et al.*, 2000). A $BOD_5/ThOD_5$ ratio of 75% was obtained in a BOD_5 test performed according to DIN 38409 part 43 (BASF AG, 1984).

Bioaccumulation

No measured data on bioaccumulation of choline chloride are available. The experimental octanol-water partition coefficient (log K_{ow}) was determined to be -3.77. The estimated BCF using the equation log BCF = 0.85*logK_{ow} – 0.70 is 0.59. Therefore, bioaccumulation is not expected in aquatic organisms.

Aquatic Toxicity

The 96-hour fish LC_{50} value is >100 mg/L (nominal and measured) in *Oryzias latipes* (MOE Japan, 1999a), and the 48-hour EC_{50} is 349 mg/L (nominal and measured) in *Daphnia magna* (MOE Japan, 1999b). The 72-hour EC_{50} to algae *Pseudokirchneriella subcapitata* is >1,000 mg/L (nominal and measured) based on growth rate; the 72-hour NOEC is 32 mg/L (MOE Japan, 1999c).

In a 21-day *Daphnia magna* reproduction test, the nominal and measured NOEC was reported to be 30.2 mg/L (MOE Japan, 1999d).

Toxicity to Terrestrial Plants

No data are available.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (>100 mg/L), invertebrates (349 mg/L), and algae (>1,000 mg/L). Results from chronic studies are available for invertebrates (21-day NOEC = 30.2 mg/L) and algae (72-hour NOEC = 32 mg/L). On the basis that the data consists of chronic studies on two trophic level (albeit not on the species with the lowest $E(L)C_{50}$), an assessment factor of 50 has been applied to the lowest reported NOEC of 30 mg/L for Daphnia. The $PNEC_{aquatic}$ is 0.6 mg/L.

PBT Assessment

Choline chloride is readily biodegradable and thus it does not meet the screening criteria for persistence.

Based on a measured log Kow of -3.77 and a calculated BCF of 0.59, choline chloride does not meet the screening criteria for bioaccumulation.

The chronic toxicity data on choline chloride show NOECs of >0.1 mg/L. Thus, choline chloride does not meet the screening criteria for toxicity.

The overall conclusion is that choline chloride is not a PBT substance.

References

BASF AG (1984). Department of Product Safety. Laboratory of Ecology. Pruefbericht ueber eine Untersuchung auf biologische Abbaubarkeit im BSB5-Test - Cholinchlorid (German). Test No. 01606. 16 Feb. 1984.BASF AG (2004b). Department of Product Safety. Unpublished calculation. Mackay Level I V2.11. 29 Jun. 2004.

MITI (1992). Biodegradation and Bioaccumulation Data of Existing Chemicals Based on the CSCL Japan. Edited by Chemicals Inspection & Testing Institute Japan, published by Japan Chemical Industry Ecology-Toxicology & Information Center. October 1992.

MOE Japan (1999a). Ministry of Environment. Acute toxicity study of choline chloride on the Orange killifish *Oryzias latipes*. Unpublished study. No. 1998-16.

MOE Japan (1999b). Ministry of Environment. Acute toxicity study of choline chloride on *Daphnia magna*. Unpublished study. No. 1998-14.

MOE Japan (1999c). Ministry of Environment. Acute toxicity study of choline chloride on the freshwater alga *Pseudokirchnerialla subcapitata*. Unpublished study. No. 1998-13.

MOE Japan (1999d). Ministry of Environment. Chronic toxicity study of choline chloride on the freshwater invertebrate *Daphnia magna*. Unpublished study. No. 1998-15.

OECD (2004). SIDS Initial Assessment Report for Choline chloride (CAS No. 67-48-1), UNEP Publications.

Tunkel J., Howard, P.H., Boethling, R.S., Sitteler, W., and Loonen, H. (2000). Predicting ready biodegradability in the Japanese Ministry of international trade and industry test. Environ. Toxicol. Chem. 19: 2478-2485.

Environmental Assessment

Crystalline Silica, Quartz
(CAS No. 14808-60-7)

Crystalline Silica, Cristobalite
(CAS No. 14464-46-1)

Silica is an off-white granule that occurs naturally in various crystalline and amorphous or other non-crystalline forms. Crystalline silica is characterized by silicon dioxide (SiO_2) molecules oriented in fixed, periodic patterns to form stable crystals. The primary crystalline form of silica is quartz. Other crystalline forms of silica include cristobalite, tripoli and tridymite.

Crystalline silica, quartz and crystalline silica, cristobalite are naturally occurring minerals that are insoluble in water.

They are persistent in the environment.

Crystalline silica, quartz, and crystalline silica, cristobalite as minerals, are not expected to bioaccumulate or be toxic to aquatic organisms because of their water insolubility and lack of bioavailability.

Crystalline silica, quartz and crystalline silica, cristobalite are not considered to be PBT substances.

Environmental Assessment

Diammonium peroxidisulfate
Ammonium persulfate
(CAS No. 7727-54-0)

Diammonium peroxisulfate or ammonium persulfate has been reviewed in the OECD-SIDS program (OECD, 2005a,b).

Environmental Fate

The inorganic persulfates are soluble in water (≥ 60 g/L) and their vapor pressures are negligible. Ammonium persulfate will be distributed into the water compartment in the ionic form of the ammonium cation and persulfate anion. Ammonium persulfate is expected to degrade in the environment mainly via hydrolysis, but metal catalyzed decomposition, and reactions with organic chemicals in the soil or water also are possible.

Persulfates are not expected to adsorb to soil due to its dissociation properties, instability (hydrolysis) and high water solubility. Persulfates should behave as free ions or decompose into sulfate ions. In soils, upon decomposition, the cation could form more stable sulfate or bisulfate salts.

Persulfates are not expected to bioaccumulate in the soil or in aqueous solution. They will decompose into inorganic sulfate or bisulfate.

Aquatic Toxicity

The 96-hour LC_{50} values for ammonium persulfate to fish are from 76 to 323 mg/L. The acute toxicity EC_{50} values for invertebrates are from 120 to 391 mg/L. The 72-hour EC_{50} values for ammonium persulfate to algae are 83.7 mg/L.

Toxicity to Terrestrial Organisms

No data were available.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (76 mg/L), Daphnia (120 mg/L), and algae (84 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 76 mg/L for fish. The $PNEC_{aquatic}$ is 0.076 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Diammonium peroxidisulfate dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc do not readily

apply to inorganics, such as diammonium peroxidisulfate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of diammonium peroxidisulfate to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The environmental distribution of diammonium peroxidisulfate is dominated by its water solubility. Sorption of diammonium peroxidisulfate should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Kow and Koc parameters do not readily apply to inorganics, such as diammonium peroxidisulfate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, diammonium peroxidisulfate is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Ammonium persulfate is an organic salt that dissociates completely to ammonium and sulfate ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both ammonium and sulfate ions are ubiquitous and are present in most water, soil and sediment. Thus, the persistent criteria is not considered applicable to this inorganic salt.

Ammonium and sulfate ions are present in all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, ammonium persulfate is not expected to bioaccumulate.

No chronic toxicity data exist on ammonium persulfate; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, ammonium persulfate does not meet the screening criteria for toxicity.

The overall conclusion is that ammonium persulfate is not a PBT substance.

References

OECD (2005a). IUCLID Data Set for Ammonium persulfate (CAS No. 7727-54-0); Potassium persulfate (CAS No. 7727- 27-1); Sodium persulfate (CAS No. 7775-27-1), UNEP Publications.

OECD (2005b). Screening Information Dataset (SIDS) Initial Assessment Report for Ammonium persulfate (CAS No. 7727-54-0); Potassium persulfate (CAS No. 7727-27-1); Sodium persulfate (CAS No. 7775-27-1), UNEP Publications.

Environmental Assessment

Diatomaceous Earth
(CAS No. 61790-53-2)

Uncalcined diatomaceous earth (CAS No. 61790-53-2) typically contains around 1% crystalline silica. When diatomaceous earth is subjected to pressure or is processed ("calcined") at temperatures above 1000°C some of the amorphous silica is converted to crystalline silica in the form of cristobalite. Calcined diatomaceous earth can contain anywhere from 1% to 75% cristobalite.

Diatomaceous earth and crystalline silica are naturally occurring minerals that are insoluble in water.

The are persistent in the environment.

Diatomaceous earth and crystalline silica as minerals, are not expected to bioaccumulate or be toxic to aquatic organisms because of their water insolubility and lack of bioavailability.

Diatomaceous earth and crystalline silica, quartz are not considered to be PBT substances.

Environmental Assessment

Glycerine
(CAS No. 56-81-5)

Glycerine is also known as glycerol or 1,2,3-propanetriol.

Biodegradation

In an OECD 301 D test, degradation was 57% after 5 days, 84% after 15 days, and 92% after 30 days. Thus, glycerine is readily biodegradable (OECD 2002).

Bioaccumulation

Glycerine is not expected to bioaccumulate. The measured octanol-water partition coefficient (log K_{ow}) is -1.76 (OECD 2002). The calculated bioconcentration factor is 3.162 using EPIWIN vs. 3.04 (OECD 2002).

Aquatic Toxicity

The 24-hour LC_{50} to goldfish (*Carassius auratus*) was reported to be >5,000 mg/L (Bridie 1979). The 48-hour LC_0 to golden orfe (*Leuciscus idus*) is 250 mg/L (OECD 2002).

The 24-hour EC_{50} to *Daphnia magna* is >10,000 mg/L (OECD 2002).

An 8-day test with green algae (*Scenedesmus quadricauda*) showed no toxicity, with an EC_0 of >10,000 mg/L(Bringmann 1980; OECD 2002).

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels, although the data on algae cannot be used for determining a PNEC value. Acute $E(L)C_{50}$ values are available for fish (5,000 mg/L) and *Daphnia* (>10,000 mg/L). On the basis that the data consists of short-term results from two trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 5,000 mg/L for fish. The $PNEC_{aquatic}$ is 5 mg/L.

PBT Assessment

Glycerine is readily biodegradable and thus does not meet the screening criteria for persistence.

The measured log K_{ow} for glycerine is -1.76 and the calculated BCF is 3.162. Thus glycerine does not meet the screening criteria for bioaccumulation.

No chronic toxicity studies are available for glycerine. However, the lowest acute toxicity value (LC_{50}) value is >0.1 mg/L. Thus glycerol does not meet the screening criteria for toxic.

The overall conclusion is that glycerine is not a PBT substance.

References

Bridie, A., Wolff, C., and Winter, M. (1979). The acute toxicity of some petrochemicals to goldfish. Water Res. 13: 623-626.

Bringmann, G., and Kuehn, R. (1980). Comparison of the toxicity thresholds of water pollutants to bacteria, algae, and protozoa in the cell multiplication inhibition test. Water. Res. 14: 231-241.

OECD (2002). OECD-SIDS document on Glycerol, CAS No. 56-81-5, UNEP Publications.

Environmental Assessment

Guar Gum
(CAS No. 9000-30-0)

Guar gum (CAS No. 9000-30-0) is the milled endosperm of the leguminous plant *Cyanopsis tetragonolobus*. Structurally, it is a galactomannan (a polysaccharide) consisting of a main chain of D-mannose with a side chain of D-galactose at approximately every second mannose unit. The mannose units are β-(l-4) linked, and the single D-galactose units are joined to the main chain by α-(1-6) linkages. The estimated molecular weight of guar gum ranges from 200,000 to 300,000 daltons (Glickman, 1969).

Biodegradation

No information was found. Guar gum, being a polysaccharide composed of galactomannan, would be expected to be readily biodegradable.

Bioaccumulation

Not expected to bioaccumulate as a polysaccharide composed of galactomannans.

Aquatic Toxicity

The 48-hour LC_{50} for *Daphnia magna* was reported to be 42 mg/L (Biesinger *et al.*, 1976).

Toxicity to Terrestrial Organisms

No data were located.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for one trophic level. An acute LC_{50} value is available for the invertebrate Daphnia (42 mg/L). On the basis that the data consists of only one short-term result from one trophic level, an assessment factor of 1,000 has been applied to the reported effect concentration of 42 mg/L for Daphnia. The $PNEC_{aquatic}$ is 0.042 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The Kow and Koc of guar gum cannot be calculated using EPISUITE because the molecular weight of guar gum greatly exceeds the limit of 1,000. Thus, the equilibrium partition method cannot be used to determine a $PNEC_{sediment}$ and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on soil organisms are available. The Kow and Koc of guar gum cannot be calculated using EPISUITE because the molecular weight of guar gum greatly exceeds the limit of 1,000. Thus, the equilibrium partition method cannot be used to determine a $PNEC_{soil}$ and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

No biodegradation was found on guar gum. However, guar gum is a naturally occurring polysaccharide which would be expected to readily biodegrade. Thus, it is not expected to meet the screening criteria for persistence.

The molecular weight of guar gum ranges from 200,000 to 300,000 daltons, and it is also water soluble. Thus, guar gum is not expected to meet the criteria for bioaccumulation.

The acute aquatic toxicity of guar gum is >0.1 mg/L. Thus, guar gum is not expected to meet the screening criteria for toxicity.

The overall conclusion is that guar gum is not a PBT substance.

References

Biesinger, K.E. et al. (1976). Comparative toxicity of polyelectrolytes to selected aquatic animals. J. Water Pollut. Control Fed. 48: 183-187; cited in NZ HSNO CCID. http://www.epa.govt.nz/search-databases/Pages/ccid-details.aspx?SubstanceID=1930

Glicksman M. (1969). Gum technology in the Food Industry, pp. 590, Academic Press, New York; cited in Yoon, S.-J., Chu, D.-C., and Juneja, L.R. (2008) Chemical and physical properties, safety and application of partially hydrolyzed guar gum as dietary fiber. J. Clin. Biochem. Nutr. 42: 1-7.

NTP (1982). NTP Technical Report on the Carcinogenesis Bioassay of Guar Gum (CAS No. 9000-30-0) in F344 Rats and B6C3F1 Mice (Feed Study), National Toxicology Program, Research Triangle Park, NC.

Environmental Assessment

Hydrochloric acid
(CAS No. 7647-01-0)

Hydrochloric acid has been reviewed in the OECD-SIDS program (OECD, 202a,b).

Environmental Fate and Transport

Hydrochloric acid is readily dissociated in water into hydrated protons and chloride ions.

The increase in the concentration of hydrochloric acid in water decreases the pH in the aquatic ecosystem. Generally, the buffer capacity to maintain the pH in the aquatic ecosystem is important and the equilibrium between CO_2, HCO_3^- and CO_3^{2-} in the aquatic ecosystem is mainly responsible for the buffer capacity of receiving water.

$CO_2 + H_2O \leftrightarrow HCO_3^- + H^+$ ($pKa_1 = 6.35$)

$HCO_3^- \leftrightarrow CO_3^{2-} + H^+$ ($pKa_2 = 10.33$)

According to UNEP (1995), the mean, the 10th-percentile and the 90th-percentile of bicarbonate concentrations for 77 rivers in North-America, South-America, Asia, Africa, Europe and Oceania were 106, 20 and 195 mg/L, respectively. The buffering capacity for neutralization of receiving water with bicarbonate concentrations of 20, 106 and 195 mg/L is calculated to be 2.19, 11.60 and 21.3 mg/L, respectively.

Aquatic Toxicity

Several studies on the acute toxicity to fish have been published. The lowest 96-hour LC_{50} was reported to be 4.92 mg/L for *Cyprinus carpio* at pH 4.3 which was conducted according to OECD 203 guidelines (MLIT, 1999). The 96-hour LC_{50} for *Oncorhynchus mykiss* was 7.45 mg/L at pH 4.12 for hard water and 10.3 mg/L at pH 3.98 for soft water (Graham and Wood, 1981). The 96-hour LC_{50} in *Lepomis macrochirus* is 55.1 to 30.9 mg/L at pH 3.25 - 3.5; the low pH caused a reduction in the oxygen carrying capacity of hemoglobin and excessive secretion of mucus from the gills which in turn interfered with gas exchange (Ellgaard and Glimore, 1984).

Generally, the results of toxicity tests with acid or base depend on the buffer capacity of the test medium. Dechlorinated tap water was used as a test medium in the three tests described above. A 96-hour LC_{50} of 30.9 to 24.6 at pH 3.5-3.6 was obtained for *Lepomis macrochirus* using artificial water prepared from distilled water and analytical or reagent grade chemicals (Cairns and Scheier, 1959); other reported values are a 96-hour LC_{50} of 282 mg/L for *Gambusia affinis* (Wallen *et al.*, 1957) and a 16-hour LC_{100} value of 0.492 mg/L at pH 5.3 for the pike perch fry (*Lucioperca lucioperca*) conducted with pond water (pH 6.0-8.2) are reported (Stangenberg, 1975). A 24-hr LC_{50} value of 60-80 mg/L for *Semotitus astromaculatus* with river water (pH 8.3) has also been reported. No long-term or chronic toxicity data on fish

were located (Gillette *et al.*, 1952).

The 48-hour EC_{50} for *Daphnia magna* is 0.492 mg/L at pH 5.3 based on immobilization (MLIT, 1999). No long-term or chronic toxicity data on invertebrates have been reported. The 72-hour EC_{50} to *Selenastrum capriornutum* is 0.78 mg/L (pH 5.1) for biomass; 0.492 mg/L (pH 5.3) for growth rate; and the 72-hr-NOEC is 0.097 mg/L (pH 6.0) for biomass and growth rate (MLIT, 1999).

The hazard of hydrochloric acid for the environment is caused by the proton (pH effect). For this reason the effect of hydrochloric acid on the organisms depends on the buffer capacity of the aquatic ecosystem. Also, the variation in acute toxicity for aquatic organisms can be explained to a significant extent by the variation in buffer capacity of the test medium. For example, LC_{50} values of acute fish toxicity tests varied from 4.92 to 282 mg/L.

It is not considered useful to calculate a PNEC for hydrochloric acid because factors such as the buffer capacity, the natural pH, and the fluctuation of the pH are very specific for a certain ecosystem.

Toxicity to Terrestrial Organisms

No data are available.

Determination of PNECS

$PNEC_{aquatic}$: Based on the information above, a $PNEC_{aquatic}$ was not derived for hydrochloric acid.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Kow and Koc parameters do not readily apply to inorganics, such as hydrochloric acid. Thus;, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of hydrochloric acid to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. Sorption of hydrochloric acid should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Koc and Kow parameters do not readily apply to inorganics, such as hydrochloric acid. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, hydrochloric acid is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Hydrochloric acid is an organic salt that dissociates completely to hydrogen and chloride ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both hydrogen and chloride ions are also ubiquitous and are present in most water, soil and sediment. Thus, the persistent criteria is not considered applicable to this inorganic salt.

Hydrogen and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, hydrochloric acid is not expected to bioaccumulate.

No chronic toxicity data exist on hydrochloric acid; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, hydrochloric acid does not meet the screening criteria for toxicity.

The overall conclusion is that hydrochloric acid is not a PBT substance.

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Environmental Assessment

Magnesium chloride
(CAS No. 7786-30-3)

Environmental Fate

Magnesium chloride dissociates completely in water to the Mg^{++} cation and the chloride anion (Cl^-).

Aquatic Toxicity

The 96-hour LC_{50} of magnesium chloride to *Pimephales promelas* is 541 mg of Mg/L (or 2,119.3 mg of $MgCl_2$/L).

The 48-hour LC_{50} for *Daphnia magna* is 140 mg Mg/L (or 548.4 mg of $MgCl_2$/L). In another study, the 48-hour LC_{50} to *Daphnia magna* and *Ceriodaphnia dubia* were 339 mg of Mg/L and 225 mg of Mg/L, respectively (or 1328 and 881.4 mg of $MgCl_2$/L, respectively).

The 72-hour EC_{50} of magnesium chloride for algae *Scenedesmus subspicatus* is >100 mg/L and the NOEC is 100 mg/L.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (2,119 mg/L as $MgCl_2$), Daphnia (548 mg/L as $MgCl_2$), and algae (100 mg/L $MgCl_2$). Even though a NOEC was obtained from the algae study, there were no chronic studies conducted on fish or Daphnia. On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 100 mg/L for algae. The $PNEC_{aquatic}$ was calculated to be 0.1 mg/L. The $PNEC_{aquatic}$ is 0.1 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Magnesium chloride dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc parameters do not readily apply to inorganics, such as magnesium chloride. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of magnesium chloride to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The environmental distribution of magnesium chloride is dominated by its water solubility. Sorption of magnesium chloride should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Koc and Kow parameters do not readily apply to inorganics, such as magnesium chloride.

Thus, the equilibrium partitioning methods cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, magnesium chloride is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Magnesium chloride is an organic salt that dissociates completely to magnesium and chloride ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both magnesium and chloride ions are ubiquitous and are present in most water, soil and sediment. Thus, the persistent criteria is not considered applicable to this inorganic salt.

Magnesium and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, magnesium chloride is not expected to bioaccumulate.

No chronic toxicity data exist on magnesium chloride; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, magnesium chloride does not meet the screening criteria for toxicity.

The overall conclusion is that magnesium chloride is not a PBT substance.

Reference

ECHA REACH database: http://echa.europa.eu/web/guest/information-on-chemicals/registered-substances

Environmental Assessment

Magnesium nitrate (CAS No. 10377-60-3)

Environmental Fate

Magnesium nitrate dissociates completely in water to Mg^{++} and the nitrate anion (NO_3^-).

Determination of PNECs

$PNEC_{aquatic}$: The ANZECC water quality guideline (2000) uses acute and chronic laboratory toxicity data for the derivation of "trigger values" for nitrate. The guideline summary for freshwaters is: *"A freshwater moderate reliability trigger value for nitrate toxicity as NO_3 (nitrate) of 700 µg/L was calculated using the statistical distribution method 95% protection and the default ACR."*

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Magnesium nitrate dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc parameters do not readily apply to inorganics, such as magnesium nitrate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of magnesium nitrate to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The environmental distribution of magnesium nitrate is dominated by its water solubility. Sorption of magnesium nitrate should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Koc and Kow parameters do not readily apply to inorganics, such as magnesium nitrate. Thus, the equilibrium partitioning methods cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, magnesium nitrate is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Magnesium nitrate is an organic salt that dissociates completely to magnesium and nitrate ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both magnesium and nitrate ions are also ubiquitous and are present in most water, soil and sediment. Thus, the persistent criteria is not considered applicable to this inorganic salt.

Magnesium ions are essential to all living organisms and its intracellular and extracellular concentrations are actively regulated. Nitrates are ions that are very

soluble in aqueous solutions. Thus, magnesium nitrate is not expected to bioaccumulate.

No chronic toxicity data exist on magnesium nitrate; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, magnesium nitrate does not meet the screening criteria for toxicity.

The overall conclusion is that magnesium nitrate is not a PBT substance.

Reference

ANZECC & ARMCANZ (2000). Australian and New Zealand guidelines for fresh and marine water quality. National Water Quality Management Strategy Paper No 4, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra, Australia.

Environmental Assessment

Vinylidene chloride/methacrylate copolymer (CAS No. 25038-72-6)

Biodegradation

Generally, polymers are considered to be essentially non-biodegradable.

Bioaccumulation

Polymers are not generally absorbed through biological membranes to bioaccumulate in tissues.

Aquatic Toxicity

This polymer is insoluble in water and is expected to be essentially non-toxic to aquatic organisms.

Determination of PNECs

$PNEC_{aquatic}$: Not determined.

PBT Assessment

Based on the information above, vinylidene chloride/methylacrylate copolymer is not considered to be a PBT substance.

Reference

Boethling, R.S. and Nabholz, J.V. (1997). Environmental Assessment of Polymers under the U.S. Toxic Substances Control Act. In: Ecological Assessment of Polymers Strategies for Product Stewardship and Regulatory Programs (Hamilton, J.D. and Sutcliffe, R. eds.), pp. 187-234, Van Nostrand Reinhold.

Environmental Assessment

Potassium borate
Dipotassium tetraborate
(CAS No. 1332-77-0)

Toxicity data on borax and boric acid will be used to read across to potassium borate ($B_4K_2O_7$). The rationale is as follows:

Borax is also known as sodium borate, sodium tetraborate, or disodium tetraborate. With water content, borax can refer to a group of compounds that differ in their crystal water content, but typically it is disodium tetraborate decahydrate with the chemical structure ($Na_2B_4O_7 \bullet 10H_2O$). Borax is moderately soluble in water, with the main species in freshwater being the borate ion $[B(OH)_4]^-$ and boric acid $B(OH)_3$, depending on the pH. The relative proportion of boric acid and borate ions is controlled by pH: $B(OH)_3 + 2H_2O \Leftrightarrow [B(OH)_4]^- + H_3O^-$. In dilute aqueous solutions, boric acid does not dissociate at pH <7; at pH values between 7 and 11, both boric acid and borate ions are present. In dilute aqueous solutions and physiological conditions, the predominant species present is un-dissociated boric acid. So, the consideration of boric acid addresses the relevant environmental stability properties for borates.

Exposure to borates are often expressed in terms of boron (B) equivalents based on the fraction of boron in the source substance on a molecular weight basis. The B equivalents used are a generic designation rather than a designation of the element boron. The factors for converting disodium tetraborate decahydrate and boric acid to B-equivalents are 0.113 and 0.175, respectively.

In natural waters, boron forms stable species and exists primarily as un-dissociated boric acid [$B(OH)_3$] and complex polyanions (*e.g.,* $B(OH)_4^-$). These forms of boron are highly soluble and not easily removed from solution by natural mechanisms. Borate and boric acid are in equilibrium depending on the pH of the water. At an acidic pH, boron exists in solution mainly as un-dissociated boric acid, whereas at alkaline pH it is present as borate ions.

Environmental Fate

At noted above, disodium tetraborate decahydrate will yield boric acid upon dissolution in water (or borate anion in higher pH conditions). Boric acid is a persistent molecule, not subject to hydrolysis, photodegradation or biodegradation.

Many mineral contain boron, which is present as the sodium or calcium borate salt. Thus, boron is ubiquitous and widely distributed in the environment. It is present in rocks, soil and water and is released into the environment primarily from the weathering of rock and soil, volatilization of sea water, and anthropogenic activity.

Bioaccumulation

The WHO (1998) review of boron noted that "highly water soluble materials are unlikely to bioaccumulate to any significant degree and that borate species are all present essentially as un-dissociated and highly soluble boric acid at neutral pH". A BCF of <0.1 was reported in Chinook salmon fed boron-supplemented diets for 60 to 90 days (Hamilton and Wiedmeyer, 1990).

Some bioconcentration is expected in terrestrial plants since boron is a critical element to terrestrial plants and is incorporated into the cell wall structure. However, the phytotoxicity of boron limits the potential for excessive accumulation beyond "normal" plant tissue concentrations (Austria, 2008). Terrestrial non-predatory organisms, such as Mallard ducks, did not accumulate boron (BCF <0.1) when fed a plant diet of 1,600 mg-B/kg for up to 48 days (Pendleton *et al.*, 1995).

Toxicity

There are many ecotoxicity laboratory and field tests that have been conducted on boron (which includes boric acid and borates). Overall, the studies show that boron does not fulfill the criteria of Toxicity in a PBT assessment with regards to aquatic organisms. The data were reviewed in the "Scientific Criteria Document for the Development of the Canadian Water Quality Guidelines for Boron" (CCME, 2009), which is summarized below:

"Primary acute toxicity data for vertebrates were available for early life stages of four fish species. Endpoints ranged from a 3 day NOEC (teratogenesis at hatching) of 0.109 mg/L for embryo- hatching stage largemouth bass (Black *et al.* 1993) to a 7 day EC_{50} (embryo test) of 969 mg/L for rainbow trout (MELP, 1996). Secondary and unclassified toxicity data were similar to the reported primary data with effect concentrations ranging between 4.6 and 3,145 mg/L."

"Primary acute toxicity data for invertebrates were available for four species. The 48 hour LC_{50} concentrations ranged from 21.3 mg/L for neonate water fleas (MELP, 1996) to 1,376 mg/L for larval midge (Maier and Knight, 1991). Secondary, unclassified and unacceptable toxicity data were similar to the reported primary data with effect concentrations ranging between 1 and 2,797 mg/L."

"Primary chronic toxicity data for vertebrates were available for three fish species." If the outliers are excluded, "effect concentrations ranged from a 36 day LOEC (mortality) of 1.34 mg/L for embryo-larval rainbow trout to a 32 day LC_{50} of 138 mg/L for rainbow trout (Black *et al.*, 1993). Lower effect concentrations (0.01 mg/L) for embryo-larval rainbow trout were observed in the unclassified toxicity studies (Birge and Black, 1977)."

"Primary chronic toxicity data for invertebrates were available for two species. Effect concentrations ranged between a 21 day LOEC (mean brood size) of 13 mg/L to a 21 day LC_{50} of 53.2 mg/L for the water flea (Lewis and Valentine, 1981). Effect concentrations for additional unclassified studies differed from those reported by the primary studies, with a range of <0.38 to ~266 mg/L."

"Primary chronic toxicity data were available for 4 to 7 day old green algae (*Selenastrum capricornutum*) (MELP, 1997). The lowest reported effect concentration for algae exposed to boron was a 72 hour LOEC of 12.3 mg/L. Effect concentrations of secondary and unclassified toxicity data ranged from 1 to ~171 mg/L."

Determination of PNECs

$PNEC_{aquatic}$: There are many ecotoxicity laboratory and field tests that have been conducted on boron (which includes boric acid and borates). Both acute and chronic toxicity studies are available for three trophic levels. A Canadian Water Quality Guidelines for the Protection of Aquatic Life of 1.5 mg/L was derived for long–term exposure to boron (CCME, 2009). Thus, the $PNEC_{aquatic}$ for disodium tetraborate decahydrate is 1.5 mg-B/L.

It should be noted, however, that Australia and New Zealand adopted a freshwater high reliability trigger value for boron of 0.37 mg-B/L (ANZECC, 2000).

The factor for converting dipotassium tetraborate to B-equivalents is 0.185.

PBT Assessment

Disodium tetraborate decahydrate is a persistent molecule, not subject to hydrolysis, photodegradation or biodegradation. Thus, it meets the criteria for persistence.

Disodium tetraborate decahydrate is a water-soluble substance that is not expected to bioaccumulate. Limited data indicate that bioaccumulation (BCF values are low) is not significant in aquatic and terrestrial food chains. Thus, it does not meet the criteria for bioaccumulation.

Overall, the aquatic toxicity studies show that boron does not fulfill the criteria of toxicity. However, there are human health concerns and boric acid (and borates) are considered reproductive toxicants; they have, for instance, been classified in the EU as known or presumed human reproductive toxicants (Category 1B). Thus, disodium tetraborate decahydrate meets the PBT criteria of toxicity.

The overall conclusion is that disodium tetraborate decahydrate is not a PBT substance.

References

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Lewis, M.A., and Valentine, L.C. (1981). Acute and chronic toxicities of boric acid to *Daphnia magna* Staus. Bull. Environ. Contam. Toxicol. 27: 309-315.

Maier, K.J., and Knight, A.W. (1991). The toxicity of waterborne boron to *Daphnia magna* and *Chironomus decorus* and the effects of water hardness and sulfate on boron toxicity. Arch. Environ. Contam. Toxicol. 20: 282-287.

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Environmental Assessment

Potassium hydroxide
(CAS No. 1310-58-3)

Potassium hydroxide (KOH) has been reviewed in the OECD-SIDS program (OECD, 2002a,b).

Environmental Fate

The high water solubility and low vapor pressure indicate that potassium hydroxide (KOH) will be found predominantly in the aquatic environment. KOH is present in the environment as potassium (K^+) and hydroxyl (OH^-) ions, which implies that it will not adsorb on particulate matter or surfaces and will not accumulate in living tissues.

Measured concentrations in aquatic ecosystems
The concentration of hydroxyl ions in the environment has been determined very extensively via pH measurements. The pH is a very important parameter of aquatic ecosystems and it is a standard parameter of water quality monitoring programs. The most important freshwater aquatic ecosystems of the world revealed average annual pH values between 6.5 and 8.3 but lower and higher values have been measured in other aquatic ecosystems (UNEP, 1995). In aquatic ecosystems with dissolved organic acids a pH of less than 4.0 has been measured, while in waters with a high chlorophyll content the bicarbonate assimilation can result in pH values of higher than 9.0 at midday (UNEP, 1995). The pH of an aquatic ecosystem is mainly determined by geochemical, hydrological and/or biological processes.

Potassium has been measured extensively in aquatic ecosystems. UNEP (1995) reported the concentration for a total number of 75 rivers in North-America, South-America, Asia, Africa, Europe and Oceania. The 10th –percentile, mean and 90th-percentile were 0.8, 3.2 and 6.0 mg/l, respectively.

KOH addition and buffer capacity
An addition of KOH to an aquatic ecosystem may increase the pH depending on the buffer capacity of the receiving water. In general the buffer capacity is regulated by the equilibria between CO_2, HCO_3^- and CO_3^{2-}:

$CO_2 + H_2O \leftrightarrow HCO_3^- + H^+$ ($pKa_1 = 6.35$)
$HCO_3^- \leftrightarrow CO_3^{2-} + H^+$ ($pKa_2 = 10.33$)

If the pH is between 7 and 9 then the bicarbonate ion is the most important species responsible for the buffer capacity of aquatic ecosystems. UNEP (1995) reported the bicarbonate concentration for a total number of 77 rivers in North-America, South-America, Asia, Africa, Europe and Oceania. The 10th– percentile, mean and 90th-percentile were 20, 106 and 195 mg/l, respectively.

Aquatic Toxicity

At concentrations reported in publications and study reports, the toxicity has been assumed to be due to hydroxide only, because at these effect concentrations the concentration of sodium is too low to explain the effects. However, it should be realized that the results of toxicity tests with KOH depend on the buffer capacity of the test medium. In a highly buffered test medium the hydroxyl ion will be neutralized and the observed toxicity will be low, while in a poorly buffered test medium the pH will increase rapidly and therefore the observed toxicity will be relatively high. Besides the direct effects (pH change) KOH could also have indirect effects. The pH change could influence the speciation of other chemicals and therefore increase and/or decrease the toxicity ***e.g.***, NH_3 is more toxic than NH_4^+.

The 96-hour LC_{50} of *Gambusia affinis* (mosquitofish) is 80 mg/L. At 56 mg/L, no effects on the fish were observed. The pH was 10.3 at 100 mg/L.

Several studies have been conducted using NaOH. The 24-hour LC_{50} to *Carassius auratus* (goldfish) is 160 mg/L (equivalent KOH: 224 mg/L). At 100 mg/L (equivalent KOH: 140 mg/L), which was equivalent to a pH of 9.8, no mortality was observed. The 48-hour LC_{50} to *Leuciscus idus melanotus*, is 189 mg/L (equivalent KOH: 265 mg/L). The 96-hour LC_{50} of *Gambusia affinis* (mosquitofish) is 125 mg/L. At 84 mg/L, no effects on the fish were observed. The pH was 9 at 100 mg/L.

No toxicity studies on invertebrates are available. For NaOH, the 48-hour LC_{50} is 40 mg/L (equivalent KOH: 56 mg/L) for *Ceriodaphnia* cf. *dubia*.

No data are available on the effects of KOH on algae.

Toxicity to Terrestrial Organisms

Significant exposure of the terrestrial environment is not expected and for this reason there is no need to perform toxicity test with terrestrial organisms. The results of terrestrial toxicity tests will depend strongly on the buffer capacity of the soil and can probably be predicted based on the buffer capacity of the soil.

Determination of PNECs

In many cases pH, buffer capacity and/or medium composition were not discussed in the publications, although this is essential information for toxicity tests with KOH. This is the most important reason why most of the studies, mentioned above were considered invalid. Although valid acute ecotoxicity tests and chronic ecotoxicity tests with KOH are not available there is no need for additional testing with KOH. A significant number of acute toxicity tests are available and the results of the tests are more or less consistent. Altogether they give a sufficient indication about acute toxicity levels of potassium hydroxide.

Furthermore acute toxicity data cannot be used to derive a PNEC or a PNEC added for potassium hydroxide. Aquatic ecosystems are characterized by an alkalinity/pH

and the organisms of the ecosystem are adapted to these specific natural conditions. Based on the natural alkalinity of waters, organisms will have different optimum pH conditions, ranging from poorly buffered waters with a pH of 6 or less to very hard waters with pH values up to 9. A lot of information is available about the relationship between pH and ecosystem structure and also natural variations in pH of aquatic ecosystems have been quantified and reported extensively in ecological publications and handbooks.

Normally a PNEC or a PNEC added has to be derived from the available ecotoxicity data. A PNEC added is a PNEC which is based on added concentrations of a chemical (added risk approach). Based on the available data it is not considered useful to derive a PNEC or a PNEC added for KOH because:

- The natural pH of aquatic ecosystems can vary significantly between aquatic ecosystems,

- Also the sensitivity of the aquatic ecosystems to a change of the pH can vary significantly between aquatic ecosystems and

- The change in pH due to an anthropogenic KOH addition is influenced significantly by the buffer capacity of the receiving water.

Although a PNEC or a PNEC added was not calculated for KOH there is a need to assess the environmental effect of an KOH (alkaline) discharge. Based on the pH and buffer capacity of effluent and receiving water and the dilution factor of the effluent, the pH of the receiving water after the discharge can be calculated. Of course the pH change can be measured also very easily via a laboratory experiment or by conducting field measurements. The change in pH should be compared with the natural variation in pH of the receiving water and based on this comparison it should be assessed if the pH change is acceptable.

$PNEC_{aquatic}$: Based on the information above, a PNEC was not derived for potassium hydroxide.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Potassium hydroxide dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc parameters do not readily apply to inorganics, such as potassium hydroxide. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of potassium hydroxide to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The environmental distribution of potassium hydroxide is dominated by its water solubility. Sorption of potassium hydroxide should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Koc and Kow parameters do not readily apply to inorganics, such as potassium hydroxide Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, potassium hydroxide is not expected to significantly

adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Potassium hydroxide is an organic salt that dissociates completely to potassium and hydroxide ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both potassium and hydroxide ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria is not considered applicable to this inorganic salt.

Potassium and hydroxide ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, potassium hydroxide is not expected to bioaccumulate.

No chronic toxicity data exist on potassium hydroxide; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, potassium hydroxide does not meet the screening criteria for toxicity.

The overall conclusion is that potassium hydroxide is not a PBT substance.

References

OECD (2002a). IUCLID Data Set for Potassium hydroxide (CAS No. 1310-58-3), UNEP Publications.

OECD (2002b). Screening Information Dataset (SIDS) Initial Assessment Report for Potassium hydroxide (CAS No. 1310-58-3), UNEP Publications.

Environmental Assessment

Talc
(CAS No. 61789-40-0)

Talc is a mineral composed of hydrated magnesium silicate with the chemical formula $Mg_3Si4O_{10}(OH)_2$ or $H_2Mg_3(SiO_3)_4$. Talc is not soluble in water.

Biodegradation

As a mineral, talc does not biodegrade.

Aquatic Toxicity

No data were found. As an insoluble mineral, talc is not expected to be bioavailable; therefore, it is not expected to toxic to aquatic organisms.

Toxicity to Sediment Organisms

No data were found. As an insoluble mineral, talc is not expected to be bioavailable; therefore, it is not expected to toxic to sediment organisms.

Toxicity to Terrestrial Organisms

No data were found.

Determination of PNECs

PNEC values for talc cannot be calculated.

PBT Assessment

Talc is an inorganic mineral that is insoluble in water. Talc is not expected to be bioavailable to aquatic organisms; thus, it is does not meet the criteria for bioaccumulation or toxicity. Talc does not biodegrade in the environment. It is a naturally-occurring mineral and is persistent in the environment. However, for the purposes of this PBT assessment, it does not meet the criteria for persistence.

Environmental Assessment

Triethanolamine
(CAS No. 102-71-6)

Environmental Fate

Triethanolamine was completely degraded after incubation in municipal activated sludge for 1 or 5 days (West and Gonsior, 1996). The rate constants in all test batches for degradation and mineralization were reported to be >0.359. Thus, triethanolamine can be considered to be readily biodegradable.

In an OECD 301E test, there was 96% degradation after 19 days, indicating ready biodegradation (ECHA).

Bioaccumulation

Triethanolamine has been tested in a bioconcentration: flow-through fish (OECD 305) test using *Cyprinus carpio*. The BCF was determined to be <0.4 and <3.9 at triethanolamine concentrations of 2.5 and 0.25 mg/L, respectively (ECHA).

Aquatic Toxicity

The 96-hour LC_{50} to fathead minnow (*Pimephales promelas*) is 11,800 mg/L (ECHA). The 48-hour EC_{50} to *Ceriodaphnia dubia* is 610 mg/L (Warne and Schifko, 1999).

In a 21-day *Daphnia* reproduction test, the NOEC for reproduction rate was 125 mg/L, and the NOEC for reproduction on the appearance of first offspring was 250 mg/L (Kuehn *et al.*, 1989).

The 72-hour EC_{50} to algae *Desmodesmus subspicatus* is 512 mg/L [neutralized media] and 216 mg/L [un-neutralized media] (ECHA).

Toxicity to Terrestrial Organisms

No data were available.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (11,800 mg/L), *Daphnia* (610 mg/L), and algae (512 mg/L). A long-term (chronic) study is available for invertebrates (21-day NOEC = 125 mg/L). On the basis that the data consists of a chronic study on one trophic level, an assessment factor of 100 has been applied to the lowest reported NOEC of 125 mg/L for *Daphnia*. The $PNEC_{aquatic}$ is 1.25 mg/L.

PBT Assessment

Triethanolamine is readily biodegradable; thus, it does not meet the screening criteria for persistence.

The BCF values for triethanolamine in fish was <3.9; thus, it does not meet the criteria for bioaccumulation.

The NOEC for triethanolamine in a 21-day *Daphnia* reproduction test is 125 mg/L, which is >0.1 mg/L. Thus, triethanolamine does not meet the screening criteria for toxicity.

The overall conclusion is that triethanolamine is not a PBT substance.

References

ECHA REACH database: http://echa.europa.eu/web/guest/information-on-chemicals/registered-substances

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Santos

APPENDIX G.7 SCHLUMBERGER SAPPHIRE LF

Environmental Assessment

Reaction mass of 5-chloro-2-methyl-4-isothiazolin-3-one and 2-methyl-2H-isothiazolin-3-one [3:1]
(CAS No. 55965-84-9)

Environmental Fate

5-Chloro-2-methyl-4-isothiazolin-3-one and 2-methyl-4-isothiazolin-3-one, the active ingredients in DOW™ CMIT/MIT antimicrobial products, have a low bioconcentration potential (tendency to accumulate in the food chain) and a high potential for mobility in soil. They are completely soluble in water. In the environment these compounds would tend to partition into water where they would rapidly biodegrade to non-persistent substances which are several orders of magnitude less toxic than parent compound. They would also be removed by common biological wastewater treatment facilities.

Biodegradation

The primary aerobic biodegradability of MIT has been examined in a river sediment-water system by use of a ^{14}C-labelled model compound. During the 7-day experiment ^{14}C-labelled MIT was rapidly metabolized as only 12.6% of the initial MIT was present after 24 hours of incubation at 25□C. The calculated half-life for the parent compound was 9.1 hours (Reynolds, 1994a). MIT was metabolized to several unidentified metabolites. One of the major metabolites reached a level corresponding to 18.2% of the ^{14}C added after 24 hours of incubation. This metabolite decreased to 6.8% after 7 days which indicates further transformation. Other metabolites tended to increase during the 7-day experiment. At the end of the experiment metabolites that were bound in the sediment corresponded to 55%, whereas $^{14}CO_2$ attained 9% of the added ^{14}C. Most of the formed metabolites have shorter chromatographic retention times than MI which indicates that they are polar compounds. On the basis of the identification of metabolites from transformation of 4,5-dichloro-2-(n-octyl)-4-isothiazolin-3-one, it has been proposed that MI is transformed via N-methyl malonamic acid, N-methyl acetamide, and malonic acid (Madsen, 2000).

The primary biodegradability of CMIT has been examined with the same type of sediment and water as described for MIT. The ^{14}C-labelled CMIT was rapidly metabolized as only 30% of the initial CMI remained after 24 hours of incubation at 25□C. The calculated half-life for the intact CMIT was 17.3 hours (Reynolds, 1994b). At the end of the 7-day experiment, the sediment bound metabolites corresponded to 57.1% of the added ^{14}C, whereas 2.8% of the added ^{14}C was released as $^{14}CO_2$. Due to the structural similarities of MI and CMIT, it is suggested that the major metabolites for the transformation of CMIT are the same as described for MIT.

MIT was tested in an OECD 301B test modified for low concentrations of ^{14}C-labelled compounds. The accumulated $^{14}CO_2$ attained 54.1%, 55.8%, and 47.6% in the respective concentrations (0.1, 0.03 and 0.01 mg/l) after 29 days. During the 10-day window, 37%, 30% and 30%, respectively, of the initial MIT was mineralized to

$^{14}CO_2$ (Bashir, 1998a).

CMIT was tested in an OECD 301B modified for low concentrations of ^{14}C-labelled compounds. The accumulated $^{14}CO_2$ attained 38.8%, 55.3%, and 62% in the respective concentrations (0.3, 0.1, and 0.03 mg/l) after 29 days. During the 10- day window, 25%, 40%, and 48%, respectively, of the initial CMIT was mineralized to $^{14}CO_2$. The ultimate biodegradability of CMIT exceeded the 60%-pass level for ready biodegradability at the lowest test concentration of 0.03 mg/L, but the pass level was not reached within the 10-day window Bashir, 1998b).

From Dow Chemicals MSDS for ROCIMA GT:
Biodegradation (aquatic metabolism): 5-Chloro-2-methyl-4-isothiazolin-3-one (CMIT): t ½ anaerobic = 0.2 day, t ½ aerobic = 0.38 – 1.3 days; 2-Methyl-4-isothiazolin-3-one (MIT): t ½ aerobic = 0.38 – 1.4 days.

Bioaccumulation

The bioaccumulation of CMIT in bluegill sunfish *(Lepomis macrochirus)* resulted in BCF values of 102, 114, and 67 at nominal concentrations of 0.02, 0.12, and 0.8 mg/L (Erikson *et al*. 1995). These BCF values are based on total accumulated ^{14}C and include both the parent compound and metabolites. The BCF for MIT has been determined to 2.3 at a nominal concentration of 0.12 mg/L (Erikson *et al*. 1995).

Aquatic Toxicity

From Dow Chemicals MSDS for ROCIMA GT:
The 96-hour LC_{50} for Bluegill sunfish (*Lepomis macrochirus*) is 0.28 mg/L, and the 96-hour LC_{50} for Rainbow trout (*Oncorhynchus mykiss*) is 0.188 mg/L. The 48-hour EC_{50} for *Daphnia magna* is 0.126 mg/L. The 72-hour ErC_{50} for algae (*Selenastrum capricornutum*) is 0.027 mg/L.

Toxicity to Terrestrial Organisms

No data were located.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (0.188 mg/L), Daphnia (0.126 mg/L), and algae (0.027 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 0.027 mg/L for Daphnia. The $PNEC_{aquatic}$ is 2.7×10^{-5} mg/L or 0.027 µg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$. The Koc was

calculated using EPISUITE (MCI Method). CMIT: Using a Koc of 19.38 and a $PNEC_{aquatic}$ of 0.027 µg/L, the $PNEC_{sediment}$ was calculated to be 0.025 µg/kg. MIT: Using a Koc of 12.08 and a $PNEC_{aquatic}$ of 0.027 µg/L, the $PNEC_{sediment}$ was calculated to be 0.022 µg/kg.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The equilibrium partition method was used to determine a $PNEC_{soil}$. The Koc was calculated using EPISUITE (MCI Method). CMIT: Using a Koc of 19.38 and a $PNEC_{aquatic}$ of 0.027 µg/L, the $PNEC_{soil}$ was calculated to be 0.007 µg/kg. MIT: Using a Koc of 12.08 and a $PNEC_{aquatic}$ of 0.027 µg/L, the $PNEC_{soil}$ was calculated to be 0.0043 µg/kg.

PBT Assessment

The half-lives of CMIT and MIT is a river water-sediment system were 17.3 hours and 9.1 hours, respectively. Thus, CMIT/MIT do not meet the criteria for persistence.

The experimental BCF for CMIT is 67-114 in bluefish sunfish, and the BCF for MIT was determined to be 2.3. Thus, CMIT/MIT do not meet the criteria for bioaccumulation.

No chronic toxicity data are available for CMIT/MIT; however, the acute $E(L)C_{50}$ values are <0.1 mg/L. Thus, CMIT/MIT meet the screening criteria for toxicity.

The overall conclusion is that the CMIT/MIT mixture is not a PBT substance.

References

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Bashir, M. (1998b). Ready biodegradability of 14C-RH-651: Modified Sturm Test . Covance Laboratories Inc., Madison, WI. Rohm and Haas Technical Report No. TR-97-15.

Dow Chemicals MSDS for ROCIMA GT

Dow Chemicals MSDS for ROCIMA 625

Dow Product Safety Assessment for DOW™ Methylisothiazoline (MIT) AntiMicrobial Products. DOW™ 5-Chloro-2-Methyl-2H-Isothiazol-3-one/2-Methyl-2H- Isothiazol-3-one (CMIT/MIT)-Based Antimicrobial Products (www.dow.com/productsafety/finder/)

Erikson, U., Johnson, A., and Törnlund, M. (1995). Risk Assessment of Slimicides. KEMI Report No. 9/95. The Swedish National Chemicals Inspectorate, Solna, Sweden.

Madsen, T. (2000). Evaluation of the biodegradability of RH-573 and RH-651. Report to Rohm and Haas. Study No. 12113. March 2000. DHI – Water and Environment, Hørsholm, Denmark.

Reynolds, J.L. (1994a). Aerobic aquatic metabolism of 14C-RH-573. Rohm and Haas Technical Report No. 34-94-122. XenoBiotic Laboratories, Inc., Plainsboro, NJ. United States.

Reynolds, J.L. (1994b). Aerobic aquatic metabolism of 14C-RH-651. Rohm and Haas Technical Report No. 34-94-64. XenoBiotic Laboratories, Inc., Plainsboro, NJ. United States.

Environmental Assessment

Choline chloride
Cholinium chloride
(CAS No. 67-48-1)

Choline chloride, also known as cholinium chloride, is a quaternary amine salt. It dissociates in water into the corresponding positively charged quaternary hydroxyl alkylammonium ion and the negatively charged chloride ion.

Choline chloride has been reviewed in the OECD-SIDS program (OECD, 2004).

Environmental Fate and Transport

Results from Mackay Level I modeling indicate that choline chloride will be distributed completely into water (BASF AG, 2004).

Biodegradation

Choline chloride is readily biodegradable (93% within 14 days) in a MITI I-test (MITI, 1992). In another MITI-I test, biodegradation was ≥60%, indicating ready biodegradation (Tunkel *et al.*, 2000). A $BOD_5/ThOD_5$ ratio of 75% was obtained in a BOD_5 test performed according to DIN 38409 part 43 (BASF AG, 1984).

Bioaccumulation

No measured data on bioaccumulation of choline chloride are available. The experimental octanol-water partition coefficient (log K_{ow}) was determined to be -3.77. The estimated BCF using the equation log BCF = 0.85*logK_{ow} – 0.70 is 0.59. Therefore, bioaccumulation is not expected in aquatic organisms.

Aquatic Toxicity

The 96-hour fish LC_{50} value is >100 mg/L (nominal and measured) in *Oryzias latipes* (MOE Japan, 1999a), and the 48-hour EC_{50} is 349 mg/L (nominal and measured) in *Daphnia magna* (MOE Japan, 1999b). The 72-hour EC_{50} to algae *Pseudokirchneriella subcapitata* is >1,000 mg/L (nominal and measured) based on growth rate; the 72-hour NOEC is 32 mg/L (MOE Japan, 1999c).

In a 21-day *Daphnia magna* reproduction test, the nominal and measured NOEC was reported to be 30.2 mg/L (MOE Japan, 1999d).

Toxicity to Terrestrial Plants

No data are available.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (>100 mg/L), invertebrates (349 mg/L), and algae (>1,000 mg/L). Results from chronic studies are available for invertebrates (21-day NOEC = 30.2 mg/L) and algae (72-hour NOEC = 32 mg/L). On the basis that the data consists of chronic studies on two trophic level (albeit not on the species with the lowest $E(L)C_{50}$), an assessment factor of 50 has been applied to the lowest reported NOEC of 30 mg/L for Daphnia. The $PNEC_{aquatic}$ is 0.6 mg/L.

PBT Assessment

Choline chloride is readily biodegradable and thus it does not meet the screening criteria for persistence.

Based on a measured log Kow of -3.77 and a calculated BCF of 0.59, choline chloride does not meet the screening criteria for bioaccumulation.

The chronic toxicity data on choline chloride show NOECs of >0.1 mg/L. Thus, choline chloride does not meet the screening criteria for toxicity.

The overall conclusion is that choline chloride is not a PBT substance.

References

BASF AG (1984). Department of Product Safety. Laboratory of Ecology. Pruefbericht ueber eine Untersuchung auf biologische Abbaubarkeit im BSB5-Test - Cholinchlorid (German). Test No. 01606. 16 Feb. 1984.BASF AG (2004b). Department of Product Safety. Unpublished calculation. Mackay Level I V2.11. 29 Jun. 2004.

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MOE Japan (1999a). Ministry of Environment. Acute toxicity study of choline chloride on the Orange killifish *Oryzias latipes*. Unpublished study. No. 1998-16.

MOE Japan (1999b). Ministry of Environment. Acute toxicity study of choline chloride on *Daphnia magna*. Unpublished study. No. 1998-14.

MOE Japan (1999c). Ministry of Environment. Acute toxicity study of choline chloride on the freshwater alga *Pseudokirchnerialla subcapitata*. Unpublished study. No. 1998-13.

MOE Japan (1999d). Ministry of Environment. Chronic toxicity study of choline chloride on the freshwater invertebrate *Daphnia magna*. Unpublished study. No. 1998-15.

OECD (2004). SIDS Initial Assessment Report for Choline chloride (CAS No. 67-48-1), UNEP Publications.

Tunkel J., Howard, P.H., Boethling, R.S., Sitteler, W., and Loonen, H. (2000). Predicting ready biodegradability in the Japanese Ministry of international trade and industry test. Environ. Toxicol. Chem. 19: 2478-2485.

Environmental Assessment

Crystalline Silica, Quartz
(CAS No. 14808-60-7)

Crystalline Silica, Cristobalite
(CAS No. 14464-46-1)

Silica is an off-white granule that occurs naturally in various crystalline and amorphous or other non-crystalline forms. Crystalline silica is characterized by silicon dioxide (SiO_2) molecules oriented in fixed, periodic patterns to form stable crystals. The primary crystalline form of silica is quartz. Other crystalline forms of silica include cristobalite, tripoli and tridymite.

Crystalline silica, quartz and crystalline silica, cristobalite are naturally occurring minerals that are insoluble in water.

They are persistent in the environment.

Crystalline silica, quartz, and crystalline silica, cristobalite as minerals, are not expected to bioaccumulate or be toxic to aquatic organisms because of their water insolubility and lack of bioavailability.

Crystalline silica, quartz and crystalline silica, cristobalite are not considered to be PBT substances.

Environmental Assessment

Diammonium peroxidisulfate
Ammonium persulfate
(CAS No. 7727-54-0)

Diammonium peroxisulfate or ammonium persulfate has been reviewed in the OECD-SIDS program (OECD, 2005a,b).

Environmental Fate

The inorganic persulfates are soluble in water (≥ 60 g/L) and their vapor pressures are negligible. Ammonium persulfate will be distributed into the water compartment in the ionic form of the ammonium cation and persulfate anion. Ammonium persulfate is expected to degrade in the environment mainly via hydrolysis, but metal catalyzed decomposition, and reactions with organic chemicals in the soil or water also are possible.

Persulfates are not expected to adsorb to soil due to its dissociation properties, instability (hydrolysis) and high water solubility. Persulfates should behave as free ions or decompose into sulfate ions. In soils, upon decomposition, the cation could form more stable sulfate or bisulfate salts.

Persulfates are not expected to bioaccumulate in the soil or in aqueous solution. They will decompose into inorganic sulfate or bisulfate.

Aquatic Toxicity

The 96-hour LC_{50} values for ammonium persulfate to fish are from 76 to 323 mg/L. The acute toxicity EC_{50} values for invertebrates are from 120 to 391 mg/L. The 72-hour EC_{50} values for ammonium persulfate to algae are 83.7 mg/L.

Toxicity to Terrestrial Organisms

No data were available.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (76 mg/L), Daphnia (120 mg/L), and algae (84 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 76 mg/L for fish. The $PNEC_{aquatic}$ is 0.076 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Diammonium peroxidisulfate dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc do not readily

apply to inorganics, such as diammonium peroxidisulfate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of diammonium peroxidisulfate to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The environmental distribution of diammonium peroxidisulfate is dominated by its water solubility. Sorption of diammonium peroxidisulfate should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Kow and Koc parameters do not readily apply to inorganics, such as diammonium peroxidisulfate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, diammonium peroxidisulfate is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

References

OECD (2005a). IUCLID Data Set for Ammonium persulfate (CAS No. 7727-54-0); Potassium persulfate (CAS No. 7727- 27-1); Sodium persulfate (CAS No. 7775-27-1), UNEP Publications.

OECD (2005b). Screening Information Dataset (SIDS) Initial Assessment Report for Ammonium persulfate (CAS No. 7727-54-0); Potassium persulfate (CAS No. 7727-27-1); Sodium persulfate (CAS No. 7775-27-1), UNEP Publications.

Environmental Assessment

Diatomaceous Earth
(CAS No. 61790-53-2)

Uncalcined diatomaceous earth (CAS No. 61790-53-2) typically contains around 1% crystalline silica. When diatomaceous earth is subjected to pressure or is processed ("calcined") at temperatures above 1000°C some of the amorphous silica is converted to crystalline silica in the form of cristobalite. Calcined diatomaceous earth can contain anywhere from 1% to 75% cristobalite.

Diatomaceous earth and crystalline silica are naturally occurring minerals that are insoluble in water.

The are persistent in the environment.

Diatomaceous earth and crystalline silica as minerals, are not expected to bioaccumulate or be toxic to aquatic organisms because of their water insolubility and lack of bioavailability.

Diatomaceous earth and crystalline silica, quartz are not considered to be PBT substances.

Environmental Assessment

Magnesium chloride
(CAS No. 7786-30-3)

Environmental Fate

Magnesium chloride dissociates completely in water to the Mg^{++} cation and the chloride anion (Cl^-).

Aquatic Toxicity

The 96-hour LC_{50} of magnesium chloride to *Pimephales promelas* is 541 mg of Mg/L (or 2,119.3 mg of $MgCl_2$/L).

The 48-hour LC_{50} for *Daphnia magna* is 140 mg Mg/L (or 548.4 mg of $MgCl_2$/L). In another study, the 48-hour LC_{50} to *Daphnia magna* and *Ceriodaphnia dubia* were 339 mg of Mg/L and 225 mg of Mg/L, respectively (or 1328 and 881.4 mg of $MgCl_2$/L, respectively).

The 72-hour EC_{50} of magnesium chloride for algae *Scenedesmus subspicatus* is >100 mg/L and the NOEC is 100 mg/L.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (2,119 mg/L as $MgCl_2$), Daphnia (548 mg/L as $MgCl_2$), and algae (100 mg/L $MgCl_2$). Even though a NOEC was obtained from the algae study, there were no chronic studies conducted on fish or Daphnia. On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 100 mg/L for algae. The $PNEC_{aquatic}$ was calculated to be 0.1 mg/L. The $PNEC_{aquatic}$ is 0.1 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Magnesium chloride dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc parameters do not readily apply to inorganics, such as magnesium chloride. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of magnesium chloride to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The environmental distribution of magnesium chloride is dominated by its water solubility. Sorption of magnesium chloride should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Koc and Kow parameters do not readily apply to inorganics, such as magnesium chloride.

Thus, the equilibrium partitioning methods cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, magnesium chloride is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Magnesium chloride is an organic salt that dissociates completely to magnesium and chloride ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both magnesium and chloride ions are ubiquitous and are present in most water, soil and sediment. Thus, the persistent criteria is not considered applicable to this inorganic salt.

Magnesium and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, magnesium chloride is not expected to bioaccumulate.

No chronic toxicity data exist on magnesium chloride; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, magnesium chloride does not meet the screening criteria for toxicity.

The overall conclusion is that magnesium chloride is not a PBT substance.

Reference

ECHA REACH database: http://echa.europa.eu/web/guest/information-on-chemicals/registered-substances

Environmental Assessment

Magnesium nitrate (CAS No. 10377-60-3)

Environmental Fate

Magnesium nitrate dissociates completely in water to Mg^{++} and the nitrate anion (NO_3^-).

Determination of PNECs

$PNEC_{aquatic}$: The ANZECC water quality guideline (2000) uses acute and chronic laboratory toxicity data for the derivation of "trigger values" for nitrate. The guideline summary for freshwaters is: *"A freshwater moderate reliability trigger value for nitrate toxicity as NO_3 (nitrate) of 700 µg/L was calculated using the statistical distribution method 95% protection and the default ACR."*

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Magnesium nitrate dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc parameters do not readily apply to inorganics, such as magnesium nitrate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of magnesium nitrate to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The environmental distribution of magnesium nitrate is dominated by its water solubility. Sorption of magnesium nitrate should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Koc and Kow parameters do not readily apply to inorganics, such as magnesium nitrate. Thus, the equilibrium partitioning methods cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, magnesium nitrate is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Magnesium nitrate is an organic salt that dissociates completely to magnesium and nitrate ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both magnesium and nitrate ions are also ubiquitous and are present in most water, soil and sediment. Thus, the persistent criteria is not considered applicable to this inorganic salt.

Magnesium ions are essential to all living organisms and its intracellular and extracellular concentrations are actively regulated. Nitrates are ions that are very

soluble in aqueous solutions. Thus, magnesium nitrate is not expected to bioaccumulate.

No chronic toxicity data exist on magnesium nitrate; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, magnesium nitrate does not meet the screening criteria for toxicity.

The overall conclusion is that magnesium nitrate is not a PBT substance.

Reference

ANZECC & ARMCANZ (2000). Australian and New Zealand guidelines for fresh and marine water quality. National Water Quality Management Strategy Paper No 4, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra, Australia.

Environmental Assessment

Vinylidene chloride/methacrylate copolymer (CAS No. 25038-72-6)

Biodegradation

Generally, polymers are considered to be essentially non-biodegradable.

Bioaccumulation

Polymers are not generally absorbed through biological membranes to bioaccumulate in tissues.

Aquatic Toxicity

This polymer is insoluble in water and is expected to be essentially non-toxic to aquatic organisms.

Determination of PNECs

$PNEC_{aquatic}$: Not determined.

PBT Assessment

Based on the information above, vinylidene chloride/methylacrylate copolymer is not considered to be a PBT substance.

Reference

Boethling, R.S. and Nabholz, J.V. (1997). Environmental Assessment of Polymers under the U.S. Toxic Substances Control Act. In: Ecological Assessment of Polymers Strategies for Product Stewardship and Regulatory Programs (Hamilton, J.D. and Sutcliffe, R. eds.), pp. 187-234, Van Nostrand Reinhold.

Environmental Assessment

Sodium Carboxymethyl Cellulose
(CAS No. 9004-32-4)

Sodium carboxycellulose is the sodium salt of carboxymethylcellulose. Carboxymethyl cellulose is a cellulose derivative with carboxymethyl groups (-CH_2COOH) bound to some of the hydroxyl groups of the glucopyranose monomers that make up the cellulose backbone.

Carboxymethyl cellulose (CMC) is a water-soluble semisynthetic polymer in which part of the hydroxyl groups of cellulose has been replaced at random by carboxymethyl groups. Carboxymethyl cellulose is therefore composed of eight different glucose units, namely one unsubstituted, three monosubstituted, three disubstituted, and one trisubstituted. The average number of carboxymethyl groups per glucose unit is denoted by the degree of substitution (DS). Carboxymethyl cellulose with a DS ranging from 0.4 to 1.3 has become the largest industrial cellulose ether because of its versatile applications in, for example, detergents and oil drilling.

Biodegradation

Carboxymethyl cellulose (DS 0.7) showed 25% biodegradation after 28 days in a OECD 301A test. Thus, sodium carboxymethyl cellulose is not readily biodegradable. Other studies have also shown partial degradation of carboxymethyl cellulose in ready and inherent biodegradability tests.

Aquatic Toxicity

Carboxymethyl cellulose has been tested in several acute aquatic toxicity tests. The 96-hour LC_{50} for *Brachydanio rerio* is >2,500 mg/L; the 48-hour LC_{50} for *Daphnia magna* is >5,000 mg/L; and the 96-hour EC_{50} for *Selenastrum capricornutum* is 500 mg/L.

Toxicity to Sediment Organisms

No data could be located.

Toxicity to Terrestial Organisms

No data could be located.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (>2,500 mg/L), Daphnia (>5,000 mg/L), and algae (>500 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 500 mg/L for algae. The $PNEC_{aquatic}$ is 0.5 mg/L.

PBT Assessment

Sodium carboxymethyl cellulose is a water-soluble semisynthetic polymer and is not readily biodegradable. Thus, it meets the screening criteria for persistence.

Sodium carboxymethyl cellulose is a water-soluble semisynthetic polymer and is expected to have a molecular weight of >1,000 which limits its bioavailability to aquatic organisms. Thus, it is not expected to bioaccumulate.

The acute $EC(L)_{50}$ of sodium carboxymethylcellulose is >0.1 mg/L in fish, invertebrates and algae. Thus, it does not meet the screening criteria for toxicity.

The overall conclusion is that sodium carboxymethylcellulose is not a PBT substance.

Reference

Van Ginkel, C.G., and Gayton, S. (1996). The biodegradability and nontoxicity of carboxymethyl cellulose (DS 0.7) and intermediates. Environ. Toxicol. Chem. 15: 270-274.

Environmental Assessment

Talc
(CAS No. 61789-40-0)

Talc is a mineral composed of hydrated magnesium silicate with the chemical formula $Mg_3Si4O_{10}(OH)_2$ or $H_2Mg_3(SiO_3)_4$. Talc is not soluble in water.

Biodegradation

As a mineral, talc does not biodegrade.

Aquatic Toxicity

No data were found. As an insoluble mineral, talc is not expected to be bioavailable; therefore, it is not expected to toxic to aquatic organisms.

Toxicity to Sediment Organisms

No data were found. As an insoluble mineral, talc is not expected to be bioavailable; therefore, it is not expected to toxic to sediment organisms.

Toxicity to Terrestrial Organisms

No data were found.

Determination of PNECs

PNEC values for talc cannot be calculated.

PBT Assessment

Talc is an inorganic mineral that is insoluble in water. Talc is not expected to be bioavailable to aquatic organisms; thus, it is does not meet the criteria for bioaccumulation or toxicity. Talc does not biodegrade in the environment. It is a naturally-occurring mineral and is persistent in the environment. However, for the purposes of this PBT assessment, it does not meet the criteria for persistence.

Environmental Assessment

Triethanolamine
(CAS No. 102-71-6)

Environmental Fate

Triethanolamine was completely degraded after incubation in municipal activated sludge for 1 or 5 days (West and Gonsior, 1996). The rate constants in all test batches for degradation and mineralization were reported to be >0.359. Thus, triethanolamine can be considered to be readily biodegradable.

In an OECD 301E test, there was 96% degradation after 19 days, indicating ready biodegradation (ECHA).

Bioaccumulation

Triethanolamine has been tested in a bioconcentration: flow-through fish (OECD 305) test using *Cyprinus carpio*. The BCF was determined to be <0.4 and <3.9 at triethanolamine concentrations of 2.5 and 0.25 mg/L, respectively (ECHA).

Aquatic Toxicity

The 96-hour LC_{50} to fathead minnow (*Pimephales promelas*) is 11,800 mg/L (ECHA). The 48-hour EC_{50} to *Ceriodaphnia dubia* is 610 mg/L (Warne and Schifko, 1999).

In a 21-day *Daphnia* reproduction test, the NOEC for reproduction rate was 125 mg/L, and the NOEC for reproduction on the appearance of first offspring was 250 mg/L (Kuehn *et al.*, 1989).

The 72-hour EC_{50} to algae *Desmodesmus subspicatus* is 512 mg/L [neutralized media] and 216 mg/L [un-neutralized media] (ECHA).

Toxicity to Terrestrial Organisms

No data were available.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (11,800 mg/L), *Daphnia* (610 mg/L), and algae (512 mg/L). A long-term (chronic) study is available for invertebrates (21-day NOEC = 125 mg/L). On the basis that the data consists of a chronic study on one trophic level, an assessment factor of 100 has been applied to the lowest reported NOEC of 125 mg/L for *Daphnia*. The $PNEC_{aquatic}$ is 1.25 mg/L.

PBT Assessment

Triethanolamine is readily biodegradable; thus, it does not meet the screening criteria for persistence.

The BCF values for triethanolamine in fish was <3.9; thus, it does not meet the criteria for bioaccumulation.

The NOEC for triethanolamine in a 21-day *Daphnia* reproduction test is 125 mg/L, which is >0.1 mg/L. Thus, triethanolamine does not meet the screening criteria for toxicity.

The overall conclusion is that triethanolamine is not a PBT substance.

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Santos

APPENDIX G.8 HALLIBURTON – WELL RM 08-14-3

Environmental Assessment

Acetic Acid
(CAS No. 64-19-7)

Acetic acid and its salts undergo dissociation in aqueous media into the acetate anion ($H_3C_2O_2^-$) and the respective cations (H^+, NH_4^+, Ca^{2+}, Mg^{2+}, Mn^{2+}, K^+, Na^+). The toxicity of each compound is driven by acetate, with the cations playing a minor role. The pH is 2.5 at 50 g/L and 20°C; and the pK_a is 4.76 at 20°C.

Environmental Transport

Level I fugacity modeling predicts that about 73% of any acetic acid released to the environment would partition to water, with the remainder partitioning into the air (U.S. HPVIS database).

Biodegradation

Acetic acid and its salts readily dissociate into their respective cations and the acetate anion; the anion acetate is readily biodegraded. In aerobic conditions using adapted wastewater from domestic sewage, degradation was 96% after 20 days (Price *et al.*, 1974). It was also shown to be readily biodegradable under anaerobic conditions using activated sludge (99% after 7 days) (Kameya *et al.*, 1995).

Aquatic Toxicity

The 96-hour LC_{50} in bluegill sunfish is 75 mg/L (Price *et al.*, 1974), and the 96-hour LC_{50} in mosquito fish is 251 mg/L (Wallen *et al.*, 1957). The 96-hour LC_{50} of 60% acetic acid in *Oncorhynchus mykiss* is 108 mg/L (64.8 mg acetic acid/L) (unpublished data, ECHA). In a chronic study with *Oncorhynchus mykiss*, the 21-day LC_{50} and NOEC for 60% acetic acid were 87 mg/L and 57.2 mg/L, respectively (unpublished data, ECHA). The 21-day LC_{50} and NOEC for 100% acetic acid were 52.2 mg/L and 34.3 mg/L, respectively (unpublished data, ECHA).

The 24-hour EC_{50} to Daphnia was reported to be 95 mg/L (un-neutralized) and 6,000 mg/L (neutralized to pH 8.0) (Bringmann and Kuehn, 1982). One other study showed the 48-hour EC_{50} to be 65 mg/L (Janssen *et al.*, 1993). In a chronic Daphnia study, the 21-day NOEC for reproduction was reported to be 22.7 mg/L for 100% acetic acid (unpublished data, ECHA). In another chronic Daphnia study, the 21-day NOEC for reproduction was 31.4 mg/L for 100% acetic acid (unpublished data, ECHA).

In an algae growth inhibition study, the reported nominal ErC_{50} to *Desmodesmus subspicatus* was 810.9 mg/L for 60% acetic acid (unpublished data, ECHA). The

reported nominal ErC_{50} was 486.5 mg/L for 100% acetic acid (unpublished data, ECHA). The toxicity threshold to algae after 8 days in a growth inhibition test was reported to be 4,000 mg/L (Bringmann and Kuehn, 1980).

Toxicity to Terrestrial Organisms

No data could be located.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (65 mg/L) and Daphnia (65 mg/L), and algae (487 mg/L). Long-term results are also available for fish (NOEC = 34 mg/L) and Daphnia (NOEC = 23 mg/L). On the basis that the data consists of short-term results from three trophic levels and two chronic study for fish and another chronic study for Daphnia, an assessment factor of 50 has been applied to the lowest NOEC of 23 mg/L for Daphnia. The $PNEC_{aquatic}$ was calculated to be 0.5 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Acetic acid dissociates completely in water with its environmental distribution dominated by its high water solubility. Since log Kow and Koc are only applicable to the non-ionized forms of a substance, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Thus, the determination of the $PNEC_{sediment}$ is not possible. Based on its properties, no adsorption of acetic acid to sediment is to be expected and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. Acetic acid dissociates completely in water with its environmental distribution dominated by its high water solubility. Since log Kow and Koc are only applicable to the non-ionized forms of a substance, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Thus, the determination of the $PNEC_{soil}$ is not possible. Based on its properties, no adsorption of acetic acid to soil is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

The acetate ion of acetic acid is readily biodegradable and thus it does not meet the screening criteria for persistence.

The log Kow for acetic acid is reported to be -0.17 (Verschueren, 1966). Acetate is also found in the body and is metabolized as part of the body's biochemical pathways. Thus,

acetic acid (specifically, the acetate ion) does not meet the screening criteria for bioaccumulation.

The NOECs from the chronic aquatic toxicity data on acetic acid are >0.01 mg/L. Thus, acetic acid does not meet the criteria for toxicity.

The overall conclusion is that acetic acid is not a PBT substance.

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Environmental Assessment

Crystalline Silica, Quartz
(CAS No. 14808-60-7)

Crystalline Silica, Cristobalite
(CAS No. 14464-46-1)

Silica is an off-white granule that occurs naturally in various crystalline and amorphous or other non-crystalline forms. Crystalline silica is characterized by silicon dioxide (SiO_2) molecules oriented in fixed, periodic patterns to form stable crystals. The primary crystalline form of silica is quartz. Other crystalline forms of silica include cristobalite, tripoli and tridymite.

Crystalline silica, quartz and crystalline silica, cristobalite are naturally occurring minerals that are insoluble in water.

They are persistent in the environment.

Crystalline silica, quartz, and crystalline silica, cristobalite as minerals, are not expected to bioaccumulate or be toxic to aquatic organisms because of their water insolubility and lack of bioavailability.

Crystalline silica, quartz and crystalline silica, cristobalite are not considered to be PBT substances.

Environmental Assessment

Diethanolamine
(CAS No. 111-42-2)

Environmental Fate

In an OECD 301F test, there was 50% degradation after 7 days, 80% after 14 days, and 93% after 28 days (OECD 2007). In modified OECD 301E screening tests using river or pond water, there was 93% and 97% degradation (measured as DOC removal) after 28 days (OECD 2007). Results from other biodegradation tests (ready, inherent, and one simulation test according to OECD 303A) indicate that diethanolamine is easily eliminated from sewage treatment plants as well as from surface water. The results of these tests indicate that diethanolamine is readily biodegradable.

Bioaccumulation

The BCF calculated from a QSAR model by Zhao *et al.* (2008) was 4 L/kg (ECHA). The BCF calculated from U.S. EPA EPIWIN is 3.16 L/kg (OECD 2007).

Aquatic Toxicity

The 96-hour LC_{50} values for fathead minnows are 1,480 mg/L [fry], 1,550 mg/L [juvenile], and 1,370 mg/L [subadults]; the geometric mean of the 96-hour LC_{50} values is 1,460 mg/L (Mayes *et al.* 1983). The 48-hour LC_{50} to *Lepomis macrochirus* is 1,850 mg/L (Turnbull *et al*. 1954).

The 48-hour EC_{50} values to *Ceriodaphnia dubia* are 89.9 ml/L and 30.1 mg/L at 20°C. and 24°C., respectively (Cowgill *et al.* 1985). The 48-hour EC_{50} to *Daphnia magna* was reported to be 55 mg/L (LeBlanc 1980) and 171 mg/L (Zurita *et al.* 2005).

The NOEC from a 21-day *Daphnia* reproduction study is 0.78 mg/L (ECHA; OECD 2007).

The 96-hour EC_{50} to *Pseudokirchnerella subcapitata* is 9.7 mg/L based on growth rate and 2 mg/L based on yield; the 96-hour NOEC is 0.6 mg/L for yield (ECHA). However, the test concentrations were not confirmed by chemical analysis.

Toxicity to Terrestrial Organisms

No data were available.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (1,460 mg/L), *Daphnia* (30 mg/L), and algae (2 mg/L). A long-term (chronic) study is available for invertebrates (21-day NOEC = 0.78 mg/L). On the basis that the data consists of two chronic studies on two trophic levels, an assessment factor of 50 has been applied to the NOEC of 0.78 mg/L for *Daphnia*. The $PNEC_{aquatic}$ is 0.0156 mg/L.

PBT Assessment

Diethanolamine is readily biodegradable; thus, it does not meet the screening criteria for persistence.

The estimated BCF values for diethanolamine calculated from QSAR models are 4 and 3.16 L/kg; thus, it does not meet the criteria for bioaccumulation.

The NOEC for diethanolamine in a 21-day *Daphnia* reproduction test is 0.78 mg/L, which is >0.1 mg/L. Thus, diethanolamine does not meet the screening criteria for toxicity.

The overall conclusion is that diethanolamine is not a PBT substance.

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Environmental Assessment

Disodium Octaborate Tetrahydrate
(CAS No. 12280-03-4)

Data on borax and boric acid will be used to read across to disodium octaborate tetrahydrate ($Na_2B_8O_{13}\bullet 4H_2O$). The rationale is as follows:

Borax is also known as sodium borate, sodium tetraborate, or disodium tetraborate. With water content, borax can refer to a group of compounds that differ in their crystal water content, but typically it is disodium tetraborate decahydrate with the chemical structure ($Na_2B_4O_7\bullet 10H_2O$). Borax is moderately soluble in water, with the main species in freshwater being the borate ion $[B(OH)_4]^-$ and boric acid $B(OH)_3$, depending on the pH. The relative proportion of boric acid and borate ions is controlled by pH: $B(OH)_3 + 2H_2O \Leftrightarrow [B(OH)_4]^- + H_3O^-$. In dilute aqueous solutions, boric acid does not dissociate at pH <7; at pH values between 7 and 11, both boric acid and borate ions are present. In dilute aqueous solutions and physiological conditions, the predominant species present is un-dissociated boric acid. So, the consideration of boric acid addresses the relevant environmental stability properties for borates.

Exposure to borates are often expressed in terms of boron (B) equivalents based on the fraction of boron in the source substance on a molecular weight basis. The B equivalents used are a generic designation rather than a designation of the element boron. The factors for converting disodium tetraborate decahydrate (or disodium octaborate tetrahydrate) and boric acid to B-equivalents are 0.113 and 0.175, respectively.

In natural waters, boron forms stable species and exists primarily as un-dissociated boric acid [$B(OH)_3$] and complex polyanions (*e.g.*, $B(OH)_{4^-}$). These forms of boron are highly soluble and not easily removed from solution by natural mechanisms. Borate and boric acid are in equilibrium depending on the pH of the water. At an acidic pH, boron exists in solution mainly as un-dissociated boric acid, whereas at alkaline pH it is present as borate ions.

Environmental Fate

At noted above, disodium tetraborate decahydrate will yield boric acid upon dissolution in water (or borate anion in higher pH conditions). Boric acid is a persistent molecule, not subject to hydrolysis, photodegradation or biodegradation.

Many mineral contain boron, which is present as the sodium or calcium borate salt. Thus, boron is ubiquitous and widely distributed in the environment. It is present in rocks, soil and water and is released into the environment primarily from the weathering of rock and soil, volatilization of sea water, and anthropogenic activity.

Bioaccumulation

The WHO (1998) review of boron noted that "highly water soluble materials are unlikely to bioaccumulate to any significant degree and that borate species are all present essentially as un-dissociated and highly soluble boric acid at neutral pH". A BCF of <0.1 was reported in Chinook salmon fed boron-supplemented diets for 60 to 90 days (Hamilton and Wiedmeyer, 1990).

Some bioconcentration is expected in terrestrial plants since boron is a critical element to terrestrial plants and is incorporated into the cell wall structure. However, the phytotoxicity of boron limits the potential for excessive accumulation beyond "normal" plant tissue concentrations (Austria, 2008). Terrestrial non-predatory organisms, such as Mallard ducks, did not accumulate boron (BCF <0.1) when fed a plant diet of 1,600 mg-B/kg for up to 48 days (Pendleton *et al.*, 1995).

Toxicity

There are many ecotoxicity laboratory and field tests that have been conducted on boron (which includes boric acid and borates). Overall, the studies show that boron does not fulfill the criteria of Toxicity in a PBT assessment with regards to aquatic organisms. The data were reviewed in the "Scientific Criteria Document for the Development of the Canadian Water Quality Guidelines for Boron" (CCME, 2009), which is summarized below:

"Primary acute toxicity data for vertebrates were available for early life stages of four fish species. Endpoints ranged from a 3 day NOEC (teratogenesis at hatching) of 0.109 mg/L for embryo- hatching stage largemouth bass (Black *et al.* 1993) to a 7 day EC_{50} (embryo test) of 969 mg/L for rainbow trout (MELP, 1996). Secondary and unclassified toxicity data were similar to the reported primary data with effect concentrations ranging between 4.6 and 3,145 mg/L."

"Primary acute toxicity data for invertebrates were available for four species. The 48 hour LC_{50} concentrations ranged from 21.3 mg/L for neonate water fleas (MELP, 1996) to 1,376 mg/L for larval midge (Maier and Knight, 1991). Secondary, unclassified and unacceptable toxicity data were similar to the reported primary data with effect concentrations ranging between 1 and 2,797 mg/L."

"Primary chronic toxicity data for vertebrates were available for three fish species." If the outliers are excluded, "effect concentrations ranged from a 36 day LOEC (mortality) of 1.34 mg/L for embryo-larval rainbow trout to a 32 day LC_{50} of 138 mg/L for rainbow trout (Black *et al.*, 1993). Lower effect concentrations (0.01 mg/L) for embryo-larval rainbow trout were observed in the unclassified toxicity studies (Birge and Black, 1977)."

"Primary chronic toxicity data for invertebrates were available for two species. Effect concentrations ranged between a 21 day LOEC (mean brood size) of 13 mg/L to a 21 day LC_{50} of 53.2 mg/L for the water flea (Lewis and Valentine, 1981). Effect concentrations

for additional unclassified studies differed from those reported by the primary studies, with a range of <0.38 to ~266 mg/L."

"Primary chronic toxicity data were available for 4 to 7 day old green algae (*Selenastrum capricornutum*) (MELP, 1997). The lowest reported effect concentration for algae exposed to boron was a 72 hour LOEC of 12.3 mg/L. Effect concentrations of secondary and unclassified toxicity data ranged from 1 to ~171 mg/L."

Determination of PNECs

$PNEC_{aquatic}$: There are many ecotoxicity laboratory and field tests that have been conducted on boron (which includes boric acid and borates). Both acute and chronic toxicity studies are available for three trophic levels. A Canadian Water Quality Guidelines for the Protection of Aquatic Life of 1.5 mg/L was derived for long–term exposure to boron (CCME, 2009). Thus, the $PNEC_{aquatic}$ for disodium octaborate tetrahydrate is 1.5 mg-B/L.

It should be noted, however, that Australia and New Zealand adopted a freshwater high reliability trigger value for boron of 0.37 mg-B/L (ANZECC, 2000).

The factor for converting disodium octaborate tetrahydrate to B-equivalents is 0.113.

PBT Assessment

Disodium octaborate tetrahydrate is a persistent molecule, not subject to hydrolysis, photodegradation or biodegradation. Thus, it meets the criteria for persistence.

Disodium octaborate tetrahydrate is a water-soluble substance that is not expected to bioaccumulate. Limited data indicate that bioaccumulation (BCF values are low) is not significant in aquatic and terrestrial food chains. Thus, it does not meet the criteria for bioaccumulation.

Overall, the aquatic toxicity studies show that boron does not fulfill the criteria of toxicity. However, there are human health concerns and boric acid (and borates) are considered reproductive toxicants; they have, for instance, been classified in the EU as known or presumed human reproductive toxicants (Category 1B). Thus, disodium octaborate tetrahydrate meets the PBT criteria of toxicity.

The overall conclusion is that disodium octaborate tetrahydrate is not a PBT substance.

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Environmental Assessment

Ethylene glycol
(CAS No. 107-21-1)

Ethylene glycol has been reviewed in the OECD-SIDS program (OECD, 2004a,b)

Environmental Transport

A Mackay Level III fugacity model predicts that ethylene glycol will distribute 45.6% to water, 52.3% to soil, 2.02% to air, and <0.1% to sediment (OECD, 2004a,).

Biodegradation

Ethylene glycol is readily biodegradable both aerobically and anaerobically. There was 97% degradation after 20 days in a BOD test (OECD, 2004a,b), and 96% degradation after 28 days in an OECD 301D test (OECD, 2004a,b).

The aerobic degradation of ethylene glycol was measured from grab river water samples at 4, 8, and 20^{o}C (Evans and David, 1974). At 20^{o}C, ethylene glycol was completely degraded in three days in all river waters tested, and at 8^{o}C degradation was complete within 14 days. Degradation at 4^{o}C was substantially slower, with degradation of less than 20% after 14 days in river samples with limited suspended matter and a starting concentration of 10 mg/L.

Bioaccumulation

The log K_{ow} of ethylene glycol was measured as -1.36 (Hansch *et al.*, 1989). The BCF for ethylene glycol in golden ide (*Leuciscus idus melanotus*) after three days of exposure was determined to be 10 (Freitag *et al.*, 1985).

Aquatic Toxicity

The 96-hour LC_{50} values to fry, juvenile, and subadult fathead minnows (*Pimephales promelas*) are 53,000, 49,000 and 57,000 mg/L, respectively (Mayes *et al.*, 1983). The 96-hour LC_{50} values to fathead minnows (*Pimephales promelas*) was also reported to be 72,860 mg/L (Pillard, 1995). The 96-hour LC_{50} to rainbow trout (*Oncorhynchus mykiss*) is 22,810 mg/L (OECD, 2004b). In a 12-day chronic study, the NOEC to rainbow trout (*Oncorhynchus mykiss*) was reported to be 14,692 mg/L (OECD, 2004b).

The 48-hour LC_{50} to *Daphnia magna* is 46,300 mg/L (Gersich *et al.*, 1986). The 48-hour EC_{50} values to *Ceriodaphnia dubia-affinis* and *Daphnia magna* are 10,000 and 51,000 mg/L at 24^{o}C, respectively; and 25,800 and 46,300 mg/L at 24^{o}C, respectively (Cowgill

et al., 1985). The NOEC for a 7-day reproduction test to *Ceriodaphnia dubia* is 3,469 mg/L (OECD, 2004b).

The 96-hour EC_{50} to green algae (*Selenastrum capricornutum*) is 10,940 mg/L based on cell growth; the NOEC is 10,000 mg/L (Pillard and DuFresne, 1999).

Toxicity to Sediment Organisms

No data were located.

Toxicity to Terrestrial Organisms

A mallard duck receiving 1.1 mL/kg ethylene glycol recovered, but ducks (1/dose) receiving 2.3, 4.5, 8.9, 13.3, and 17.8 mL/kg died (Stowe *et al.*, 1981). Ethylene glycol (0.1 mL/chicken egg) significantly decreased hatchability relative to controls and significantly increased embryonic mortality during weeks 1 and 3 (Ameenuddin and Suude, 1984). Doses of 0, 0.05, 0.1, and 0.15 ml/egg resulted in hatchability of approximately 82, 75, 45 and 45%, respectively.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (22,810 mg/L), Daphnia (10,000 mg/L), and algae (10,940 mg/L). NOEC values from long-term studies are available for fish (14,692 mg/L), invertebrates (3,469 mg/L), and algae (10,000 mg/L). On the basis that the data consists of short-term and long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported NOEC of 3,469 mg/L for invertebrates. The $PNEC_{aquatic}$ is 347 mg/L.

PBT Assessment

Ethylene glycol is readily biodegradable and thus does not meet the screening criteria for persistence.

The octanol-water coefficient (log K_{ow}) for ethylene glycol is -1.36. The measured BCF in fish is 10. Thus, ethylene glycol does not meet the criteria for bioaccumulation.

The chronic toxicity data on ethylene glycol show NOECs of >0.01 mg/L. Thus, ethylene glycol does not meet the screening criteria for toxicity.

The overall conclusion is that ethylene glycol is not a PBT substance.

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Environmental Assessment

Hemicellulase
(CAS No. 9025-56-3)

Hemicellulases are a group of enzymes that break down hemicellulose, which are polysaccharides that are present in cell walls of all terrestrial plants. These polysaccharides have a β-(1→4)-linked backbone and are composed of pentoses (xylose, arabinoses), hexoses (mannose, glucose, galactose), and sugar acids. Unlike cellulose which are polysaccharides consisting of linear chains of several hundred to over ten thousand β-(1→4) linked D-glucoses, hemicelluloses are not chemically homogeneous. The best characterized hemicellulases are the 1,4- β -D-xylanases and, in particular, those derived from fungal sources presumably because their substrates, xylans, constitute the largest proportion of hemicelluloses in pasture plants.

No toxicity information could be located on hemicellulases; however, mammalian toxicity information were found on the cellulase enzymes (HERA report, 2005). Cellulases cleave the ß-1,4-glycosidic bonds in cellulose, and are used in the pulp and paper industry, the textile industry, and in detergents to remove deposits and stains.

Enzymes are catalytic proteins or polypeptides and consist of amino acid residues coupled via peptide bonds. They are primarily characterized by their biocatalytic or enzymatic activity. There is a broad range of detergent cellulases used both from fungal as well as from bacterial origin; all are characterized by ß-1,4-endoglucanase activity. For the purposes of risk assessment, the structure of hemicellulases would be expected to be similar to that of cellulases, given that hemicellulases and cellulases are both enzyme families that hydrolyze polysaccharides, although differing in their substrates. Thus, the toxicity data on cellulases will be used as read-across to hemicellulases.

Biodegradation

Three different cellulase enzymes were considered readily biodegradable based on the results of OECD 301C and 301E tests (HERA, 2005). In an OECD 301E test, there was 84% DOC removal of the enzyme Carezyme after 28 days. In another OECD 301E test, there was 92% DOC removal of the enzyme Clazinase® after 28 days. In an OECD 301C test, BOD/COD was 78% after 28 days. Likewise, hemicellulase is expected to be readily biodegradable.

Aquatic Toxicity

The 96-hour LC_{50} of an alkaline cellulase to zebrafish (*Brachydanio rerio*) is 330 mg aep/L (HERA, 2005). The 48-hour EC_{50} of the same alkaline cellulase to *Daphnia magna* is >1,000 mg aep/L (HERA, 2005). The same alkaline cellulase was also tested in algae (*Scenedesmus subspicatus*), with a 72-hour EC_{50} of >1000 mg aep/L (HERA,

2005).

The 24- and 48-hour EC_{50} values of an alkaline cellulase (SP 227, Celluzyme) to *Daphnia magna* are >1,000 mg aep/L and approximately 1,000 mg aep/L respectively (HERA, 2005).

Two additional acute fish toxicity studies showed findings with LC_{50} values of >100 mg aep/L, but no references were provided (HERA, 2005).

Toxicity to Sediment Organisms

No data could be located.

Toxicity to Terrestial Organisms

No data could be located.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (330 mg aep/L), Daphnia (>1,000 mg aep/L), and algae (1,000 mg aep/L). Although the HERA report provides information on two acute fish studies with LC_{50} values of >100 mg aep/L, no references were provided and were therefore excluded from the determination of PNECs. On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 330 mg aep/L for fish. The $PNEC_{aquatic}$ is 0.33 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$. A calculated Koc of <1.3 was reported in the HERA report, calculated according to the TGD. Using a Koc of 1.3 and a $PNEC_{aquatic}$ of 0.33 mg aep/L, the $PNEC_{sediment}$ was calculated to be 0.21 mg aeg/kg.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The equilibrium partition method was used to determine a $PNEC_{soil}$. A calculated Koc of <1.3 was reported in the HERA report, calculated according to the TGD. Using a Koc of 1.3 and a $PNEC_{aquatic}$ of 0.33 mg aep/L, the $PNEC_{soil}$ was calculated to be 0.006 mg aeg/kg.

PBT Assessment

Hemicellulase is expected to be readily biodegradable based on read-across to cellulases. Thus, hemicellulase does not meet the screening criteria for persistence.

Based on the similarity to cellulase, hemicellulase has a high molecular weight (20 to 80 kD), has hydrophilic properties (high water solubility, log Kow <0), and is readily metabolized in organisms by proteolytic enzymes or proteases. Thus, hemicellulose does not meet the screening criteria for bioaccumulation.

The acute $EC(L)_{50}$ of hemicellulase is >0.1 mg/L in fish, invertebrates and algae. Thus, hemicellulase does not meet the screening criteria for toxicity.

The overall conclusion is that hemicellulase is not a PBT substance.

Reference

Human and Environmental Risk Assessment (HERA) on Ingredients of Household Cleaning Products: α-amylase, CAS No. 9000-90-2; Cellulase (β-(1,4)-glucanase), CAS No. 9012-54-8; Lipase, 9001-62-1, 2005. http://www.heraproject.com

Environmental Assessment

Hydroxypropyl Guar Gum
(CAS No. 39421-75-5)

No data could be located on hydroxypropyl guar gum; information in this assessment will be read-across from guar gum.

Guar gum (CAS No. 9000-30-0) is the milled endosperm of the leguminous plant *Cyamopsis tetragonolobus*. Structurally, it is a galactomannan (high molecular weight carbohydrate polymer) consisting of a main chain of D-mannose with a side chain of D-galactose at approximately every second mannose unit. The mannose units are β-(l-4) linked, and the single D-galactose units are joined to the main chain by α-(1-6) linkages. The estimated molecular weight of guar gum ranges from 200,000 to 300,000 daltons (Glickman, 1969).

Biodegradation

No information was found. Guar gum, being a polysaccharide composed of galactomannan, would be expected to be readily biodegradable.

Bioaccumulation

Not expected to bioaccumulate as a polysaccharide composed of galactomannans.

Aquatic Toxicity

The 48-hour LC_{50} for *Daphnia magna* was reported to be 42 mg/L (Biesinger *et al.*, 1976).

Toxicity to Terrestrial Organisms

No data were located.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for one trophic level. An acute LC_{50} value is available for the invertebrate Daphnia (42 mg/L). On the basis that the data consists of only one short-term result from one trophic level, an assessment factor of

1,000 has been applied to the reported effect concentration of 42 mg/L for Daphnia. The $PNEC_{aquatic}$ is 0.042 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The Kow and Koc of guar gum cannot be calculated using EPISUITE because the molecular weight of guar gum greatly exceeds the limit of 1,000. Thus, the equilibrium partition method cannot be used to determine a $PNEC_{sediment}$ and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on soil organisms are available. The Kow and Koc of guar gum cannot be calculated using EPISUITE because the molecular weight of guar gum greatly exceeds the limit of 1,000. Thus, the equilibrium partition method cannot be used to determine a $PNEC_{soil}$ and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

No biodegradation was found on guar gum. However, guar gum is a naturally occurring polysaccharide which would be expected to readily biodegrade. Thus, it is not expected to meet the screening criteria for persistence.

The molecular weight of guar gum ranges from 200,000 to 300,000 daltons, and it is also water soluble. Thus, guar gum is not expected to meet the criteria for bioaccumulation.

The acute aquatic toxicity of guar gum is >0.1 mg/L. Thus, guar gum is not expected to meet the screening criteria for toxicity.

The overall conclusion is that guar gum, and therefore hydroxypropyl guar gum, is not a PBT substance.

References

Biesinger, K.E. et al. (1976). Comparative toxicity of polyelectrolytes to selected aquatic animals. J. Water Pollut. Control Fed. 48: 183-187; cited in NZ HSNO CCID. http://www.epa.govt.nz/search-databases/Pages/ccid-details.aspx?SubstanceID=1930

Glicksman M. (1969). Gum technology in the Food Industry, pp. 590, Academic Press, New York; cited in Yoon, S.-J., Chu, D.-C., and Juneja, L.R. (2008) Chemical and physical properties, safety and application of partially hydrolyzed guar gum as dietary fiber. J. Clin. Biochem. Nutr. 42: 1-7.

NTP (1982). NTP Technical Report on the Carcinogenesis Bioassay of Guar Gum (CAS No. 9000-30-0) in F344 Rats and $B6C3F_1$ Mice (Feed Study), National Toxicology Program, Research Triangle Park, NC.

Environmental Assessment

Lactose
(CAS No. 63-42-3)

Lactose is a disaccharide sugar composed of galactose and glucose. It is naturally synthesized in the mammary gland of virtually all mammals, occurring in milk at levels between 1 and 7%. Commercially, lactose is extracted from the whey of cow's milk (whey is the residual liquid of milk following cheese and casein production) and is purified extensively to remove fats, proteins, vitamins and minerals (Baldrick and Bamford, 1997; Goodhart, 1994).

Biodegradation

No biodegradation studies were found on lactose. The QSAR model BIOWIN estimates that the biodegradation of lactose would be fast, with primary degradation in hours-days and ultimate degradation in days-weeks (U.S. EPA, 2011).

Aquatic Toxicity

No aquatic toxicity studies were found on lactose.

Using ECOSAR, the 96-hour LC_{50} in fish was estimated to be 81,045 mg/L; the 48-hour LC_{50} in *Daphnia* was estimated to be 3,460,000 mg/L; and the 96-hour EC_{50} in green algae was estimated to be 583,000 mg/L (U.S. EPA, 2011).

Toxicity to Sediment Organisms

No data could be located.

Toxicity to Terrestrial Organisms

No data could be located.

Determination of PNECs

$PNEC_{aquatic}$: No experimental results are available for lactose. Acute $E(L)C_{50}$ estimates using the QSAR model ECOSAR are: fish (81,045 mg/L), Daphnia (3,460,000 mg/L), and algae (583,000 mg/L). On the basis that the data consists of short-term results from

three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 81,045 mg/L for fish. The $PNEC_{aquatic}$ is 81 mg/L.

PBT Assessment

No experimental biodegradation data are available on lactose. The QSAR model BIOWIN predict that lactose will biodegrade fast, with primary degradation in hours-days and ultimate degradation in days-weeks. Thus, lactose does not meet the screening criteria for persistence.

The estimated log K_{ow} and BCF for lactose is -5.03 and 3.162, respectively (U.S. EPA, 2011). Thus, lactose does not meet the screening criteria for bioaccumulation.

The estimated acute $EC(L)_{50}$ values of lactose indicate that it is non-toxic to fish, invertebrates and algae. Thus, it does not meet the screening criteria for toxicity.

The overall conclusion is that lactose is not a PBT substance.

References

Baldrick, P., and Bamford, D.R. (1997). A toxicological review of lactose to support clinical administration by inhalation. Food Chem. Toxicol. 35: 719-733.

Goodhart, F.W. (1994). Lactose. In: handbook of Pharmaceutical Excipients, 2nd Edition, pp. 252-261, The Pharmaceutical Press, London.

U.S. EPA (2011). EPISuite v. 4.10, United States Environmental Protection Agency, Office of Pollution Prevention and Toxics and Syracuse Research Corporation.

Environmental Assessment

Monoethanolamine borate
(CAS No. 26038-87-9)

Monoethanolamine borate is also known as orthoboric acid, compound with 2-aminoethanol. It is a UVCB substance with the chemical formula: $C_2H_7NO.xBH_3O_3$.

Environmental Transport

Monoethanolamine (MEA) Polyborate 1:1 and MEA Polyborate 1:3 do not significantly adsorb to soil. The experimental log Koc was determined to be approximately 1.26.

Biodegradation

MEA Polyborate 1:1 was considered readily biodegradable in a modified Sturm test (OECD 301B). Degradation was 73% after 28 days.

MEA Polyborate 1:3 was considered readily biodegradable in a modified Sturm test (OECD 301B). Degradation was 75% after 28 days.

Aquatic Toxicity

The 96-hour LC_{50} in Carp for MEA Polyborate 1:3 is 617 mg/L.

The 48-hour EC_{50}s in *Daphnia magna* for MEA Polyborate 1:3 and MEA Polyborate 1:1 are 496 and 423 mg/L, respectively.

The 72-hour ErC_{50} in fresh water algae species *Pseudokirchneriella subcapitata* for MEA Polyborate 1:1 is 26 mg/L. The 72-hr EyC_{50} (yield inhibition) is 13 mg/L. The NOEC for growth rate reduction and yield inhibition is 3.2 mg/L. The 72-hr ErC_{50} in fresh water algae species *Pseudokirchneriella subcapitata* for MEA Polyborate 1:3 is 67 mg/L.

Toxicity to Sediment Organisms

No data are available.

Toxicity to Terrestrial Organisms

No data are available.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (617 mg/L), Daphnia (423 mg/L), and algae (13 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 13 mg/L for algae. The $PNEC_{aquatic}$ is 0.013 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$. The Koc was experimentally determined to be approximately 18.20. Using a Koc of 18.20 and a $PNEC_{aquatic}$ of 0.013 mg/L, the $PNEC_{sediment}$ was calculated to be 0.012 mg/kg.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The equilibrium partition method was used to determine a $PNEC_{soil}$. The Koc was experimentally determined to be approximately 18.20. Using a Koc of 18.20 and a $PNEC_{aquatic}$ of 0.013 mg/L, the $PNEC_{soil}$ was calculated to be 0.003 mg/kg (3.1 μg/kg).

PBT Assessment

Monoethanolamine borate is readily biodegradable and thus it does not meet the screening criteria for persistence.

Monoethanolamine borate is a UVCB substance and a log Kow cannot be accurately determined. For monoethanolamine itself, the measured log Kow and estimated BCF from BCFBAF v.3.01 are -1.6122 and 3.16 L/kg, respectively. The borate salt of monoethanolamine would not be expected to meet the screening criteria for bioaccumulation.

No chronic aquatic toxicity studies are available for monoethanolamine borate. The acute toxicity studies in fish, invertebrates and algae are >0.1 mg/L. Thus, monoethanolamine borate does not meet the criteria for toxicity.

The overall conclusion is that monoethanolamine borate is not a PBT substance.

Reference

ECHA REACH database: http://apps.echa.europa.eu/registered/registered-sub.aspx

Environmental Assessment

Amorphous/Non-crystalline Silica
(CAS No. 7631-86-9[1])

Silica Gel
(CAS No. 112926-00-8)

Amorphous Silica and silica gel have been reviewed in the OECD-SIDS program (OECD, 2004a,b).

The CAS No. 7631-86-9 is the general CAS registry number for silicon dioxide which includes all forms of silicas (*e.g.*, also crystalline and natural forms). Only the silica sub-classes, the synthetic amorphous silicas, are subject of this assessment.

Synthetic amorphous silica and silicates are in powder form which have a low water solubility, based on the sum of soluble SiO_2 and cations (water-soluble fraction): ≤70 mg/l (SAS), approx. 70 – 80 mg/l (NAS), and approx. 260 mg/l (CS) at 20 °C.

Environmental Fate and Transport

Silicon oxides are the most abundant compounds in the earth's crust mass. Synthetic amorphous silica and silicates are released into the environment are expected to be distributed mainly into soils and sediments, weakly into water and probably not at all in the air due to their physico-chemical properties, particularly low water solubility and very low vapor pressure.

Synthetic amorphous silica and silicates released into the environment are expected to combine indistinguishably with the soil or sediment due to their similarity with inorganic soil/sediment matter and will be subjected to natural processes under environmental conditions (cation exchange, dissolution, sedimentation).

Biodegradation is not applicable to these inorganic substances. The bioavailable form of synthetic amorphous silica and silicates is the dissolved form which exists exclusively as monosilicic [$Si(OH)_4$] acid under environmental pH. In analogy to the general chemical reaction of weak acids and salts of weak acids with water, the water-soluble fraction of silica acts as a weak acid and, therefore, will tend to lower the pH value, while that of a silicate acts as a base tending to bind protons and, thus, raise the pH value by forming hydroxyl ions. But pH shifts which are measurable at high loadings under laboratory conditions are not expected to occur from the anthropogenic deposition in the aquatic environment of synthetic amorphous silicas due to low aquatic releases and sufficient natural buffer capacities. Finally, these materials are supposed to combine indistinguishably with the soil layer or sediment due to their chemical similarity with inorganic soil matter.

Dissolved silica can be actively assimilated by some marine and terrestrial organisms as normal natural processes mainly related to structural function.

Aquatic Toxicity

Studies on fish, Daphnia and algae using excess loadings of SAS or NAS showed no acute toxicity, although physical effects on Daphnia were observed in tests using unfiltered test medium. Test results, based on loading rates, are as follows: 96-hour LL_0 *(Brachydanio rerio)* is 10,000 mg/L for SAS and NAS; 24-hour EL_{50} *(Daphnia magna)* >10,000 mg/L for SAS; 72-hour NOEL *(Scenedesmus subspicatus)* is 10,000 mg/L for NAS.

There are no chronic aquatic toxicity data, but due to the known inherent physico-chemical properties, absence of acute toxic effects as well as the ubiquitous presence of silica/silicates in the environment, there is no evidence of harmful long-term effects arising from exposure to synthetic amorphous silica/silicates.

Toxicity to Terrestrial Organisms

No data are available.

PBT Assessment

Noncrystalline silica (silica gel) is silicon dioxide, an inorganic compound which is ubiquitous in the environment. It is persistent in the environment.

A log Kow is not applicable to noncrystalline silica. Noncrystalline silica (silica gel), as a stable crystalline solid, is expected to have negligible uptake through the gill or gut of aquatic organisms. Thus, noncrystalline silica (silica gel) is not expected to bioaccumulate.

No chronic toxicity data exist on noncrystalline silica or silica gel; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, noncrystalline silica (silica gel) does not meet the screening criteria for toxicity.

The overall conclusion is that noncrystalline silica (silica gel) is not a PBT substance.

References

OECD (2004a). IUCLID Data Set for Synthetic Amorphous Silica and Silicates: Silicon Dioxide (CAS No. 7631-86-9, 112945-52-5, 112926-00-8; Silicic Acid, Aluminum

Sodium Salt (CAS No. 1344-00-9); Silicic Acid, Calcium Salt (CAS No. 1344-95-2), UNEP Publications.

OECD (2004b). Screening Information Dataset (SIDS) Initial Assessment Report for Synthetic Amorphous Silica and Silicates: Silicon Dioxide (CAS No. 7631-86-9, 112945-52-5, 112926-00-8; Silicic Acid, Aluminum Sodium Salt (CAS No. 1344-00-9); Silicic Acid, Calcium Salt (CAS No. 1344-95-2), UNEP Publications.

Environmental Assessment

Sodium carbonate
(CAS No. 497-19-8)

Sodium carbonate has been reviewed in the OECD-SIDS program (OECD, 2002a,b).

Sodium carbonate is a strong alkaline compound with a pH of 11.6 for a 0.1M aqueous solution (The Merck Index, 1983; Johnson and Swanson, 1987). The pKa of CO_3^{2-} is 10.33, which means that at a pH of 10.33 both carbonate and bicarbonate are present in equal amounts.

Environmental Fate

The high water solubility and low vapor pressure indicate that sodium carbonate will be found predominantly in the aquatic environment. In water, sodium carbonate dissociates into sodium (Na^+) and carbonate (CO_3^{2-}) and both ions will not adsorb on particulate matter or surfaces and will not accumulate in living tissues. Addition of potassium carbonate to water will result in an increase in alkalinity and a tendency to raise the pH value. The carbonate ions will react with water, resulting in the formation of bicarbonate (HCO_3^-) and hydroxide (OH^-), until an equilibrium is established.

Background concentration of carbonate
If carbonate (CO_3^{2-}) is dissolved in water a re-equilibration takes place according to the following equations:

$HCO_3^- \rightleftharpoons CO_3^{2-} + H^+$ pKa=10.33
$CO_2 + H_2O \rightleftharpoons HCO_3^- + H^+$ pKa = 6.35

Only a small fraction of the dissolved CO_2 is present as H_2CO_3, the major part is present as CO_2. The amount of CO_2 in water is in equilibrium with the partial pressure of CO_2 in the atmosphere. The CO_2/ HCO_3^-/ CO_3^{2-} equilibria are the major buffer of the pH of freshwater and seawater throughout the world.

Based on the above equations, CO_2 is the predominant species at a pH smaller than 6.35, while HCO_3^- is the predominant species at a pH in the range of 6.35-10.33 and CO_3^{2-} is the predominant species at a pH higher than 10.33.

The natural concentration of CO_2/ HCO_3^-/ CO_3^{2-} in freshwater is influenced by geochemical and biological processes. Many minerals are deposited as salts of the carbonate ion and for this reason the dissolution of these minerals is a continuous source of carbonate in freshwater. Carbon dioxide is produced in aquatic ecosystems from microbial decay of organic matter. On the other hand plants utilize dissolved carbon dioxide for the synthesis of biomass (photosynthesis). Because many factors influence the

natural concentration of CO_2/ HCO_3^-/ CO_3^{2-} in freshwater, significant variations of the concentrations do occur.

If the pH is between 7 and 9 then the bicarbonate ion is the most important species responsible for the buffer capacity of aquatic ecosystems. UNEP (1995) reported the bicarbonate concentration for a total number of 77 rivers in North-America, South-America, Asia, Africa, Europe and Oceania. The 10th – percentile, mean and 90th-percentile were 20, 106 and 195 mg/L, respectively.

Aquatic Toxicity

The acute 96-hour LC_{50} to three sizes of Bluegill sunfish (*Lepomis macrochirus*) exposed to sodium carbonate is 300 mg/L for all sizes. The acute 96-hour LC_{50} to mosquitofish (*Gambusia affinis*) is 740 mg/L. The acute 48-hour EC_{50} value to the invertebrate *Ceriodaphnia* cf. *dubia* is from 200 to 227 mg/L.

Toxicity to Terrestrial Organisms

Toxicity tests which determined the effect of sodium carbonate on terrestrial organisms are not available. The results of the tests will depend strongly on the buffer capacity of the soil and can probably be predicted based on the buffer capacity of the soil. Furthermore, carbonates are natural components of soil minerals.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for two trophic levels. Acute $E(L)C_{50}$ values are available for fish (300 mg/L) and *Ceriodaphnia* (200 mg/L). On the basis that the data consists of short-term results from two trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 200 mg/L for Daphnia. The $PNEC_{aquatic}$ is 0.2 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Sodium carbonate dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc parameters do not readily apply to inorganics, such as sodium carbonate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of sodium carbonate to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The environmental distribution of sodium carbonate is dominated by its water solubility. Sorption of sodium carbonate should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Koc and Kow parameters do not

readily apply to inorganics, such as sodium carbonate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, sodium carbonate is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

References

OECD (2002a). IUCLID Data Set for Sodium carbonate (CAS No. 497-19-8), UNEP Publications (http://www.chem.unep.ch/irptc/sids/OECDSIDS/Naco.pdf)

OECD (2002b)b Screening Information Dataset (SIDS) Initial Assessment Report for Sodium carbonate (CAS No. 497-19-8), UNEP Publications (http://www.chem.unep.ch/irptc/sids/OECDSIDS/Naco.pdf)

UNEP (1995). Water quality of world river basins, UNEP Environment Library No.14.

Environmental Assessment

Sodium hydroxide
(CAS No. 1310-73-2)

Sodium hydroxide (NaOH) has been reviewed in the OECD-SIDS program (OECD, 2002a,b).

Environmental Fate

The high water solubility and low vapor pressure indicate that sodium hydroxide (NaOH) will be found predominantly in the aquatic environment. NaOH is present in the environment as sodium (Na^+) and hydroxyl (OH^-) ions, which implies that it will not adsorb on particulate matter or surfaces and will not accumulate in living tissues.

Measured concentrations in aquatic ecosystems
The concentration of hydroxyl ions in the environment has been determined very extensively via pH measurements. The pH is a very important parameter of aquatic ecosystems and it is a standard parameter of water quality monitoring programs. The most important freshwater aquatic ecosystems of the world revealed average annual pH values between 6.5 and 8.3 but lower and higher values have been measured in other aquatic ecosystems (UNEP, 1995). In aquatic ecosystems with dissolved organic acids a pH of less than 4.0 has been measured, while in waters with a high chlorophyll content the bicarbonate assimilation can result in pH values of higher than 9.0 at midday (UNEP, 1995). The pH of an aquatic ecosystem is mainly determined by geochemical, hydrological and/or biological processes.

Also sodium has been measured extensively in aquatic ecosystems. For example UNEP (1995) reported the concentration for a total number of 75 rivers in North-America, South-America, Asia, Africa, Europe and Oceania. The 10th –percentile, mean and 90th-percentile were 1.5, 28 and 68 mg/l, respectively.

NaOH addition and buffer capacity
An addition of NaOH to an aquatic ecosystem may increase the pH depending on the buffer capacity of the receiving water. In general the buffer capacity is regulated by the equilibria between CO_2, HCO_3^- and CO_3^{2-}:

$CO_2 + H_2O \leftrightarrow HCO_3^- + H^+$ ($pKa_1 = 6.35$)
$HCO_3^- \leftrightarrow CO_3^{2-} + H^+$ ($pKa_2 = 10.33$)

If the pH is between 7 and 9 then the bicarbonate ion is the most important species responsible for the buffer capacity of aquatic ecosystems. UNEP (1995) reported the bicarbonate concentration for a total number of 77 rivers in North-America, South-America, Asia, Africa, Europe and Oceania. The 10th– percentile, mean and 90th-percentile were 20, 106 and 195 mg/l, respectively.

Aquatic Toxicity

At concentrations reported in publications and study reports, the toxicity has been assumed to be due to hydroxide only, because at these effect concentrations the concentration of sodium is too low to explain the effects. However, it should be realized that the results of toxicity tests with NaOH depend on the buffer capacity of the test medium. In a highly buffered test medium the hydroxyl ion will be neutralized and the observed toxicity will be low, while in a poorly buffered test medium the pH will increase rapidly and therefore the observed toxicity will be relatively high. Besides the direct effects (pH change) NaOH could also have indirect effects. The pH change could influence the speciation of other chemicals and therefore increase and/or decrease the toxicity *e.g.*, NH_3 is more toxic than NH_4^+.

The 24-hour LC_{50} to *Carassius auratus* (goldfish) is 160 mg/L . At 100 mg/L, which was equivalent to a pH of 9.8, no mortality was observed. The 48-hour LC_{50} to *Leuciscus idus melanotus*, is 189 mg/L. The 96-hour LC_{50} of *Gambusia affinis* (mosquitofish) is 125 mg/L. At 84 mg/L, no effects on the fish were observed. The pH was 9 at 100 mg/L. The 48-hour LC_{50} is 40 mg/L for *Ceriodaphnia* cf. *dubia*. The toxicity threshold concentration of NaOH for *Daphnia magna* was reported to range from 40 to 240 mg/L.

No data are available on the effects of NaOH on algae.

Toxicity to Terrestrial Organisms

Toxicity tests, which determined the effects of NaOH on terrestrial organisms, are not available. Significant exposure of the terrestrial environment is not expected and for this reason there is no need to perform toxicity test with terrestrial organisms. The results of terrestrial toxicity tests will depend strongly on the buffer capacity of the soil and can probably be predicted based on the buffer capacity of the soil.

Determination of PNECs

In many cases pH, buffer capacity and/or medium composition were not discussed in the publications, although this is essential information for toxicity tests with NaOH. This is the most important reason why most of the studies, mentioned above were considered invalid. Although valid acute ecotoxicity tests and chronic ecotoxicity tests with NaOH are not available there is no need for additional testing with NaOH. A significant number of acute toxicity tests are available and the results of the tests are more or less consistent. Altogether they give a sufficient indication about acute toxicity levels of sodium hydroxide.

Furthermore acute toxicity data cannot be used to derive a PNEC or a PNEC added for sodium hydroxide. Aquatic ecosystems are characterized by an alkalinity/pH and the organisms of the ecosystem are adapted to these specific natural conditions. Based on the natural alkalinity of waters, organisms will have different optimum pH conditions, ranging from poorly buffered waters with a pH of 6 or less to very hard waters with pH values up to 9. A lot of information is available about the relationship between pH and ecosystem structure and also natural variations in pH of aquatic ecosystems have been quantified and reported extensively in ecological publications and handbooks.

Normally a PNEC or a PNEC added has to be derived from the available ecotoxicity data. A PNEC added is a PNEC which is based on added concentrations of a chemical (added risk approach). Based on the available data it is not considered useful to derive a PNEC or a PNEC added for NaOH because:

- The natural pH of aquatic ecosystems can vary significantly between aquatic ecosystems,

- Also the sensitivity of the aquatic ecosystems to a change of the pH can vary significantly between aquatic ecosystems and

- The change in pH due to an anthropogenic NaOH addition is influenced significantly by the buffer capacity of the receiving water.

Although a PNEC or a PNEC added was not calculated for NaOH there is a need to assess the environmental effect of an NaOH (alkaline) discharge. Based on the pH and buffer capacity of effluent and receiving water and the dilution factor of the effluent, the pH of the receiving water after the discharge can be calculated. Of course the pH change can be measured also very easily via a laboratory experiment or by conducting field measurements. The change in pH should be compared with the natural variation in pH of the receiving water and based on this comparison it should be assessed if the pH change is acceptable.

$PNEC_{aquatic}$: Based on the information above, a PNEC was not derived for sodium hydroxide.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Sodium hydroxide dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc parameters do not readily apply to inorganics, such as sodium hydroxide. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of sodium hydroxide to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The environmental distribution of sodium hydroxide is dominated by its water solubility.

Sorption of sodium hydroxide should probably be regarded as a reversible situation, i.e., the substance is not tightly nor permanently bound. Koc and Kow parameters do not readily apply to inorganics, such as sodium hydroxide Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, sodium hydroxide is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Sodium hydroxide is an organic salt that dissociates completely to sodium and hydroxide ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both sodium and hydroxide ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria is not considered applicable to this inorganic salt.

Sodium and hydroxide ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, sodium hydroxide is not expected to bioaccumulate.

No chronic toxicity data exist on sodium hydroxide; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, sodium hydroxide does not meet the screening criteria for toxicity.

The overall conclusion is that sodium hydroxide is not a PBT substance.

References

OECD (2002a). IUCLID Data Set for Sodium hydroxide (CAS No. 1310-73-2), UNEP Publications.

OECD (2002b). Screening Information Dataset (SIDS) Initial Assessment Report for Sodium hydroxide (CAS No. 1310-73-2), UNEP Publications.

Environmental Assessment

Triethanolamine
(CAS No. 102-71-6)

Environmental Fate

Triethanolamine was completely degraded after incubation in municipal activated sludge for 1 or 5 days (West and Gonsior, 1996). The rate constants in all test batches for degradation and mineralization were reported to be >0.359. Thus, triethanolamine can be considered to be readily biodegradable.

In an OECD 301E test, there was 96% degradation after 19 days, indicating ready biodegradation (ECHA).

Bioaccumulation

Triethanolamine has been tested in a bioconcentration: flow-through fish (OECD 305) test using *Cyprinus carpio*. The BCF was determined to be <0.4 and <3.9 at triethanolamine concentrations of 2.5 and 0.25 mg/L, respectively (ECHA).

Aquatic Toxicity

The 96-hour LC_{50} to fathead minnow (*Pimephales promelas*) is 11,800 mg/L (ECHA). The 48-hour EC_{50} to *Ceriodaphnia dubia* is 610 mg/L (Warne and Schifko, 1999).

In a 21-day *Daphnia* reproduction test, the NOEC for reproduction rate was 125 mg/L, and the NOEC for reproduction on the appearance of first offspring was 250 mg/L (Kuehn *et al.*, 1989).

The 72-hour EC_{50} to algae *Desmodesmus subspicatus* is 512 mg/L [neutralized media] and 216 mg/L [un-neutralized media] (ECHA).

Toxicity to Terrestrial Organisms

No data were available.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (11,800 mg/L), *Daphnia* (610 mg/L), and algae (512 mg/L). A long-term (chronic) study is available for invertebrates (21-day NOEC = 125 mg/L).

On the basis that the data consists of a chronic study on one trophic level, an assessment factor of 100 has been applied to the lowest reported NOEC of 125 mg/L for *Daphnia*. The $PNEC_{aquatic}$ is 1.25 mg/L.

PBT Assessment

Triethanolamine is readily biodegradable; thus, it does not meet the screening criteria for persistence.

The BCF values for triethanolamine in fish was <3.9; thus, it does not meet the criteria for bioaccumulation.

The NOEC for triethanolamine in a 21-day *Daphnia* reproduction test is 125 mg/L, which is >0.1 mg/L. Thus, triethanolamine does not meet the screening criteria for toxicity.

The overall conclusion is that triethanolamine is not a PBT substance.

References

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Warne, M.S.J., and Schifko, A.D. (1999). Toxicity of laundry components to a freshwater *Cladoceran* and their contribution to detergent toxicity. Ecotoxicol. Environ. Saf. 44: 196-206.

West, R.J., and Gonsior, S.J. (1996). Biodegradation of triethanolamine. Environ. Toxicol. Chem. 15: 472-480.

Environmental Assessment

Tributyl Tetradecyl Phosphonium Chloride [TTPC]
(CAS No. 81741-28-8)

Limited information was located for this alkyl phosphonium salt.

Hydrolysis
TTPC is stable in water over a wide range of pH values (BuruEnergy).

Photolysis
TTPC is not susceptible to photolysis (BuruEnergy).

Biodegradation
TTPC was not readily biodegradable in an OECD 301 test (BuruEnergy).

In a die-away [simulation] test (using activated sludge) with radiolabelled TTPC for 168 hours at 0.31 mg/L, the first-order rate constant was 0.69/hour and the half-life was 6.6 hours. After 24 and 168 hours, degradation was >81% and >98%, respectively (BuruEnergy).

TTPC was evaluation in simulation tests over a 40-day period using double ^{14}C labeled TTPC. In activated sludge, there was >40% degradation after 30 days with 50 ppb TTPC and >30% degradation after 7 days with 5 ppb TTPC. In river water, there was >20% after 35 days with 5 ppb TTPC. In sea water, there was >30% degradation after 35 days with 5 ppb TTPC (BuruEnergy).

Adsorption/Desorption
The soil adsorption/desorption of TTPC was tested with three soils differing in sand/silt/clay content, by running an aqueous solution of radiolabelled TTPC through a column of soil. Soil adsorption ranged from 93-96% (BuruEnergy).

Bioaccumulation
The octanol-water coefficient (K_{ow}) was determined experimentally to be 2.45 from an OECD 107 test (BuruEnergy).

Aquatic Toxicity

Bellacide 350 MSDS: The 96-hour LC_{50}s in rainbow trout and Bluegill sunfish were reported to be 0.46 mg/L and 0.06 mg/L, respectively. The 48-hour EC_{50} in *Daphnia* was reported to be 0.025 mg/L.

U.S. EPA OPP Pesticide Ecotoxicity Database (wit study details): The 96-hour LC_{50}s in

rainbow trout are 0.49 and 0.2 mg/L. The 96-hour LC_{50}s in Bluegill sunfish and common carp (*Cyprinus carpio*) are 0.06 and 0.09 mg/L, respectively. The 48-hour EC_{50} in *Daphnia* is 0.025 mg/L.

Environmental Properties of Proposed Biocide BE-9 (Document from BuruEnergy)
The 96-hour LC_{50}s in rainbow trout and Bluegill sunfish were reported to be 0.46 mg/L and 0.06 mg/L, respectively. The 48-hour EC_{50} in *Daphnia* was reported to be 0.025 mg/L. The 72-hour EC_{50} in green algae *Selenastrum capricornutum* was reported to be 0.019 mg/L.

Toxicity to Sediment Organisms

No data were found.

Toxicity to Terrestrial Organisms

U.S. EPA OPP Pesticide Ecotoxicity Database: The 8-day dietary LC_{50} in Bobwhite Quail is 4,215 ppm, with a NOEL of 1,980 ppm. The 8-day dietary LC_{50} in Mallard Duck is 3,663 ppm, with a NOEL of 1,780 ppm. The 14-day oral gavage LD_{50} in Mallard Duck is 232 mg/kg, with a NOEL of 178 mg/kg.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (0.2 mg/L), Daphnia (0.025 mg/L), and algae (0.019 mg/L). While the lowest acute value is 0.019 mg/L, it has only been reported in summary document from BuruEnergy and needs to be substantiated. For the purposes of PNEC determination, the acute EC_{50} value for Daphnia will be used. It should be noted that the two values are very similar.

On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the effect concentration of 0.025 mg/L for *Daphnia*. The $PNEC_{aquatic}$ is calculated to be 2.5×10^{-5} mg/L (0.025 μg/L).

PBT Assessment

TTPC is not readily biodegradable. In a simulation test using river water, there was >20% after 35 days. Thus, TTPC appears to meet the screening criteria for persistence.

The octanol-water coefficient (K_{ow}) for TTPC is 2.45. Thus, TTPC does not meet the screening criteria for bioaccumulation.

No chronic toxicity data are available for TTPC. The lowest acute $EC(L)_{50}$ of TTPC is 0.025 mg/L in invertebrates. Since this value is <0.1 mg/L, TTPC does meet the screening criteria for toxicity.

References

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Material Safety Data Sheet for Bellacide 350, BWA Water Additives, SDS No. 10794, Report Date: 10/03/2009.

U.S. EPA OPP Pesticide Ecotoxicity Database: National Information System of the Regional Integrated Pest Management (IPM) Centers, U.S. Department of Agriculture and National Institutes of Food and Agriculture (www.ipmcenters.org).

Environmental Assessment

Ulexite
(CAS No. 1319-33-1)

Ulexite is a structurally complex mineral with the chemical structure ($NaCaB_5O_6(OH)_6 \bullet 5H_2O$). It is slightly soluble in water. One of the uses of ground alexite is in agricultural applications as a source of slow-release boron. No environmental fate or aquatic toxicity exist for ulexite. However, for the purposes of this assessment, data on borax and boric acid will be used to read across to ulexite. The rationale is as follows:

Borax is also known as sodium borate, sodium tetraborate, or disodium tetraborate. With water content, borax can refer to a group of compounds that differ in their crystal water content, but typically it is disodium tetraborate decahydrate with the chemical structure ($Na_2B_4O_7 \bullet 10H_2O$). Borax is moderately soluble in water, with the main species in freshwater being the borate ion $[B(OH)_4]^-$ and boric acid $B(OH)_3$, depending on the pH. The relative proportion of boric acid and borate ions is controlled by pH: $B(OH)_3 + 2H_2O \Leftrightarrow [B(OH)_4]^- + H_3O^-$. In dilute aqueous solutions, boric acid does not dissociate at pH <7; at pH values between 7 and 11, both boric acid and borate ions are present. In dilute aqueous solutions and physiological conditions, the predominant species present is un-dissociated boric acid. So, the consideration of boric acid addresses the relevant environmental stability properties for borates.

Exposure to borates are often expressed in terms of boron (B) equivalents based on the fraction of boron in the source substance on a molecular weight basis. The B equivalents used are a generic designation rather than a designation of the element boron. The factors for converting disodium tetraborate decahydrate, boric acid, and ulexite to B-equivalents are 0.113, 0.175, and 0.133, respectively.

In natural waters, boron forms stable species and exists primarily as un-dissociated boric acid [$B(OH)_3$] and complex polyanions (*e.g.,* $B(OH)_{4-}$). These forms of boron are highly soluble and not easily removed from solution by natural mechanisms. Borate and boric acid are in equilibrium depending on the pH of the water. At an acidic pH, boron exists in solution mainly as un-dissociated boric acid, whereas at alkaline pH it is present as borate ions.

<u>Environmental Fate</u>

At noted above, disodium tetraborate decahydrate will yield boric acid upon dissolution in water (or borate anion in higher pH conditions). Boric acid is a persistent molecule, not subject to hydrolysis, photodegradation or biodegradation.

Many mineral contain boron, which is present as the sodium or calcium borate salt. Thus, boron is ubiquitous and widely distributed in the environment. It is present in

rocks, soil and water and is released into the environment primarily from the weathering of rock and soil, volatilization of sea water, and anthropogenic activity.

Bioaccumulation

The WHO (1998) review of boron noted that "highly water soluble materials are unlikely to bioaccumulate to any significant degree and that borate species are all present essentially as un-dissociated and highly soluble boric acid at neutral pH". A BCF of <0.1 was reported in Chinook salmon fed boron-supplemented diets for 60 to 90 days (Hamilton and Wiedmeyer, 1990).

Some bioconcentration is expected in terrestrial plants since boron is a critical element to terrestrial plants and is incorporated into the cell wall structure. However, the phytotoxicity of boron limits the potential for excessive accumulation beyond "normal" plant tissue concentrations (Austria, 2008). Terrestrial non-predatory organisms, such as Mallard ducks, did not accumulate boron (BCF <0.1) when fed a plant diet of 1,600 mg-B/kg for up to 48 days (Pendleton *et al.*, 1995).

Toxicity

There are many ecotoxicity laboratory and field tests that have been conducted on boron (which includes boric acid and borates). Overall, the studies show that boron does not fulfill the criteria of Toxicity in a PBT assessment with regards to aquatic organisms. The data were reviewed in the "Scientific Criteria Document for the Development of the Canadian Water Quality Guidelines for Boron" (CCME, 2009), which is summarized below:

"Primary acute toxicity data for vertebrates were available for early life stages of four fish species. Endpoints ranged from a 3 day NOEC (teratogenesis at hatching) of 0.109 mg/L for embryo- hatching stage largemouth bass (Black *et al.* 1993) to a 7 day EC_{50} (embryo test) of 969 mg/L for rainbow trout (MELP, 1996). Secondary and unclassified toxicity data were similar to the reported primary data with effect concentrations ranging between 4.6 and 3,145 mg/L."

"Primary acute toxicity data for invertebrates were available for four species. The 48 hour LC_{50} concentrations ranged from 21.3 mg/L for neonate water fleas (MELP, 1996) to 1,376 mg/L for larval midge (Maier and Knight, 1991). Secondary, unclassified and unacceptable toxicity data were similar to the reported primary data with effect concentrations ranging between 1 and 2,797 mg/L."

"Primary chronic toxicity data for vertebrates were available for three fish species." If the outliers are excluded, "effect concentrations ranged from a 36 day LOEC (mortality) of 1.34 mg/L for embryo-larval rainbow trout to a 32 day LC_{50} of 138 mg/L for rainbow

trout (Black *et al.*, 1993). Lower effect concentrations (0.01 mg/L) for embryo-larval rainbow trout were observed in the unclassified toxicity studies (Birge and Black, 1977)."

"Primary chronic toxicity data for invertebrates were available for two species. Effect concentrations ranged between a 21 day LOEC (mean brood size) of 13 mg/L to a 21 day LC_{50} of 53.2 mg/L for the water flea (Lewis and Valentine, 1981). Effect concentrations for additional unclassified studies differed from those reported by the primary studies, with a range of <0.38 to ~266 mg/L."

"Primary chronic toxicity data were available for 4 to 7 day old green algae (*Selenastrum capricornutum*) (MELP, 1997). The lowest reported effect concentration for algae exposed to boron was a 72 hour LOEC of 12.3 mg/L. Effect concentrations of secondary and unclassified toxicity data ranged from 1 to ~171 mg/L."

Determination of PNECs

$PNEC_{aquatic}$: There are many ecotoxicity laboratory and field tests that have been conducted on boron (which includes boric acid and borates). Both acute and chronic toxicity studies are available for three trophic levels. A Canadian Water Quality Guidelines for the Protection of Aquatic Life of 1.5 mg/L was derived for long–term exposure to boron (CCME, 2009). Thus, the $PNEC_{aquatic}$ for disodium octaborate tetrahydrate is 1.5 mg-B/L.

It should be noted, however, that Australia and New Zealand adopted a freshwater high reliability trigger value for boron of 0.37 mg-B/L (ANZECC, 2000).

The factor for converting ulexite to B-equivalents is 0.133.

PBT Assessment

Ulexite is a persistent molecule, not subject to hydrolysis, photodegradation or biodegradation. Thus, it meets the criteria for persistence.

Ulexite is slightly water-soluble substance that is not expected to bioaccumulate. Limited data indicate that bioaccumulation (BCF values are low) is not significant in aquatic and terrestrial food chains. Thus, it does not meet the criteria for bioaccumulation.

Overall, the aquatic toxicity studies show that boron does not fulfill the criteria of toxicity. However, there are human health concerns and boric acid (and borates) are considered reproductive toxicants; they have, for instance, been classified in the EU as known or presumed human reproductive toxicants (Category 1B). Thus, ulexite meets the PBT criteria of toxicity.

The overall conclusion is that ulexite is not a PBT substance.

References

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Santos

APPENDIX G.9 FLUOROSCEIN DYE

Environmental Assessment

Potassium chloride
(CAS No. 7447-40-7)

Potassium chloride (KCl) has been reviewed in the OECD-SIDS program (OECD, 2001a,b).

Environmental Fate

KCl is a solid inorganic salt that is highly soluble in water (342 g/L at 20^{o} C). Potassium chloride fully dissociates in aqueous solutions to K^+ and Cl^- ions.

KCl, either as an inorganic salt or as K^+ and Cl^- ions, is ubiquitous in the environment. There is no potential for bioaccumulation or bioconcentration. Potassium and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated.

Aquatic Toxicity

In a guideline study, the 96-hour LC_{50} in *Pimephales promelas* was reported to be 880 mg/L (Mount *et al.*, 1997). The 48-hour LC_{50} values from two studies on *Lepomis macrochirus* (Patrick *et al.*, 1968; Trama, 1954), and one study each on *Oncorhyncus mykiss* and *Ictalurus punctatus* (Waller *et al.*, 1993) ranged from 720 to 2,010 mg/L.

In a guideline study, the 48-hour EC_{50}s in *Daphnia magna* and *Ceriodaphnia dubia* were 660 and 630 mg/L, respectively (Mount *et al.*, 1997; ECHA REACH database). The 48-hour EC_{50} in *Daphnia magna* in another study was also reported to be 177 mg/L (Biesinger and Christensen, 1972).

The toxicity of KCl has been investigated in one algae species (*Nitzschia linearis*), showing 120 hour-EC_{50} (growth rate) of 1,337 mg/L (Patrick *et al.*, 1968). The 72-hour EC_{50} to *Scenedesmus subspicatus* is >100 mg/L (growth rate), with a NOEC of $\geq$100 mg/L (ECHA REACH database).

In a fish early-life-stage test with the fathead minnow (*Pimephales promelas*), the 7-day NOEC is 500 mg/L (ECHA REACH database). A long term (21-day) study has been performed on *Daphnia magna* where effects on reproduction were investigated for several metals. A 16% impairment of reproduction (LOEC) was observed at a concentration of 53 mg/L of K +, equal to KCl concentration of 101 mg/L (Biesinger and Christensen, 1972).

Toxicity to Terrestrial Organisms

Potassium is one of the three major nutrients and chloride is an essential micronutrient for plants. No data could be located on the toxicity to terrestrial organisms.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (720 mg/L), Daphnia (177 mg/L), and algae (>100 mg/L). Although chronic studies has been conducted on fish and invertebrates, these tests are not valid for deriving PNECs (ECHA REACH database). On the basis of the short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 100 mg/L for algae. The $PNEC_{aquatic}$ is determined to be 0.1 mg/L.

$PNEC_{sediment}$: No reliable experimental toxicity data on sediment organisms are available. Potassium chloride dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc parameters do not readily apply to inorganics, such as potassium chloride. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of potassium chloride to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No reliable experimental toxicity data on terrestrial organisms are available. The environmental distribution of potassium chloride is dominated by its water solubility. Sorption of potassium chloride should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Koc and Kow parameters do not readily apply to inorganics, such as potassium chloride. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, potassium chloride is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Potassium chloride is an organic salt that dissociates completely to potassium and chloride ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both potassium and chloride ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria is not considered applicable to this inorganic salt.

Potassium and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, potassium chloride is not expected to bioaccumulate.

No chronic toxicity data exist on potassium chloride; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, potassium chloride does not meet the screening criteria for toxicity.

The overall conclusion is that potassium chloride is not a PBT substance.

References

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Environmental Assessment

Sodium Fluorescein
[D&C Yellow No. 8; Acid Yellow 73]
(CAS No. 518-47-8)

Biodegradation

In a modified OECD 302B test using an activated sludge inoculum, sodium fluorescein showed <25% elimination in 42 days with no indication of biodegradation (Pagga and Brown 1986).

Bioaccumulation

The estimated BCF for sodium fluorescein based on an estimated log K_{ow} of 3.35 is 75 (EPA 2012).

Aquatic Toxicity

The 48-hour LC_{50} in Oryzias latipes (medaka fish) was reported to be 3,000 mg/L (Tonogai *et al.* 1979). The 48-hour LC_{50} to *Daphnia pulex* neonates (<24 hours old) is 337 mg/L (Walthall and Stark 1999).

Toxicity to Terrestrial Organisms

No data were located.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for two trophic levels. Acute LC_{50} values are available for fish (3,000 mg/L) and the invertebrate *Daphnia* (337 mg/L). On the basis that the data consists of short-term results from two trophic levels, an assessment factor of 1,000 has been applied to the reported lowest effect concentration of 337 mg/L for *Daphnia*. The $PNEC_{aquatic}$ is 0.34 mg/L.

PBT Assessment

Sodium fluorescein is not biodegradable and thus it meets the screening criteria for persistence.

The estimated BCF for sodium fluorescein based on an estimated log K_{ow} of 3.35 is 75 (EPA 2012). Thus, sodium fluorescein would not be expected to meet the screening criteria for bioaccumulation.

No chronic aquatic toxicity studies are available for sodium fluorescein. The acute toxicity studies in fish and invertebrates are >0.1 mg/L. Thus, sodium fluorescein does not meet the criteria for toxicity.

The overall conclusion is that sodium fluorescein is not a PBT substance.

References

Pegga, U., and Brown, D. (1986). The degradation of dyestuffs: Part II. Behavior of dyestuffs in aerobic biodegradation tests. Chemosphere 15: 479-491.

Tonogai, Y., Ito, Y., Iwaida, M., Tati, M., Ose, Y., and Sato, T. (1979). Studies on the toxicity of coal-tar dyes. I. Photodecomposed products of four xanthene dyes and their acute toxicity to fish. J. Toxicol. Sci. 4: 115-126.

EPA (2012). EPISuite v. 4.11, United States Environmental Protection Agency, Office of Pollution Prevention and Toxics and Syracuse Research Corporation.

Walthall, W.K., and Stark, J.D. (1999). The acute and chronic toxicity of two xanthene dyes, fluorescein sodium salt and phloxine B, to *Daphnia pulex*. Environ. Poll. 104: 207-215.

Environmental Assessment

Tributyl Tetradecyl Phosphonium Chloride [TTPC]
(CAS No. 81741-28-8)

Limited information was located for this alkyl phosphonium salt.

Hydrolysis
TTPC is stable in water over a wide range of pH values (BuruEnergy).

Photolysis
TTPC is not susceptible to photolysis (BuruEnergy).

Biodegradation
TTPC was not readily biodegradable in an OECD 301 test (BuruEnergy).

In a die-away [simulation] test (using activated sludge) with radiolabelled TTPC for 168 hours at 0.31 mg/L, the first-order rate constant was 0.69/hour and the half-life was 6.6 hours. After 24 and 168 hours, degradation was >81% and >98%, respectively (BuruEnergy).

TTPC was evaluation in simulation tests over a 40-day period using double ^{14}C labeled TTPC. In activated sludge, there was >40% degradation after 30 days with 50 ppb TTPC and >30% degradation after 7 days with 5 ppb TTPC. In river water, there was >20% after 35 days with 5 ppb TTPC. In sea water, there was >30% degradation after 35 days with 5 ppb TTPC (BuruEnergy).

Adsorption/Desorption
The soil adsorption/desorption of TTPC was tested with three soils differing in sand/silt/clay content, by running an aqueous solution of radiolabelled TTPC through a column of soil. Soil adsorption ranged from 93-96% (BuruEnergy).

Bioaccumulation
The octanol-water coefficient (K_{ow}) was determined experimentally to be 2.45 from an OECD 107 test (BuruEnergy).

Aquatic Toxicity

Bellacide 350 MSDS: The 96-hour LC_{50}s in rainbow trout and Bluegill sunfish were reported to be 0.46 mg/L and 0.06 mg/L, respectively. The 48-hour EC_{50} in *Daphnia* was reported to be 0.025 mg/L.

U.S. EPA OPP Pesticide Ecotoxicity Database (wit study details): The 96-hour LC_{50}s in

rainbow trout are 0.49 and 0.2 mg/L. The 96-hour LC_{50}s in Bluegill sunfish and common carp (*Cyprinus carpio*) are 0.06 and 0.09 mg/L, respectively. The 48-hour EC_{50} in *Daphnia* is 0.025 mg/L.

Environmental Properties of Proposed Biocide BE-9 (Document from BuruEnergy)
The 96-hour LC_{50}s in rainbow trout and Bluegill sunfish were reported to be 0.46 mg/L and 0.06 mg/L, respectively. The 48-hour EC_{50} in *Daphnia* was reported to be 0.025 mg/L. The 72-hour EC_{50} in green algae *Selenastrum capricornutum* was reported to be 0.019 mg/L.

Toxicity to Sediment Organisms

No data were found.

Toxicity to Terrestrial Organisms

U.S. EPA OPP Pesticide Ecotoxicity Database: The 8-day dietary LC_{50} in Bobwhite Quail is 4,215 ppm, with a NOEL of 1,980 ppm. The 8-day dietary LC_{50} in Mallard Duck is 3,663 ppm, with a NOEL of 1,780 ppm. The 14-day oral gavage LD_{50} in Mallard Duck is 232 mg/kg, with a NOEL of 178 mg/kg.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (0.2 mg/L), Daphnia (0.025 mg/L), and algae (0.019 mg/L). While the lowest acute value is 0.019 mg/L, it has only been reported in summary document from BuruEnergy and needs to be substantiated. For the purposes of PNEC determination, the acute EC_{50} value for Daphnia will be used. It should be noted that the two values are very similar.

On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the effect concentration of 0.025 mg/L for *Daphnia*. The $PNEC_{aquatic}$ is calculated to be 2.5×10^{-5} mg/L (0.025 μg/L).

PBT Assessment

TTPC is not readily biodegradable. In a simulation test using river water, there was >20% after 35 days. Thus, TTPC appears to meet the screening criteria for persistence.

The octanol-water coefficient (K_{ow}) for TTPC is 2.45. Thus, TTPC does not meet the screening criteria for bioaccumulation.

No chronic toxicity data are available for TTPC. The lowest acute $EC(L)_{50}$ of TTPC is 0.025 mg/L in invertebrates. Since this value is <0.1 mg/L, TTPC does meet the screening criteria for toxicity.

References

Environmental Properties of Proposed Biocide BE-9. BuruEnergy. Accessed at: http://www.buruenergy.com/wp-content/uploads/BE-Environmental-Properties-of-Proposed-Biocide-BE-91.pdf

Material Safety Data Sheet for Bellacide 350, BWA Water Additives, SDS No. 10794, Report Date: 10/03/2009.

U.S. EPA OPP Pesticide Ecotoxicity Database: National Information System of the Regional Integrated Pest Management (IPM) Centers, U.S. Department of Agriculture and National Institutes of Food and Agriculture (www.ipmcenters.org).

Santos

APPENDIX G.10 CONDOR ENERGY SYSTEMS

Environmental Assessment

2-Ethoxynaphthalene
(CAS No. 93-18-5)

Biodegradation

There are no biodegradation studies on 2-ethoxynaphthalene. A biodegradation study on 1-methoxynapthalene (method not specified) showed 0% degradation (measured as BOD) and 4% (measured by HPLC) after 28 days (ECHA) [Kl. score = 4]. Thus, 2-ethoxynaphthalene is not expected to be readily biodegradable.

Bioaccumulation

No bioconcentration studies have been conducted on 2-ethoxynaphthalene. 2-Ethoxynaphthalene is unlikely to bioaccumulate based on the experimental log K_{ow} of 3.748 (ECHA) [Kl. score = 1] and a calculated BCF of 136.6 (ECHA).

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies on 2-ethoxynaphthalene.

Table 1: Acute Aquatic Toxicity Studies on 2-Ethoxynaphthalene

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Oryzias latipes	48-hr LC_{50}	11.1	2	ECHA
Daphnia magna	48-hr EC_{50}	3.9	2	ECHA
Daphnia pulex	48-hr EC_{50}	4.04	2	ECHA
Desmodesmus subspicatus	72-hr EC_{50}	4.93	1	ECHA

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (11.1 mg/L), *Daphnia* (3.9 mg/L), and algae (4.93 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 100 has been applied to the lowest reported $E(L)C_{50}$ value of 3.9 mg/L for *Daphnia*. The $PNEC_{water}$ is 0.04 mg/L.

PBT Assessment

2-Ethoxynaphthalene is not readily biodegradable; thus, it does not meet the screening criteria for persistence.

No bioconcentration studies are available for 2-ethyoxynaphthalene. The measured log K_{ow} for cinnamaldehyde is 3.748; thus, 2-ethoxynaphthalene does not meet the screening criteria for bioaccumulation.

There are no chronic toxicity studies on 2-ethoxynaphthalene. The acute E(L)C_{50} values for 2-ethoxynaphthalene in fish, invertebrates, and algae are >1 mg/L. Thus, 2-ethoxynaphthalene does not meet the screening criteria for toxicity.

The overall conclusion is that 2-ethoxynaphthalene is not a PBT substance.

References

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

Environmental Assessment

2-Mercaptoethyl alcohol
(CAS No. 60-24-2)

Biodegradation

In an OECD 310 test, biodegradation was 69% after 60 days (ECHA) [Kl. score = 1]. In an OECD 301A test, biodegradation was <10% after 28 days (ECHA) [Kl. score = 1]. In an OECD 301C test, biodegradation was ≥15% and ≤21% after 28 days (ECHA) [Kl. score = 2]. In an OECD 302 C test, biodegradation was 90% after 28 days (ECHA) [Kl. score = 2].

In an OECD 309 test, the mineralization of 2-ME in surface water was determined in a GLP-compliant study following OECD guideline 309. Mineralization was a significant route of degradation and activity recovered as CO_2 increased to >60% after 14 days of incubation at two different test concentrations. Three major transformation products were detected which exceeded 10% of applied activity at both test concentrations. Transformation product M-1 reached a maximum of 26% after 4 hours (0.17 days) at the low-test concentration and a maximum of 13% after 8 hours (0.33 days) at the high-test concentration, and then decreased to non-detectable amounts after 6 days of incubation (both concentrations). Transformation product M-3 reached a maximum of 36% (low test concentration) and 30% (high test concentration after 2 days and then decreased to 14% after 9 days of incubation (low test concentration) and to <5% after 14 days of incubation (high test concentration). Transformation product M-6C reached a maximum of 41% (low test concentration) and 39% (high test concentration) after 4 hours (0.17 days) and then decreased to non-detectable amounts after 6 days of incubation. It was concluded that 2-mercaptoethanol degrades quickly in water, with a half-life of 0.079 days, and no parent compound was detected in the water layers of both test concentrations after 1 day of incubation. Based on the results of the OECD 309 study, the substance degrades in the aquatic environment to a level of >70% within a 28-day period and therefore, the substance is considered to be rapidly biodegradable (ECHA) [Kl. score = 1].

Bioaccumulation

No bioconcentration studies have been conducted on 2-mercaptoethanol. 2-Mercaptoethanol is not expected to bioaccumulate based on the experimental log K_{ow} of -0.056 at pH 7 (ECHA) [Kl. score = 2].

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies on salts of 2-ME.

Table 1: Acute Aquatic Toxicity Studies on Salts of 2-Mercaptoethyl Alcohol

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Leuciscus idus	96-hr LC_{50}	37	2	ECHA
Daphnia magna	48-hr EC_{50}	0.4	2	ECHA

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Desmodesmus subspicatus	96-hr EC_{50} NOEC	19 1.7	1	ECHA

The 21-day NOEC from a *Daphnia* reproduction test was determined to be >0.063 mg/L (ECHA) [Kl. score = 1].

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (37 mg/L), *Daphnia* (0.4 mg/L), and algae (19 mg/L). Results from chronic toxicity studies are available for invertebrates (>0.063 mg/L) and algae (1.7 mg/L). On the basis that the data consists of short-term results from three trophic levels and long-term results from two trophic levels, an assessment factor of 50 has been applied to the lowest reported NOEC value of 0.063 mg/L for *Daphnia*. The $PNEC_{water}$ is 0.0013 mg/L.

PBT Assessment

2-ME is readily biodegradable in the aquatic environment; thus, it does not meet the screening criteria for persistence.

No bioconcentration studies are available for formic acid. The measured log K_{ow} for 2-ME is -0.056; thus, 2-ME does not meet the screening criteria for bioaccumulation.

The chronic toxicity data on 2-ME show a NOEC of <0.1 mg/L. Thus, 2-ME meets the screening criteria for toxicity.

The overall conclusion is that 2-ME is not a PBT substance.

References

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

Environmental Assessment
Acetic acid

(CAS No. 64-19-7)

Acetic acid readily dissociates in aqueous media to the acetate ($H_3C2O_2^-$) and hydrogen (H^+) ions. The toxicity is driven by acetate, with the hydrogen ion playing a minor role. The pK_a is 4.76 at 20°C.

Biodegradation

Acetic acid was readily biodegradable in a non-acclimated freshwater study. Degradation was 96% after 20 days (Price et al., 1974; ECHA) [Kl. score = 2]. Acetic acid is also readily biodegradable under anaerobic conditions (Kameya et al., 1995) [Kl. score = 2].

Bioaccumulation

There are no bioaccumulation studies on acetic acid. Bioaccumulation of acetic acid is not expected to occur because acetic acid dissociates completely in aqueous solution to acetate and its hydrogen ion. Both ions are ubiquitous in the environment. Acetate is naturally found in eukaryotic and prokaryotic cells and is involved in their biochemical pathways.

Aquatic Toxicity

Table 1 presents the results of acute aquatic toxicity studies on acetic acid and potassium acetate.

Table 1: Acute Aquatic Toxicity Studies on Acetic acid and Potassium Acetate

Test Substance	Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Potassium acetate	*Oncorhynchus mykiss*	96-h LC_{50}	>300.82*	2	ECHA
Potassium acetate	*Danio rerio*	96-h LC_{50}	>300.82*	2	ECHA
Acetic acid	*Oncorhynchus mykiss*	96-h LC_{50}	64.8 (measured)	4	ECHA
Acetic acid	*Oncorhynchus mykiss*	96-h LC_{50}	31.3 – 67.6	4	ECHA
Potassium acetate	*Daphnia magna*	48-h EC_{50}	>300.82*	2	ECHA
Acetic acid	*Daphnia magna*	48-h EC_{50}	79.5	4	ECHA

Test Substance	Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
			(measured)		
Acetic acid	*Daphnia magna*	48-h EC_{50}	18.9 (measured)	4	ECHA
Acetic acid	*Desmodesmus subspicatus*	72-h EC_{50}	486.5	4	ECHA

*As the acetate ion.

In a 21-day fish (*Oncorhynchus mykiss*) chronic study, the measured NOEC values for 60% and 100% acetic acid were 57.2 and 34.3 mg/L, respectively (ECHA). [Kl. score = 4]

In a 21-day *Daphnia* reproduction study, the measured NOEC for 60% and 100% acetic acid were 80 and 31.4 mg/L, respectively (ECHA). [Kl. score = 4]

In a 21-day *Daphnia* reproduction study, the measured NOEC for 100% acetic acid was 22.7 mg/L (ECHA). [Kl. score = 4]

Terrestrial Toxicity

No data are available.

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for three trophic levels. For the acute toxicity studies, data are available on both acetic acid and potassium acetate; both substances dissociate completely in aqueous media to the acetate anion and the corresponding cations (H^+ and K^+). The toxicity of these substances is expected to be driven by the acetate ion, with the cations having a minor role. The toxicity data on potassium acetate are preferred because of the absence of a potential pH change from the dissociated H^+ ion of acetic acid. For the chronic toxicity studies, only acetic acid has been tested for two trophic levels: fish and invertebrates. These studies will not be used to derive the PNEC value; however, an assessment factor of 100 will be applied to the lowest acute $E(L)C_{50}$ values.

From the potassium acetate studies, acute $E(L)C_{50}$ values (adjusted for acetic acid) are available for fish (300.82 mg/L) and *Daphnia* (300.82 mg/L). By applying an assessment factor of 100 to the $E(L)C_{50}$ value of 300.82 mg/L from either fish or *Daphnia*, the $PNEC_{aquatic}$ for acetic acid is 3.0 mg/L.

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 1.9 mg/kg sediment wet weight.

The calculations are as follows:

$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$
$= (0.82/1280) \times 1000 \times 3.0$
$= 1.9$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$K_{sed\text{-}water} = 0.8 + [(0.2 \times Kp_{sed})/1000 \times BD_{solid}]$
$= 0.8 + [(0.2 \times 0.04/1000 \times 2400]$
$= 0.82$

Where:
Kp_{sed} = solid-water partition coefficient (L/kg).
BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$Kp_{sed} = K_{oc} \times f_{oc}$
$= 1.0 \times 0.04$
$= 0.04$

Where:
K_{oc} = organic carbon normalized distribution coefficient (L/kg). The K_{oc} for acetic acid calculated from EPISUITE™ using the MCI is 1.0 L/kg .
F_{oc} = fraction of organic carbon in sediment = 0.04 [default].

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is 0.04 mg/kg soil dry weight.

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
$= (0.02/1500) \times 1000 \times 3.0$
$= 0.04$

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
$= 1.0 \times 0.02$
$= 0.02$

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for acetic acid calculated from EPISUITE™ using the MCI is 1.0 L/kg .
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

PBT Assessment

Acetic acid is readily biodegradable; thus, it does not meet the screening criteria for persistence.

Bioaccumulation of acetic acid is not expected to occur because acetic acid dissociates completely in aqueous media to acetate and its hydrogen ion. Both ions are ubiquitous in the environment. Acetate is naturally found in eukaryotic and prokaryotic cells and is involved in their biochemical pathways. The log K_{ow} for acetic acid is -0.17. Thus, acetic acid does not meet the screening criteria for bioaccumulation.

The NOECs from the chronic aquatic toxicity studies on acetic acid are >0.1 mg/L. The $E(L)C_{50}$ values for potassium acetate are >1 mg/L. Thus, acetic acid does not meet the criteria for toxicity.

The overall conclusion is that acetic acid is not a PBT substance.

References

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances

Kameya, T., Murayama, T., Urano, K., and Kitano, M. (1995). Biodegradation ranks of priority organic compounds under anaerobic conditions. Sci. Total Environ. 170: 43-51.

Price, K.S., Waggy, G.T., and Conway, R.A. (1974). Brine shrimp bioassay and seawater BOD of petrochemicals. J. Water Pollut Control Fed. 46: 63- 77.

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Environmental Assessment

Acrylamide/sodium acrylate copolymer (anionic polyacrylamide) (CAS No. 25085-02-3)

Polyacrylamide polymers can exist in cationic, anionic, or non-ionic forms, depending on their ionic charge. The non-ionic form of polyacrylamide is generated from the basic polymerization of acrylamide. Anionic polyacrylamide polymer can then be formed from the hydrolysis of the acrylamide homopolymer either simultaneously during the polymerization process or as a subsequent step (Zheng et al., 2013). Anionic polyacrylamide polymer can also be formed from the copolymerization of acrylamide and acrylic acid (Lyons and Vasconellos, 1997; Zheng et al., 2013). The molecular weight of polyacrylamide co-polymers uses as flocculents are 1,000,000 to >50,000,000 (Lyons and Vasconcellos, 1997.

Environmental Fate

No studies on the environmental fate of anionic polyacrylamide are available. As a high-molecular-weight polymer, it is not expected to biodegrade or bioaccumulate (Lyons and Vasconcellos, 1997). The environmental fate of anionic polyacrylamide will be determined primarily by adsorption (Lyons and Vasconcellos, 1997).

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies on the powder form of anionic polyacrylamides, respectively. The data were reported in a table as LC_{50} values with no details on the individual studies.

Table 1: Acute Aquatic Toxicity Studies on Anionic Polyacrylamide* in Powder Form

Test Species	Ionic Charge	LC_{50} (mg/L)	Reference
Fathead minnow	-31	810	Betz Laboratories, Inc. (1995)
Rainbow trout	-31	>100	Betz Laboratories, Inc. (1995)
Bluegill sunfish	-31	>300	Betz Laboratories, Inc. (1995)
Rainbow trout	-22	>100	Betz Laboratories, Inc. (1995)
Bluegill sunfish	-22	>300	Betz Laboratories, Inc. (1995)
Rainbow trout	-12	>100	Betz Laboratories, Inc. (1995)
Bluegill sunfish	-12	>300	Betz Laboratories, Inc. (1995)
Daphnia magna	-39	470	Betz Laboratories, Inc. (1995)

*Acrylic acid-acrylamide copolymers with molecular weights of >1,000,000.

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for two trophic levels. Acute LC_{50} values are available for fish (>100 mg/L) and invertebrates (470 mg/L). On the basis that the data consist of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest LC_{50} value of 100 mg/L for fish. The $PNEC_{water}$ is 0.1 mg/L.

$PNEC_{sediment}$: There are no toxicity data for sediment-dwelling organisms. The K_{ow} and K_{oc} have not been experimentally derived for anionic polyacrylamide; these values cannot be estimated using QSAR models because of the high molecular weight of anionic polyacrylamide. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sed}$.

$PNEC_{soil}$: There are no toxicity data for soil-dwelling organisms. The K_{ow} and K_{oc} have not been experimentally derived for anionic polyacrylamide; these values cannot be estimated using QSAR models because of the high molecular weight of anionic polyacrylamide. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$.

PBT Assessment

Anionic polyacrylamide is a large molecular weight, water-soluble polymer. It is not expected to be readily biodegradable; thus, it meets the screening criteria for persistence.

Pharmacokinetic studies showed that anionic polyacrylamide was not bioavailable to rats when ingested; this is most likely due to its large size (high molecular weight) and presumed resistance to breakdown in the gastrointestinal tract. Anionic polyacrylamide is thus not expected to be bioavailable to aquatic or terrestrial organisms. It is not expected to meet the criteria for bioaccumulation.

No chronic aquatic toxicity data are available on polyacrylamide. The acute LC_{50} values in fish and invertebrates are >1 mg/L. Thus, it does not meet the criteria for toxicity.

The overall conclusion is that anionic polyacrylamide is not a PBT substance.

References

Betz Laboratories, Inc. (1995). Betz Handbook of Industrial Water Conditioning, 9th Ed., Trevose, PA; cited in Lyons and Vasconcellos (1997).

Lyons, L.A., and Vasconcellos, S.R. (1997). Water treatment polymers. In: Ecological Assessment of Polymers. Strategies for Product Stewardship and Regulatory Programs (Hamilton, J.D. and R. Sutcliffe, Eds.), pp. 113-145, Wiley.

Zheng, H., Ma, J., Ji, F., Tang, X., Chen, W., Zhu, J., Liao, Y., and Tan, M. (2013). Synthesis and application of anionic polyacrylamide in water treatment. Asian J. Chem. 25(13): 7071-7074.

Environmental Assessment

Ammonium persulfate
(CAS No. 7727-54-0)

Environmental Fate

Ammonium persulfate dissociates in aqueous media to the ammonium cation (NH_4^+) and persulfate anion ($S_2O_8^{2-}$) (OECD 2005a and 2005b; ECHA). The persulfate anion will readily hydrolyze (decompose) into sulfate ions.

The rates of hydrolysis are expected to be similar for sodium persulfate, potassium persulfate, and ammonium persulfate. The rates of decomposition (hydrolysis) were measured at 50°C at various pHs. The half-lives increased from 20 hours at pH 1 to 210 hours at pH 10 (Koltoff and Miller, 1951).

Biodegradation is not applicable to inorganic compounds. Ammonium persulfate is not expected to bioaccumulate; it will dissociate (and decompose) to ions that are ubiquitous in the environment. Ammonium persulfate is not expected to absorb to soil or sediment because of its dissociation properties, instability (hydrolysis), and high water solubility.

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies on ammonium persulfate.

Table 1: Acute Aquatic Toxicity Studies on Ammonium Persulfate

Test Species	**Endpoint**	**Results (mg/L)**	**Klimisch score**	**Reference**
Oncorhynchus mykiss	96-h LC_{50}	76.3	1	ECHA
Daphnia magna	48-h EC_{50}	120	1	ECHA
Selenastrum capricornutum	72-h EC_{50}	83.7	1	ECHA

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (76.3 mg/L), *Daphnia* (120 mg/L), and algae (83.7 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 100 has been applied to the lowest reported $E(L)C_{50}$ value of 76.3 mg/L for fish. The $PNEC_{water}$ is 0.8 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Ammonium persulfate dissociates completely in water; its environmental distribution is dominated by its high water solubility. K_{ow} and K_{oc} parameters do not readily apply to inorganics, such as ammonium persulfate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on its properties, no adsorption of ammonium persulfate to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The environmental distribution of ammonium persulfate is dominated by its water solubility. Sorption of ammonium persulfate should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. K_{oc} and K_{ow} parameters do not readily apply to inorganics, such as ammonium persulfate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, ammonium persulfate is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Ammonium persulfate is an inorganic compound that dissociates completely to ammonium and persulfate ions in aqueous solutions. Persulfate ions are further hydrolysed to sulphate ions. Biodegradation is not applicable to these compounds. For the purposes of this PBT assessment, the persistent criteria are not considered applicable to ammonium persulfate or its dissociated compounds.

Ammonium persulfate is an inorganic compound that dissociates completely in water to ionic compounds that are ubiquitous in the environment. Thus, ammonium persulfate is not expected to bioaccumulate.

There are no chronic aquatic toxicity data on ammonium persulfate. The acute $E(L)C_{50}$ values for fish, invertebrates, and algae are >1 mg/L. Thus, ammonium persulfate does not meet the criteria for toxicity.

The overall conclusion is that ammonium persulfate is not a PBT substance.

References

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

Koltoff, I., and Miller, I.K. (1951). The chemistry of persulfate. I. The kinetics and mecanism of the decomposition of the persulfate ion in aqueous medium. J. Am. Chem. Soc. 73: 3055-3059.

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OECD (2005b). Screening Information Dataset (SIDS) Initial Assessment Report for Ammonium persulfate (CAS No. 7727-54-0); Potassium persulfate (CAS No. 7727-27-1); Sodium persulfate (CAS No. 7775-27-1), UNEP Publications. Available at: http://webnet.oecd.org/Hpv/UI/SIDS_Details.aspx?id=5D4B16BE-8BA8-4BE4-8787-469DE31A76E9

Environmental Assessment

2-Propenoic acid, homopolymer, ammonium salt
(CAS No. 9003-03-6)

No information could be located on 2-propenoic acid, homopolymer, ammonium salt (ammonium polyacrylate). Therefore, data on sodium polyacrylates will be used to read-across to ammonium polyacrylate.

Sodium polyacrylates are polymers that range in molecular weight (MW) from 1,000 to 78,000 (HERA, 2014). The sodium polyacrylates mostly used in detergents have a typical molecular weight of approximately 4,500 (HERA, 2014).

Biodegradation

Sodium polyacrylates are not readily biodegradable, but are partly accessible to ultimate biodegradation particularly under long incubation conditions. Sodium polyacrylates with MW of <2,000 are partly biodegradable under the conditions of soil and sediment inoculation. Test results with activated sludge inoculum indicate different elimination degrees, apparently due to adsorption and precipitation processes. The removal degrees of different sodium polyacrylates show no clear relationship between elimination extent and molecular weight (HERA, 2014).

Bioaccumulation

No experimental studies are available on sodium polyacrylates. Estimated bioconcentration factors based on octanol-water coefficients are not appropriate since the molecular weights of these polymers are higher than the molecular weight range for the QSAR models. Due to their high molecular weights, sodium polyacrylates are not expected to bioaccumulate. In addition, these water-soluble polymers can form insoluble calcium salts in natural waters, suggesting that bioaccumulation is unlikely.

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies on sodium polyacrylates.

Table 1: Acute Aquatic Toxicity Studies on Sodium Polyacrylates

Mean MW	Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
1,000	*Brachydanio rerio*	96-hr LC_{50}	>200	1	HERA, 2014
1,000	*Salmo gairdneri*	96-hr LC_{50}	>1,000	1	HERA, 2014
1,200	*Leuciscus idus*	96-hr LC_{50}	>500	1	HERA, 2014
2,000	*Brachydanio rerio*	96-hr LC_{50}	>200	1	HERA, 2014
2,500	*Leuciscus idus*	96-hr LC_{50}	>500	1	HERA, 2014
4,500	*Lepomis macrochirus*	96-hr LC_{50}	>1,000	1	HERA, 2014

Mean MW	Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
4,500	*Lepomis macrochirus*	96-hr LC_{50}	>1,000	1	HERA, 2014
8,000	*Leuciscus idus*	96-hr LC_{50}	>500	1	HERA, 2014
10,000	*Lepomis macrochirus*	96-hr LC_{50}	>1,000	1	HERA, 2014
15,000	*Leuciscus idus*	96-hr LC_{50}	>10,000	1	HERA, 2014
78,000	*Brachydanio rerio*	96-hr LC_{50}	>400	2	HERA, 2014
1,000	*Daphnia magna*	48-hr EC_{50}	>200	1	HERA, 2014
1,000	*Daphnia magna*	48-hr EC_{50}	>1,000	1	HERA, 2014
2,000	*Daphnia magna*	48-hr EC_{50}	>200	1	HERA, 2014
4,500	*Daphnia magna*	48-hr EC_{50}	>200	1	HERA, 2014
4,500	*Daphnia magna*	48-hr EC_{50}	>1,000	1	HERA, 2014
78,000	*Daphnia magna*	24-hr EC_{50}	276	2	HERA, 2014
8,000	*Selenastrum capricornutum*	72-hr EC_{50}	40	1	HERA, 2014
78,000	*Scenedesmus subspicatus*	96-hr EC_{50}	44	2	HERA, 2014

Table 2 lists the results of chronic aquatic toxicity studies on sodium polyacrylates.

Table 2: Chronic Aquatic Toxicity Studies on Sodium Polyacrylates (HERA, 2014)

Mean MW	Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
4,500	*Pimephales promelas*	32-d NOEC	56	2	HERA, 2014
4,500	*Brachydanio rerio*	28-d NOEC	>450	1	HERA, 2014
78,000	*Brachydanio rerio*	14-d NOEC	>400	2	HERA, 2014
4,500	*Daphnia magna*	21-d NOEC	450	1	HERA, 2014
4,500	*Daphnia magna*	21-d NOEC	58	1	HERA, 2014
4,500	*Daphnia magna*	21-d NOEC	12	2	HERA, 2014
78,000	*Daphnia magna*	21-d NOEC	100	2	HERA, 2014
4,500	*Scenedesmus subspicatus*	96-hr NOEC	180	2	HERA, 2014
78,000	*Scenedesmus subspicatus*	96-hr NOEC	32.8	2	HERA, 2014

There is considerable variability in the chronic aquatic toxicity results for *Daphnia magna* for sodium polyacrylates with the same molecular weight of 4,500. This was discussed in HERA (2014) and was explained by the solubility of sodium polyacrylates in water. In distilled water, the solubility of sodium polyacrylates with the molecular weight of 4,500 is >400 mg/L; however, under test conditions water solubility will decrease due to the presence of Ca^{++} and Mg^{++} (as measured by water hardness). In a study by BASF (reviewed in HERA, 2014), the water solubility of sodium polyacrylate (MW 4,500) was determined with radiolabelled compounds in a test system with a calcium concentration of 70 mg/L, which corresponds to the mean water hardness to the media used in an OECD TG 202 test. Under these conditions, the water solubility of sodium polyacrylate was 1.3 mg/L after 24 hours. So, one explanation for the variability of the chronic *Daphnia* studies may be due to differences in water hardness.

Toxicity to Sediment Organisms

The 96-hr EC_0 to *Chironomus riparius* (larvae) is >4,500 mg/kg sediment dry weight (HERA, 2014).

Terrestrial Toxicity

The results of terrestrial toxicity studies on sodium polyacrylate polymers are listed below in Table 3.

Table 3: Terrestrial Toxicity Studies on Sodium Polyacrylates (HERA, 2014)

Mean MW	Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
4,500	*Eisenia foetida*	14-d EC_0	1,000	1	HERA, 2014
78,000	*Eisenia foetida andrei*	14-d EC_0	1,000	2	HERA, 2014
78,000	*Brassica rapa*	21-d NOEC	1,000	2	HERA, 2014
4,500	Nitrogen transformation*	28-d EC_{10}	>2,500	1	HERA, 2014
4,500	Carbon transformation*	28-d EC_{10}	>2,500	1	HERA, 2014

*Soil organisms.

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (>200 mg/L), invertebrates (>200 mg/L), and plants (40 mg/L). Results from chronic studies are also available for all three trophic levels, with the lowest NOEC being 12 mg/L for invertebrates. On the basis that the data consists of short-term and long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported NOEC of 12 mg/L for invertebrates. The $PNEC_{water}$ is 1.2 mg/L.

$PNEC_{sediment}$: Experimental results are available for one trophic level. There were no visual signs of toxicity to *Chironomus riparius* (larvae) at the highest concentration tested (>4,500 mg/kg sediment dry weight) (HERA, 2014). The EC_0 is considered to be above 4,500 mg/kg and an assessment factor cannot apply. Thus, the equilibrium partitioning method will be used to determine the $PNEC_{sed}$. The HERA (2014) risk assessment calculated a $PNEC_{sed}$ of 130 mg/kg sediment wet weight using the default of 0.05 as the weight fraction of organic carbon in sediment according to the EU Technical Guidance Document (TGD) (EU, 2003).

$PNEC_{soil}$: Experimental results are available for three trophic levels. An acute LC_{50} value is available for earthworms (1,000 mg/kg soil dry weight). A 21-day NOEC for *Brassica rapa* was reported to be 1,000 mg/kg soil dry weight. Results from two long-term studies are available for soil microorganisms, with the NOECs for nitrogen and carbon transformation being >2,500 mg/kg soil dry weight. On the basis that the data consists of short-term tests, as well as one long-term test from one trophic level, an assessment factor of 100 has been applied to the lowest reported long-term NOEC of >2,500 mg/kg soil dry weight. The $PNEC_{soil}$ is 25 mg/kg soil dry weight.

PBT Assessment

The sodium polyacrylates are not readily biodegradable; thus, they meet the screening criteria for persistence.

The sodium polyacrylates are expected to have high molecular weights and are not expected to be bioavailable. Thus, these polymers do not meet the criteria for bioaccumulation.

Chronic NOECs for fish, daphnia and algae are available for sodium polyacrylates, and the NOEC values are >0.1 mg/L. Thus, sodium polyacrylates do not meet the screening criteria for toxicity.

The overall conclusion is that sodium polyacrylates are not PBT substances.

References

EU. (2003). Technical Guidance Document, European Union

HERA (2014). Human & Environmental Risk Assessment (HERA) on ingredients of European household cleaning products. Polycarboxylates used in detergents (Part I): Polyacrylic acid homopolymers and their sodium salts (CAS 9003-04-7). (http://www.heraproject.com/files/HERA_P-AA_final_v3_23012014.pdf)

Environmental Assessment

Ammonium sulfate
(CAS No. 7783-20-2)

Environmental Fate

Ammonium sulfate dissociates in aqueous media to ammonium (NH_4^+) and sulfate (SO_4^{2-}) ions in water.

Biodegradation is not applicable to inorganic compounds. Ammonium sulfate is not expected to bioaccumulate; it will dissociate to ions that are ubiquitous in the environment. Ammonium sulfate is not expected to absorb to soil or sediment because of its dissociation properties and high water solubility.

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies on salts of ammonium sulfate.

Table 1: Acute Aquatic Toxicity Studies on Ammonium Sulfate

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Oncorhynchus mykiss	96-hr LC_{50}	53	1	ECHA
Ceriodaphnia acanthina	48-hr EC_{50}	121.7	1	ECHA

The 30-d EC_{10} for ammonium sulfate to *Lepomis macrochirus* is 5.29 mg/L (ECHA) [Kl. score = 1].

The 10-wk EC_{10} for ammonium sulfate to *Hyalella azteca* in a reproduction test is 3.12 mg/L (ECHA) [Kl. score = 1].

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for two trophic levels. Acute $E(L)C_{50}$ values are available for fish (53 mg/L) and *Daphnia* (122 mg/L). Results from chronic studies are also available for two trophic levels, with the lowest EC_{10} being 3.12 for invertebrates. On the basis that the data consists of short-term results from two trophic levels and long-term results from two trophic level, an assessment factor of 50 has been applied to the NOEC value of 3.12 mg/L for fish. The $PNEC_{water}$ is 0.06 mg/L.

$PNEC_{sediment}$: No reliable experimental toxicity data on sediment organisms are available. Ammonium sulfate dissociates completely in water; its environmental distribution is dominated by its high water solubility. K_{ow} and K_{oc} parameters do not readily apply to inorganics, such as ammonium sulfate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on its properties, no adsorption of ammonium sulfate to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No reliable experimental toxicity data on terrestrial organisms are available. The environmental distribution of ammonium sulfate is dominated by its water solubility. Sorption of ammonium sulfate should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. K_{ow} and K_{oc} parameters do not readily apply to inorganics, such as ammonium sulfate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, ammonium sulfate is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Ammonium sulfate is an organic salt that dissociates completely to ammonium and sulfate ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both ammonium and sulfate ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria are not considered applicable to ammonium sulfate or its dissociated ions.

Ammonium and sulfate ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, ammonium sulfate is not expected to bioaccumulate.

The NOECs from a chronic toxicity studies on ammonium sulfate are >0.1 mg/L, and the acute $E(L)C_{50}$ values for fish and *Daphnia* are >1 mg/L. Thus, ammonium sulfate does not meet the screening criteria for toxicity.

The overall conclusion is that sodium sulfate is not a PBT substance.

References

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

Environmental Assessment

Alpha-Amylase
[α-Amylase]
(CAS No. 9000-90-2)

Enzymes are catalytic proteins or polypeptides and consist of amino acid residues coupled via peptide bonds. α-Amylases are enzymes that catalyze the endo-hydrolysis of 1,4-α-D-glycosidic linkages in polysaccharide, such as starches, glycogen, and oligosaccharides containing three or more 1,4-α-linked glucose units. (HERA, 2005).

Biodegradation

In an OECD 301 E test, degradation was 95% after 7 days and 99% after 28 days (ECHA) [Kl. score = 1]. Thus, alpha-amylase is readily biodegradable.

Bioaccumulation

No bioconcentration studies have been conducted on alpha-amylase. Alpha-Amylases are not expected to bioaccumulate due to their high molecular weight (40,000 to 50,000 daltons [Yutani, 1973]) and their octanol-water partition coefficient (log K_{ow} is <-1.3, [ECHA]). Moreover, alpha-amylases are rapidly biotransformation in an organism to lower molecular-weight protein fragments by proteolytic enzymes (proteases), and eventually to the basic amino acids by peptidase enzymes.

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies on alpha-amylase.

Table 1: Acute Aquatic Toxicity Studies on alpha-Amylase

Test Species	Endpoint	Results (mg aep*/L)	Klimisch score	Reference
Oncorhynchus mykiss	96-hr LC_{50}	>100	1	ECHA
Daphnia magna	48-hr EC_{50}	212	1	ECHA
Desmodesmus subspicatus	72-hr EC_{50} NOEC	5.2 2.6	1	ECHA

*active enzyme protein.

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (>100 mg aep/L), *Daphnia* (212 mg aep/L), and algae (5.2 mg aep/L).

On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 100 has been applied to the lowest reported $E(L)C_{50}$ value of 5.2 mg/L for algae. The $PNEC_{water}$ is 0.05 mg/L.

PBT Assessment

Alpha-Amylase is readily biodegradable; thus, it does not meet the screening criteria for persistence.

Alpha-Amylase has a high molecular weight (20 to 80 kD), hydrophilic properties (high water solubility, log K_{ow} <-1.3), and is readily biotransformed in organisms by proteases and peptidases. Thus, alpha-amylase does not meet the screening criteria for bioaccumulation.

There are no chronic toxicity studies on alpha-amylase. The acute $E(L)C_{50}$ values for alpha-amylase are >1 mg/L in fish, invertebrates, and algae. Thus, alpha-amylase does not meet the criteria for toxicity.

The overall conclusion is that alpha-amylase is not a PBT substances.

References

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

HERA (2005). Human and Environmental Risk Assessment (HERA) on Ingredients of Household Cleaning Products: α-amylase, CAS No. 9000-90-2; Cellulase (β-(1,4)-glucanase), CAS No. 9012-54-8; Lipase, 9001-62-1, 2005. http://www.heraproject.com.

Yutani, K. (1973). Molecular weight of thermostable α-amylase from *B. stearothermophilus*. J. Biochemistry 74: 581-586.

Environmental Assessment

Alcohols, C9-11, ethoxylated
(CAS No. 68439-46-3)

Alcohol ethoxylates (AE) are a class of non-ionic surfactants that have the basic structure $C_{x-y}AE_n$. The subscript (x-y) following the 'C' indicates the range of carbon chain units. The hydrocarbon chain can be either linear or branched. AEs also contain an ethylene oxide (E) chain attached to the alcohol. The degree of ethylene oxide polymerization is indicated by the subscript (n) which indicates the average number of ethylene oxide units. In household products the average ethylene oxide chain length commonly ranges between 3 and 12 units.

Biodegradation

The alcohols, C9-11, ethoxylated are readily biodegradable. In an ISO 14593 test, degradation of $C_{9-11}AE_{2.5}$ was 72% in 28 days (ECHA) [Kl. score = 2]. In another ISO 14593 test, degradation of $C_{9-11}AE_3$ was essentially 100% (measured as CO_2 evolution) in 28 days (ECHA) [Kl. score = 2].

Bioaccumulation

The BCF-values for alcohol ethoxylates in fathead minnows have been reported to range from <5 to 387.5 (Toll et al., 2000). The uptake rates varied from 330 to 1660 (L x kg/d) and elimination rates varied from 3.3 to 59 per day (Toll et al., 2000). Toll et al. (2000) concluded that the high values of elimination rate constants suggested that the tested fathead minnow efficiently biotransformed alcohol ethoxylates, thereby preventing them from attaining high concentrations in fish.

Aquatic Toxicity

In developing a water quality guideline for alcohol ethoxylates (ANZECC, 2000), the toxicity data was normalized for a specific alkyl chain length or a specific number of ethoxylate (EO) groups. The NOECs listed below were normalized to an alkyl chain length of C13.3 and EO of 8.2.

Freshwater fish: 2 species, 720 to 1,500 μg/L.

Freshwater crustaceans: 2 species, 590 to 860 μg/L.

Freshwater rotifers: 1 species, *Brachionus calyciflorus,* 1,300 μg/L.

Freshwater algae, diatoms and blue-green algae: 6 species, 200 to 8,700 μg/L.

Freshwater mesocosms: Four NOEC data for multiple species tests were 80, 80, 320, and 330 μg/L, although replication was insufficient to meet OECD (1992) requirements. Normalized data were 380, 380, 320, and 1,520 μg/L.

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

$PNEC_{water}$: The ANZECC water quality guideline (2000) for freshwater is: **"A high reliability trigger value of 140 μg/L was derived for AE (normalized data) using the statistical distribution method with 95% protection."**

PBT Assessment

Alcohols C9-11, ethoxylated is readily biodegradable and thus does not meet the screening criteria for persistence.

The bioconcentration factors (BCF) in fish for alcohols, C9-11, ethoxylated has been reported to range from <5 to 387.5. Thus, alcohols, C9-11, ethoxylated does not meet the screening criteria for bioaccumulation.

The NOEC values for alcohols ethoxylates are <1 mg/L. Thus, alcohols, C9-11, ethoxylated meets the screening criteria for toxicity.

The overall conclusion is that alcohols, C9-11, ethoxylated is not a PBT substance.

References

ANZECC & ARMCANZ (2000). Australian and New Zealand guidelines for fresh and marine water quality. National Water Quality Management Strategy Paper No 4, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra, Australia.

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

OECD (1992). Report of the OECD workshop on extrapolation of laboratory aquatic toxicity data to the real environment. OECD Environment Monographs No. 59, Organisation for Economic Co-operation and Development, Paris.

Toll, J., Haller, M., Labee, E., Verweij, M., and Sijm, D.T.H.M. (2000). Toxicology and Chemistry, 19 646–653.

Environmental Assessment

Castor Oil, Ethoxylated
(CAS No. 61791-12-6)

Biodegradation

Castor oil, ethoxylated is readily biodegradable, based on the results of a study involving biodegradation of aliphatic-based surfactants in reactors by activated sludge method. Castor oil, ethoxylated was one of the ingredients of the surfactants. There was 90% degradation, as indicated by TOC removal, after 5 days. The reactor approached ultimate BOD after about 20 days incubation. Based on comparison with the ThOD of the feed, 100% biodegradation was achieved under the BOD test conditions (ECHA) [Kl. score = 2].

Bioaccumulation

No bioconcentration studies have been conducted on castor oil, ethoxylated. Castor oil, ethoxylated is not expected to bioaccumulate based on the experimental log K_{ow} of 1.33 (ECHA) [Kl. score = 1].

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies of castor oil, ethoxylated.

Table 1: Acute Aquatic Toxicity Studies on Castor Oil, Ethoxylated

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Danio rerio	96-hr LC_{50}	>45	1	ECHA
Daphnia magna	48-hr EC_{50}	>100	4	ECHA
Desmodesmus subspicatus	72-hr EC_{50}	>93	1	ECHA

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (45 mg/L), *Daphnia* (100 mg/L), and algae (93 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 100 has been applied to the lowest reported $E(L)C_{50}$ value of 45 mg/L for fish. The $PNEC_{water}$ is 0.45 mg/L.

PBT Assessment

Castor oil, ethoxylated is readily biodegradable and thus does not meet the screening criteria for persistence.

No bioconcentration studies are available for cinnamaldehyde. The measured log K_{ow} for castor oil, ethoxylated is 1.33; thus, castor oil, ethoxylated does not meet the screening criteria for bioaccumulation.

The acute E(L)C_{50} values for castor oil, ethoxylated in fish, invertebrates, and algae are >1 mg/L. Thus, castor oil, ethoxylated does not meet the screening criteria for toxicity.

The overall conclusion is that castor oil, ethoxylated is not a PBT substance.

References

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

Environmental Assessment

N-benzyl-alkylpyridium chloride
(CAS No. 68909-18-2)

N-benzyl-alkylpyridium chloride is a UVCB substance.

Biodegradation

No data are available.

Bioaccumulation

No bioconcentration studies have been conducted on N-benzyl alkylpyridium chloride. N-benzyl alkylpyridium chloride is not expected to bioaccumulate based on the experimental log K_{ow} of 3 (ECHA) [Kl. score = 1].

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies on salts of N-benzyl-alkylpyridium chloride.

Table 1: Acute Aquatic Toxicity Studies on N-benzylalkylpyridium chloride

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Daphnia magna	48-hr EC_{50}	3.1	1	ECHA
Pseudokirchneriella subcapitata	72-hr EC_{50} NOEC	0.47 0.02	1	ECHA

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for two trophic levels. Acute $E(L)C_{50}$ values are available for *Daphnia* (3.1 mg/L), and algae (0.47 mg/L). On the basis that the data consists of short-term results from two trophic levels, an assessment factor of 1,000 has been applied to the lowest reported $E(L)C_{50}$ value of 0.47 mg/L for algae. The $PNEC_{water}$ is 0.005 mg/L.

PBT Assessment

No data are available on the persistence of N-benzyl alkylpyridium chloride.

No bioconcentration studies are available for N-benzyl alkylpyridium chloride. The measured log K_{ow} for N-benzyl alkylpyridium chloride is 3; thus, N-benzyl alkylpyridium chloride does not meet the screening criteria for bioaccumulation.

The acute E(L)C_{50} values for N-benzyl alkylpyridium chloride in algae is <1 mg/L. Thus, N-benzyl alkylpyridium chloride meets the screening criteria for toxicity.

The overall conclusion is that N-benzyl alkylpyridium chloride is not a PBT substance.

References

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

Environmental Assessment

Cinnamaldehyde
(CAS No. 104-55-2)

Biodegradation

In an OECD 301B test, degradation of cinnamaldehyde was 89% after 7 days, 94% after 14 days, and 100% after 28 days, indicating ready biodegradation (ECHA) [Kl. score = 2]. In an OECD 301D test, biodegradation was 24.98% after 5 days. The BOD_5 value was 0.635 mg O_2/mg (ECHA) [Kl. score = 1].

Bioaccumulation

No bioconcentration studies have been conducted on cinnamaldehyde. Cinnamaldehyde is not expected to bioaccumulate based on the experimental log K_{ow} of 2.107 (ECHA) [Kl. score = 1].

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies on cinnamaldehyde.

Table 1: Acute Aquatic Toxicity Studies on Cinnamaldehyde.

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Brachydanio rerio	96-hr LC_{50}	4.15	1	ECHA
Poecilia reticulata	96-hr LC_{50}	>3.5	1	ECHA
Daphnia magna	48-hr EC_{50}	3.21	1	ECHA
Desmodesmus subspicatus	72-hr EC_{50}	31.6	1	ECHA
Chlorella vulgaris	72-hr EC_{50}	16.09	1	ECHA

In a OECD 210 chronic fish toxicity study, the 28-day LOEC to *Oryzias latipes* was 66.08 mg/L (ECHA) [Kl. score = 2].

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (4.15 mg/L), *Daphnia* (3.21 mg/L), and algae (16.09 mg/L). Results from

a chronic fish study are available, with a LOEC of 66.08 mg/L. On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 100 has been applied to the lowest reported E(L)C_{50} value of 4.15 mg/L for fish. The $PNEC_{water}$ is 0.04 mg/L.

PBT Assessment

Cinnamaldehyde is readily biodegradable and thus does not meet the screening criteria for persistence.

No bioconcentration studies are available for cinnamaldehyde. The measured log K_{ow} for cinnamaldehyde is 2.107; thus, cinnamaldehyde does not meet the screening criteria for bioaccumulation.

The acute E(L)C_{50} values for cinnamaldehyde in algae is <1 mg/L. Thus, cinnamaldehyde meets the screening criteria for toxicity.

The overall conclusion is that cinnamaldehyde is not a PBT substance.

References

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

Environmental Assessment

Diethylene Glycol
(CAS No. 111-46-6)

Biodegradation

Diethylene glycol is readily biodegradable. In an OECD 301B test, there was 70-80% and 90-100% degradation after 28 days, as determined by CO_2 evolution and DOC removal respectively (ECHA) [Kl. score = 2]. In an OECD 301A test, there was 90-100% degradation after 28 days, although the 10-day window was missed (ECHA) [Kl. score = 1]. In a modified MITI I test (OECD 301C), there was up to 92% degradation after 28 days (ECHA) [Kl. score = 2].

Bioaccumulation

Diethylene glycol has low potential to bioaccumulate. In a three-day bioaccumulation fish study with *Leuciscus idus melanotus*, the BCF was determined to be 100 (Freitag *et al.*, 1985) [Kl. score = 2]. The calculated log K_{ow} for diethylene glycol is -1.98 (Verschueren, 1993).

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies on diethylene glycol.

Table 1: Acute Aquatic Toxicity Studies on Diethylene Glycol

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Pimephales promelas	96-h LC_{50}	75,200	2	ECHA
Oncorhynchus mykiss	96-h LC_{50}	66,000	2	ECHA
Daphnia magna	24-h EC_{50}	>10,000	2	ECHA
Daphnia magna	48-h EC_{50}	65,980	2	ECHA
Daphnia magna	48-h EC_{50}	62,630	2	ECHA
Scenedesmus quadricauda	8-d TGK	2,700	2	ECHA

Terrestrial Toxicity

No data are available.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (66,000 mg/L), and *Daphnia* (>10,000 mg/L). Results from a chronic algae study is available on diethylene glycol (2,700 mg/L). On the basis that the data consists of short-term results from two trophic levels and a long-term result from one trophic level, an assessment factor of 100 has been applied to the lowest reported value, which is the chronic value for algae. The $PNEC_{aquatic}$ is 27 mg/L.

PBT Assessment

Diethylene glycol has been shown to be readily biodegradable; thus, it does not meet the screening criteria for persistence.

The calculated log K_{ow} is -1.98, and the experimental BCF is 100. Thus, diethylene glycol does not meet the screening criteria for bioaccumulation.

The lowest chronic toxicity value for diethylene glycol is >0.1 mg/L. Thus, diethylene glycol does not meet the criteria for toxicity.

The overall conclusion is that diethylene glycol is not a PBT substance.

References

ECHA REACH database: http://echa.europa.eu/web/guest/information-on-chemicals/registered-substances)

Freitag, D., Ballhorn, L., Geyer, H., and Korte, F. (1985). Environmental hazard profile of organic chemicals. An experimental method for the assessment of the behavior of organic chemicals in the ecosphere by means of simple laboratory tests with 14C labeled chemicals. Chemosphere 14: 1589-1616.

Verschueren, K. (1993). Handbook of Environmental Data on Organic Chemicals, 2nd Edition, Van Nostrand, New York.

Environmental Assessment

Distillates, Petroleum, Hydrotreated Light
(CAS No. 64742-47-8)

Distillates, petroleum, hydrotreated light (CAS No. 64742-47-8) is defined as follows:

"A complex combination of hydrocarbons obtained by treating a petroleum fraction with hydrogen in the presence of a catalyst. It consists of hydrocarbons having carbon numbers predominantly in the range of C9 through C16 and boiling in the range of approximately 150ºC to 290ºC. (302ºF to 554ºF)."

Biodegradation

Distillates, petroleum, hydrotreated light is inherently biodegradable. In an OECD 301F test, kerosene (CAS No. 64742-47-8) was degraded 58.6% after 28 days (ECHA) [Kl. score = 1]. In an OECD 301F test, a solvent, naphtha (petroleum), heavy aromatic (CAS No. 64742-94-5) was degraded 48% after 10 days and 61% after 28 days (ECHA) [Kl. score = 1].

Bioaccumulation

Distillates, petroleum, hydrotreated light is a UVCB substance. Standard tests for this endpoint are intended for single substances and are not appropriate for this complex substance. This endpoint can be calculated for representative hydrocarbon structures using the BCFWIN v2.16 model within EPISUITE as input to the hydrocarbon block method incorporated into the PETRORISK model. The predicted BCFs for hydrocarbons are generally overly conservative since biotransformation is not quantitatively taken into account. Therefore, indirect exposure and resulting risk estimates predicted by PETRORISK are likely to be overestimated (ECHA). An evaluation of representative hydrocarbon structures indicates that some structures meet the Bioaccumulative criterion.

Aquatic Toxicity

The acute toxicity of petroleum streams similar to distillates, petroleum, hydrotreated light (CAS No. 64742-47-8) are shown in Table 1.

Table 1: Acute Toxicity of Petroleum Streams Similar to Distillates, Petroleum, Hydrotreated Light (CAS No. 64742-47-8) [ECHA]

Test Substance	Test Species	Endpoint	Results (mg/L) [WAF]	Kl. score
solvent, naphtha (petroleum), heavy aromatic kerosene (CAS No. 64742-94-5)	*Oncorhynchus mykiss*	96-h LL_{50}	2 to 5	1
kerosene (petroleum), hydrodesulferized (CAS No. 64742-81-0)	*Oncorhynchus mykiss*	96-h LL_{50}	20	1
kerosene, petroleum, sweetened (CAS No. 91770-14-9)	*Oncorhynchus mykiss*	96-h LL_{50}	18	1

Test Substance	Test Species	Endpoint	Results (mg/L) [WAF]	Kl. score
solvent, naphtha (petroleum), heavy aromatic kerosene (CAS No. 64742-94-5)	*Daphnia magna*	48-h EL_{50}	3 to 10	1
kerosene (petroleum), hydrodesulferized (CAS No. 64742-81-0)	*Daphnia magna*	48-h EL_{50}	1.4	1
kerosene, petroleum, sweetened (CAS No. 91770-14-9)	*Daphnia magna*	48-h EL_{50}	21	1
solvent, naphtha (petroleum), heavy aromatic kerosene (CAS No. 64742-94-5)	*Raphidocelis subcaptata*	72-h EL_{50} NOEL	1 to 3 1	1
kerosene (petroleum), hydrodesulferized (CAS No. 64742-81-0)	*Selenastrum capricornutum*	96-h EL_{50} NOEL	6.2 0.4	1
kerosene, petroleum, sweetened (CAS No. 91770-14-9)	*Selenastrum capricornutum*	96-h EL_{50} NOEL	4.3 0.2	1

The 21-day NOEC of hydrodesulfurized kerosene to *Daphnia magna* was 0.48 mg/L [WAF] (ECHA) [Kl. score = 1].

Terrestrial Toxicity

No studies are available.

Determination of PNECs

$PNEC_{water}$: Substance is a hydrocarbon with a complex, unknown or variable composition. Conventional methods of deriving PNECs are not appropriate.

PBT Assessment

Distillates, petroleum, hydrotreated light (CAS No. 64742-47-8) is inherently biodegradable. Thus, it meets the criteria for persistence.

The ECHA database for distillates, petroleum hydrotreated light (CAS No. 64742-47-8) states that some structures meet the criterion for bioaccumulation.

The ECHA database for distillates, petroleum hydrotreated light (CAS No. 64742-47-8) states that structures do not meet the criterion for toxicity.

Toxicity

The overall conclusion is that distillates, petroleum, hydrotreated light (CAS No. 64742-47-8) is not a PBT substance.

Reference

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

Environmental Assessment

Ethoxylated C11 alcohol
(CAS No. 34398-01-1)

Alcohol ethoxylates (AE) are a class of non-ionic surfactants that have the basic structure $C_{x-y}AE_n$. The subscript (x-y) following the 'C' indicates the range of carbon chain units. The hydrocarbon chain can be either linear or branched. AEs also contain an ethylene oxide (E) chain attached to the alcohol. The degree of ethylene oxide polymerization is indicated by the subscript (n) which indicates the average number of ethylene oxide units. In household products the average ethylene oxide chain length commonly ranges between 3 and 12 units.

Biodegradation

The alcohols, C9-11, ethoxylated are readily biodegradable. In an ISO 14593 test, degradation of $C_{9-11}AE_{2.5}$ was 72% in 28 days (ECHA) [Kl. score = 2]. In another ISO 14593 test, degradation of $C_{9-11}AE_3$ was essentially 100% (measured as CO_2 evolution) in 28 days (ECHA) [Kl. score = 2].

Bioaccumulation

The BCF-values for alcohol ethoxylates in fathead minnows have been reported to range from <5 to 387.5 (Toll et al., 2000). The uptake rates varied from 330 to 1660 (L x kg/d) and elimination rates varied from 3.3 to 59 per day (Toll et al., 2000). Toll et al. (2000) concluded that the high values of elimination rate constants suggested that the tested fathead minnow efficiently biotransformed alcohol ethoxylates, thereby preventing them from attaining high concentrations in fish.

Aquatic Toxicity

In developing a water quality guideline for alcohol ethoxylates (ANZECC, 2000), the toxicity data was normalized for a specific alkyl chain length or a specific number of ethoxylate (EO) groups. The NOECs listed below were normalized to an alkyl chain length of C13.3 and EO of 8.2.

Freshwater fish: 2 species, 720 to 1,500 μg/L.

Freshwater crustaceans: 2 species, 590 to 860 μg/L.

Freshwater rotifers: 1 species, *Brachionus calyciflorus,* 1,300 μg/L

Freshwater algae, diatoms and blue-green algae: 6 species, 200 to 8,700 μg/L.

Freshwater mesocosms: 4 NOEC data for multiple species tests were 80, 80, 320, and 330 μg/L, although replication was insufficient to meet OECD (1992) requirements. Normalized data were 380, 380, 320, and 1,520 μg/L.

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

$PNEC_{water}$: The ANZECC water quality guideline (2000) for freshwater is: **"A high reliability trigger value of 140 μg/L was derived for AE (normalized data) using the statistical distribution method with 95% protection."**

PBT Assessment

Ethoxylated C11 alcohol is readily biodegradable and thus does not meet the screening criteria for persistence.

The bioconcentration factors (BCF) in fish for ethoxylated C11 alcohol has been reported to range from <5 to 387.5. Thus, ethoxylated C11 alcohol does not meet the screening criteria for bioaccumulation.

The NOEC values for alcohols ethoxylates are <1 mg/L. Thus, ethoxylated C11 alcohol meets the screening criteria for toxicity.

The overall conclusion is that ethoxylated C11 alcohol is not a PBT substance.

References

ANZECC & ARMCANZ (2000). Australian and New Zealand guidelines for fresh and marine water quality. National Water Quality Management Strategy Paper No 4, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra, Australia.

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

OECD (1992). Report of the OECD workshop on extrapolation of laboratory aquatic toxicity data to the real environment. OECD Environment Monographs No. 59, Organisation for Economic Co-operation and Development, Paris.

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Environmental Assessment

Polyoxyethylene-polyoxypropylene Block Copolymer
(CAS No. 9003-11-6)

The generic CAS RN 9003-11-6 refers to polymers that are synthetic block copolymers of ethylene oxide and propylene oxide. There are over 50 various amphiphilic nonionic block polymers of hydrophobic propylene oxide (PO) and hydrophilic ethylene oxide (EO) (CIR, 2008). These copolymers consist of a central polyoxypropylene molecule, flanked on both sides by two hydrophilic polyoxyethylene chains. These copolymers are also known as Poloxamers. The average molecular weights of several Poloxamer products are as follows: 2,090-2360 for Poloxamer 124; 7,680-9,510 for Poloxamer 188; and 9,840-14,600 for Poloxamer 407 (CIR, 2008).

Environmental Fate

No studies are available.

The following information is from the Dow Chemical Company's Product Safety Assessment document (Dow, 2014) on their EO/PO copolymer products with CASRN 9003-11-6 and 53637-25-5:

> Polyglycol EP Series Polymers are non-volatile (do not evaporate) and vary in water solubility. If released to water or soil, they would tend to remain in and be transported with the surface or ground water to which they are emitted, and will be adsorbed to soil and sediment particles. Polyglycol EP Series Polymers are unlikely to persist in the environment, as all products are known or expected to be either readily biodegradable (>65% biodegraded in 28 days per OECD 301F test) or inherently biodegradable according to Organisation for Economic and Co-operation and Development (OECD) test guidelines. As such, these products will be efficiently removed during treatment in biological wastewater-treatment facilities.

These products are not expected to accumulate in the food chain (low bioconcentration potential).

Aquatic Toxicity

No studies are available.

The following information is from the Dow Chemical Company's Product Safety Assessment document on their EO/PO copolymer products with CASRN 9003-11-6 and 53637-25-5 (Dow, 2014):

> [EO/PO copolymers] are practically non-toxic to aquatic organisms (LC_{50}/EC_{50} >100 mg/L for the most sensitive species tested) on an acute basis.

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

$PNEC_{water}$: No experimental studies were found. However, Dow Chemical's Product Safety Assessment document on their EO/PO copolymers indicates that acute toxicity testing has been conducted on these copolymers and the $E(L)C_{50}$ value for the most sensitive species is >100 mg/L. On the basis of the short-term results, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 100 mg/L. The $PNEC_{water}$ is 0.1 mg/L.

$PNEC_{sediment}$: A $PNEC_{sed}$ was not calculated for EO/PO copolymer. There are no experimental toxicity data on sediment organisms and a K_{oc} value EO/PO copolymer is unavailable for calculating the $PNEC_{sed}$ using the equilibrium partition method. A K_{oc} value for the EO/PO polymers has not been determined experimentally, and QSAR models are invalid for high molecular weight polymers, such as EO/PO polymers.

$PNEC_{soil}$: A $PNEC_{soil}$ was not calculated for EO/PO copolymer. There are no experimental toxicity data on soil organisms and a K_{oc} value EO/PO copolymer is unavailable for calculating the $PNEC_{soil}$ using the equilibrium partition method. A K_{oc} value for the EO/PO polymers has not been determined experimentally, and QSAR models are invalid for high molecular weight polymers, such as EO/PO polymers.

PBT Assessment

EO/PO copolymers are either readily biodegradable or inherently biodegradable; thus, they do not meet the screening criteria for persistence.

EO/PO copolymers are expected to have high molecular weights and are not expected to be bioavailable. Thus, these copolymers do not meet the criteria for bioaccumulation.

There are no chronic aquatic toxicity studies on the EO/PO copolymers. However, the acute $E(L)C_{50}$ on these copolymers are >1 mg/L in aquatic organisms based on information from Dow Chemical's Product Safety Assessment (Dow, 2014). EO/PO copolymers also have a high molecular weight and are not expected to be bioavailable. Thus, they do not meet the screening criteria for toxicity.

The overall conclusion is that EO/PO copolymers are not PBT substances.

References

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Environmental Assessment

Ethylene Glycol
(CAS No. 107-21-1)

Biodegradation

Ethylene glycol was readily biodegradable in an OECD 301A test. After 10 days, degradation was 90-100% (ECHA) [Kl. score = 1]. There was 97% degradation after 20 days in a BOD test; and 96% degradation after 28 days in an OECD 301D test (Waggy et al., 1994; OECD, 2004a,b) [Kl. score = 2].

The aerobic degradation of ethylene glycol was measured from grab river water samples at 4, 8, and 20°C. At 20°C, ethylene glycol was completely degraded in three days in all river waters tested; at 8°C, degradation was complete within 14 days. Degradation at 4°C was substantially slower, with degradation of <20% after 14 days in river samples with limited suspended matter and a starting concentration of 10 mg/L (Evans and David, 1974).

Adsorption/Desorption

No experimental data are available for ethylene glycol. Using KOCWIN in EPISUITE™ (EPA, 2017), the estimated K_{oc} values from the molecular connectivity index (MCI) and from the log K_{ow} are 1 and 0.2239 L/kg, respectively.

Bioaccumulation

The calculated log K_{ow} for ethylene glycol is -1.36 (ECHA). The BCF for ethylene glycol in golden ide (*Leuciscus idus melanotus*) after three days of exposure was determined to be 10 (Freitag *et al.*, 1985).

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies conducted on ethylene glycol.

Table 1: Acute Aquatic Toxicity Studies on Ethylene Glycol

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Pimephales promelas	96-h LC_{50}	>72,860	1	Pillard (1995)
Oncorhynchus mykiss	96-h LC_{50}	22,810 24,591	2	OECD (2004a,b)
Daphnia magna	48-h EC_{50}	>100	1	ECHA
Daphnia magna	48-h EC_{50}	46,300	2	Gersich et al. (1986)

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Ceriodaphnia dubia-affinis	48-h EC_{50}	25,800 (20^oC) 10,000 (24^oC)	2	Cowgill et al. (1985)
Daphnia magna	48-h EC_{50}	46,300 (20^oC) 51,000 (24^oC)	2	Cowgill et al. (1985)
Selenastrum capricornutum	96-h IC_{50} NOEC	10,940 10,000	2	Pillard and DuFrescne (1999)

Table 2 lists the results of chronic aquatic toxicity studies conducted on ethylene glycol.

Table 2: Chronic Aquatic Toxicity Studies on Ethylene Glycol

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Pimephales promelas	7-day NOEC	15,380	2	Pillard (1995)
Ceriodaphnia dubia	7-day NOEC (reproduction)	8,590	2	Pillard (1995)

Terrestrial Toxicity

No guideline studies are available.

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (22,810 mg/L), *Daphnia* (>100 mg/L), and algae (10,940 mg/L). NOEC values from long-term studies are available for fish (15,380 mg/L), invertebrates (8,590 mg/L), and algae (10,000 mg/L). On the basis that the data consists of short-term and long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported $E(L)C_{50}$ value of 100 mg/L for fish. The $E(L)C_{50}$ value is used because the value for fish is lower than the NOEC values for all three trophic levels. The $PNEC_{aquatic}$ is 10 mg/L.

$PNEC_{sediment}$: There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 6.4 mg/kg sediment wet weight.

The calculations are as follows:

$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$
$= (0.82/1280) \times 1000 \times 10$
$= 6.4$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$K_{sed\text{-}water} = 0.8 + [(0.2 \times Kp_{sed})/1000 \times BD_{solid}]$
$= 0.8 + [(0.2 \times 0.04/1000 \times 2400]$
$= 0.82$

Where:
Kp_{sed} = solid-water partition coefficient (L/kg).
BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$Kp_{sed} = K_{oc} \times f_{oc}$
$= 1 \times 0.04$
$= 0.04$

Where:
K_{oc} = organic carbon normalized distribution coefficient (L/kg). The K_{oc} for ethylene glycol calculated from EPISUITE™ using the MCI is 1 L/kg.
F_{oc} = fraction of organic carbon in sediment = 0.04 [default].

$PNEC_{soil}$: There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is <u>0.13 mg/kg soil dry weight</u>.

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
$= (0.02/1500) \times 1000 \times 10$
$= 0.13$

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
$= 1 \times 0.02$
$= 0.02$

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for ethylene glycol calculated from EPISUITE™ using the MCI is 1 L/kg.
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

PBT Assessment

Ethylene glycol is readily biodegradable and thus does not meet the screening criteria for persistence.

The measured BCF in fish is 10. Thus, ethylene glycol does not meet the criteria for bioaccumulation.

The NOECs from the chronic aquatic toxicity studies on ethylene glycol are >0.1 mg/L. The acute E(L)C_{50} values from the acute aquatic toxicity studies on ethylene glycol are >1 mg/L. Thus, ethylene glycol does not meet the criteria for toxicity.

The overall conclusion is that ethylene glycol is not a PBT substance.

References

Cowgill, U.M., Takahash, I.T., and Applegath, S.L. (1985). A comparison of the effect of four benchmark chemicals on Daphnia magna and Ceriodaphnia dubia-affinis tested at two different temperatures. Environ. Toxicol. Chem. 4: 415-422.

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Environmental Assessment

Formic acid
(CAS No. 64-18-6)

Biodegradation

In an OECD 301C test, biodegradation was 100% after 14 days, indicating that formic acid is readily biodegradable (ECHA) [Kl. score = 2].

Bioaccumulation

No bioconcentration studies have been conducted on sodium erythrobate. Sodium erythrobate is not expected to bioaccumulate based on the experimental log K_{ow} of -2.1 at pH 7 (ECHA).

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies on salts of formic acid.

Table 1: Acute Aquatic Toxicity Studies on Salts of Formic Acid

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Brachydanio rerio	96-hr LC_{50}	130*	1	ECHA
Daphnia magna	48-hr EC_{50}	365*	1	ECHA
Pseudokirchneriella subcapitata	72-hr EC_{50}	1,240**	1	ECHA

*Potassium formate
**Ammonium formate

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (130 mg/L), *Daphnia* (365 mg/L), and algae (1,240 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 100 has been applied to the lowest reported $E(L)C_{50}$ value of 100 mg/L for fish. The $PNEC_{aquatic}$ is 1.0 mg/L.

PBT Assessment

Formic acid is readily biodegradable; thus, it does not meet the screening criteria for persistence.

No bioconcentration studies are available for formic acid. The measured log K_{ow} for formic acid is -2.1 at pH 7; thus, formic acid does not meet the screening criteria for bioaccumulation.

The acute E(L)C_{50} values for formic acid in fish, invertebrates, and algae are >1 mg/L. Thus, formic acid does not meet the screening criteria for toxicity.

The overall conclusion is that formic acid is not a PBT substance.

References

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

Environmental Assessment

Glutaraldehyde
(CAS No. 111-30-8)

Biodegradation

Glutaraldehyde was considered readily biodegradable in an OECD 301A (DOC die away test). Degradation was 90-100% in 28 days (ECHA). [Kl. score = 1]

In a simulation test involving aerobic sewage treatment [activated sludge units] (OECD TG 303A), glutaraldehyde degraded 97% after 73 days based on DOC removal (ECHA). [Kl. score = 1]

In an aerobic aquatic metabolism test, [^{14}C]-glutaraldehyde had a half-life of 10.6 hours in the water/sediment system. A minor transformation product was glutaric acid: the maximum yield was 18.9 to 21.5% at 12 hours, which then declined rapidly to 10.1 to 11% by 24 hours; and was not observed at the end of the study period in the aqueous phase (ECHA). [Kl. score = 1]

In an anaerobic aquatic metabolism test, [^{14}C]-glutaraldehyde was rapidly metabolised with the first-order half-life being 7.7 hours. Glutaraldehyde was transformed to 5-hydroxypentanal (ca 37% of applied radioactivity) on day 1; after that, it declined to <10%; it was not detected at all after 30 days. The second stable transformation product was 1,5-pentanediol (35% of radioactivity on Day 1), which accounted for 70% of the radioactivity at the end of the test. A minor transformation product was a compound formed via Aldol condensation, cyclisation and dehydration. This compound accounted for about 10-20% of total radioactivity from day 1 onwards (ECHA). [Kl. score = 1]

In an aerobic soil metabolism test, the half-life of the degradation of [^{14}C]-glutaraldehyde was calculated to be 1.7 days, indicating rapid degradation in soil by microbial biotransformation. Degradation products were measured but not identified. (ECHA). [Kl. score = 1]

Adsorption/Desorption

The organic carbon/water partition coefficients (K_{oc}) values were determined for sediment and four types of soil. The values are as follows: 120 for sediment; 210 for sandy loam; 500 for silty clay loam; 340 for silt loam; and 460 for loamy sand (ECHA; Leung, 2001). [Kl. score = 1]

Bioaccumulation

Glutaraldehyde is not expected to bioaccumulate. The measured log Pow at pH 5, 7 and 9 are -0.41, -0.36 and -0.80, respectively (ECHA).

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies conducted on glutaraldehyde.

Table 1: Acute Aquatic Toxicity Studies on Glutaraldehyde

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Bluegill sunfish	96-hr LC_{50}	13	2	ECHA
Oncorhynchus mykiss	96-hr LC_{50}	10	2	ECHA
Daphnia magna	48-hr LC_{50}	14.87	2	ECHA
Daphnia magna	48-hr LC_{50}	14	2	ECHA
Scenedesmus subspicatus	72-hr EC_{50}	0.375 (biomass) 0.6 (growth rate) 0.025 (NOEC)	1	ECHA
Scenedesmus subspicatus	72-hr EC_{50}	0.92 (growth rate) 0.61(biomass) 0.33 (NOEC)	2	ECHA; Leung, 2001
Scenedesmus subspicatus	72-hr EC_{50}	0.61 (growth rate)	2	ECHA

The chronic aquatic toxicity studies conducted on glutaraldehyde are listed in Table 2.

Table 2: Chronic Aquatic Toxicity Studies on Glutaraldehyde

Test Species	Endpoint	Results (mg/L)	Kl. score	Reference
Oncorhynchus mykiss	97-day (OECD 210)	LOEC = 5 NOEC = 1.6	1	ECHA
Daphnia magna	21-day	NOEC = 5	1	ECHA

Terrestrial Toxicity

Table 3 lists the results of toxicity studies conducted on glutaraldehyde with earthworms, soil microorganisms, and birds.

Table 3: Terrestrial Toxicity Studies on Glutaraldehyde

Test Species (method)	Endpoint	Results	Kl. score	Reference
Earthworm *Eisenia fetida* (OECD 207)	14-d LC_{50}	>500 mg/kg soil dw	1	ECHA
Soil microorganisms* (OECD 216)	28-d EC_{50} 28-d EC_{10}	360 mg/kg soil dw 11.5 mg/kg soil dw	1	ECHA
Soil microorganisms* (OECD 217)	28-d EC_{50} 28-d EC_{10}	>593 mg/kg soil dw 1.5 mg/kg soil dw	1	ECHA
Mallard ducks	Single-dose (oral gavage) LC_{50}	206 mg/kg	2	ECHA
Mallard ducks	5-d (dietary) NOEC	>2,500 ppm	1	ECHA

*organic carbon content of soil = 1.34% dry weight

Glutaraldehyde has also been evaluated in a terrestrial plants test: seedling emergence and seedling growth test (OECD TG 208). The test material contained 48.9% glutaraldehyde. The results are as follows:

Avena sativa (oats): 19-day EC_{50} value is >1,000 mg/kg soil dry weight based on emergence rate, dry weight and shoot length. The NOECs for *Avena sativa* (oats) were $\geq$1,000 mg/kg dry weight on all three parameters tested.

Brassica napus (rapeseed): 19-day EC_{50} is >1,000 mg/kg soil dry weight based on emergence rate and shoot length and 994 mg/kg soil dry weight based on dry weight. The NOECs were $\geq$1,000, 500, and 250 mg/kg soil dry weight for emergence rate, dry matter, and shoot length, respectively.

Vicia sativa (vetch): 19-day EC_{50} is >1,000 mg/kg soil dry weight based on emergence rate and shoot length, and 901 mg/kg soil dry weight based on dry weight. The NOECs were $\geq$1,000, 125, and 125 mg/kg soil dry weight for emergence rate, dry matter, and shoot length, respectively (ECHA). [Kl. score = 1]

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (10 mg/L), *Daphnia* (14 mg/L), and algae (0.375 mg/L). Results from chronic studies are also available for all three trophic levels, with the lowest NOEC being 0.025 mg/L for algae. On the basis that the data consists of short-term and long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported NOEC of 0.025 mg/L for algae. The $PNEC_{water}$ is 0.0025 mg/L.

$PNEC_{sediment}$: There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 0.006 mg/kg wet weight.

The calculations are as follows:

$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$
$= (3.1/1280) \times 1000 \times 0.0025$
$= 0.006$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$K_{sed\text{-}water} = 0.8 + [(0.2 \times Kp_{sed})/1000 \times BD_{solid}]$
$= 0.8 + [(0.2 \times 4.8)/1000 \times 2400]$
$= 3.1$

Where:
Kp_{sed} = solid-water partition coefficient (L/kg).
BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$Kp_{sed} = K_{0c} \times f_{oc}$
$= 120 \times 0.04$
$= 4.8$

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for glutaraldehyde in sediment is 120.
F_{oc} = fraction of organic carbon suspended sediment = 0.04 [default].

$PNEC_{soil}$: Experimental results are available for three trophic level. An acute LC_{50} value is available for earthworms (>500 mg/kg). Results from long-term studies are available for two trophic levels, with the lowest NOEC or EC_{10} being 1.5 mg/kg soil dry weight for soil organisms.

The EC_{10} value is corrected for bioavailability of glutaraldehyde in soil by normalising the organic carbon content in the soil using the following equation:

$EC_{10(std)} = EC_{10(exp)} \times Fom_{soil(std)}/Fom_{soil(exp)}$

Where:
$Fom_{soil(std)}$ = 1% (www.scew.gov.au/node/941)
$Fom_{soil(exp)}$ = 1.34% (see Table 3)

$EC_{10(std)}$ = 1.5 mg/kg x 1/1.34 = 1.12 mg/kg

On the basis that the data consists of one short-term from one trophic level and two long-term results from two additional levels, an assessment factor of 50 has been applied to the lowest

reported long-term EC_{10} of 1.12 mg/kg soil dry weight [corrected for organic carbon content] for soil organisms. The $PNEC_{soil}$ is 0.02 mg/kg soil dry weight.

PBT Assessment

Glutaraldehyde is readily biodegradable and therefore does not meet the screening criteria for persistence.

The log P_{ow} for glutaraldehyde at different pH values ranges from -0.36 to -0.80. Therefore, glutaraldehyde does not meet the screening criteria for bioaccumulation.

Chronic NOECs for fish, daphnia and algae are available for glutaraldehyde, and the NOEC values are >0.01 mg/L. Therefore, glutaraldehyde does not meet the screening criteria for toxic.

The overall conclusion is that glutaraldehyde is not a PBT substance.

References

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

Leung, H.W. (2001). Ecotoxicology of glutaraldehyde: review of environmental fate and effects studies. Ecotoxicol. Environ. Safety 49: 26-39.

Environmental Assessment

Glycerol
(CAS No. 56-81-5)

Biodegradation

Glycerolwas readily biodegradable in an OECD 301D test. Degradation was 57% after 5 days, 84% after 15 days, and 92% after 30 days (OECD, 2002) [Kl. score = 2].

Adsorption/Desorption

No experimental data are available for glycerol. Using KOCWIN in EPISUITE™ (EPA, 2017), the estimated K_{oc} value from log K_{ow} is 0.1345 L/kg. The estimated K_{oc} value from the molecular connectivity index (MCI) is 1 L/kg.

Bioaccumulation

No bioconcentration studies have been conducted on glycerol. Glycerol is not expected to bioaccumulate based on the experimental log K_{ow} of -1.75 (ECHA).

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies on glycerol.

Table 1: Acute Aquatic Toxicity Studies on Glycerol

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Oncorhynchus mykiss	96-h LC_{50}	54,000	2	ECHA
Sheepshead minnow	96-h LC_{50}	>11,000	2	ECHA
Daphna magna	24-h EC_{50}	>10,000	2	ECHA
Scenedesmus quadricauda	8-d EC_0	>10,000	2	Bringmann and Kuehn, 1980; OECD, 2002

No chronic toxicity studies are available.

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for three trophic levels, although the data on algae cannot be used for determining a PNEC value. Acute $E(L)C_{50}$ values are available for fish (>11,000 mg/L) and *Daphnia* (>10,000 mg/L). On the basis that the data consists of short-term results from two trophic levels, an assessment factor of 1,000 has been applied to the lowest reported $E(L)C_{50}$ value of 10,000 mg/L for *Daphnia*. The $PNEC_{aquatic}$ is 10 mg/L.

$PNEC_{sediment}$: There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 6.4 mg/kg sediment wet weight.

The calculations are as follows:

$$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$$
$$= (0.82/1280) \times 1000 \times 10$$
$$= 6.4$$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$$K_{sed\text{-}water} = 0.8 + [0.2 \times Kp_{sed}/1000 \times BD_{solid}]$$
$$= 0.8 + [0.2 \times 0.04/1000 \times 2400]$$
$$= 0.82$$

Where:
Kp_{sed} = solid-water partition coefficient (L/kg).
BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$$Kp_{sed} = K_{oc} \times f_{oc}$$
$$= 1 \times 0.04$$
$$= 0.04$$

Where:
K_{oc} = organic carbon normalized distribution coefficient (L/kg). The K_{oc} for glycerol calculated from EPISUITE™ using MCI is 1 L/kg.
F_{oc} = fraction of organic carbon in sediment = 0.04 [default].

$PNEC_{soil}$: There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is 0.13 mg/kg soil dry weight.

The calculations are as follows:

$$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$$

= (0.02/1500) x 1000 x 10
= 0.13

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
= 1 x 0.02
= 0.02

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for glycerol calculated from EPISUITE™ using MCI is 1 L/kg.
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

PBT Assessment

Glycerol is readily biodegradable and thus does not meet the screening criteria for persistence.

No bioconcentration studies are available for glycerol. The measured log K_{ow} for glycerol is -1.75; thus, glycerine does not meet the screening criteria for bioaccumulation.

The acute $E(L)C_{50}$ values for glycerol in fish, invertebrates, and algae are >1 mg/L. Thus, glycerol does not meet the screening criteria for toxicity.

The overall conclusion is that glycerol is not a PBT substance.

References

Bringmann, G., and Kuehn, R. (1980). Comparison of the toxicity thresholds of water pollutants to bacteria, algae, and protozoa in the cell multiplication inhibition test. Water. Res. 14: 231-241.

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

OECD (2002). SIDS Initial Assessment Report (SIAR) and IUCLID Data Set on Glycerol (CAS No. 56-81-5), UNEP Publications. Available at: http://www.inchem.org/documents/sids/sids/56815.pdf.

U.S. Environmental Protection Agency [EPA] (2017). EPISuite™ v. 4.11, United States Environmental Protection Agency, Office of Pollution Prevention and Toxics and Syracuse Research Corporation. Available at: https://www.epa.gov/tsca-screening-tools/epi-suitetm-estimation-program-interface.

Environmental Assessment

Guar Gum
(CAS No. 9000-30-0)

Guar gum (CAS No. 9000-30-0) is a resinous material derived from milled endosperm from guar beans of the legume *Cyamopsis tetragonolobus*. Structurally, it is a galactomannan (high molecular weight carbohydrate polymer) consisting of a main chain of D-mannose with a side chain of D-galactose at approximately every second mannose unit. The mannose units are β-(l-4) linked, and the single D-galactose units are joined to the main chain by α-(1-6) linkages. The molecular weight of guar gum is 200,000 to 300,000 daltons (Glicksman, 1969).

Environmental Fate

Guar gum is a carbohydrate polymer consisting of D-mannose and D-galactose sugars from the guar plant or cluster bean. It is expected to be readily biodegradable and not bioaccumulate.

Aquatic Toxicity

The 96-hour LC_{50} for *Oncorhynchus mykiss* is 218 mg/L (Biesinger *et al.*, 1976). [Kl. score = 2]

The 48-hour and 96-hour LC_{50} values for *Daphnia magna* are 42 mg/L and <6.2 mg/L, respectively (Biesinger *et al.*, 1976). [Kl. score = 2]

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for two trophic levels. The acute $E(L)C_{50}$ values are available for fish (218 mg/L) and *Daphnia* (<6.2 mg/L). On the basis that the data consists of short-term results from two trophic levels, an assessment factor of 1,000 has been applied to the lowest reported $E(L)C_{50}$ value of 6.2 mg/L for *Daphnia*. The $PNEC_{water}$ is 0.006 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The K_{ow} and K_{oc} of guar gum cannot be calculated using EPISUITE because the molecular weight of guar gum greatly exceeds the limit of 1,000. Thus, the equilibrium partition method cannot be used to determine a $PNEC_{sediment}$ and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on soil organisms are available. The K_{ow} and K_{oc} of guar gum cannot be calculated using EPISUITE because the molecular weight of guar gum greatly exceeds the limit of 1,000. Thus, the equilibrium partition method cannot be used to determine a $PNEC_{soil}$ and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Guar gum is a naturally occurring polysaccharide from the guar plant or cluster bean; it expected to be readily biodegradable. Thus, it is not expected to meet the screening criteria for persistence.

The molecular weight of guar gum ranges from 200,000 to 300,000 daltons and is water-soluble. Thus, guar gum is not expected to meet the criteria for bioaccumulation.

The 96-hour LC_{50} value for *Daphnia* is <6.2 mg/L. Thus, guar gum may potentially meet the screening criteria for toxicity.

The overall conclusion is that guar gum is not a PBT substance.

References

Biesinger, K.E., Lemke, A.E., Smith, W.E., and Tyo, R.M. (1976). Comparative toxicity of polyelectrolytes to selected aquatic animals. J. Water Pollut. Control Fed. 48: 183-187; cited in U.S. EPA ECOTOX database.

Glicksman M. (1969). Gum technology in the Food Industry, pp. 590, Academic Press, New York; cited in Yoon *et al.* (2008).

Yoon, S.-J., Chu, D.-C., and Juneja, L.R. (2008) Chemical and physical properties, safety and application of partially hydrolyzed guar gum as dietary fiber. J. Clin. Biochem. Nutr. 42: 1-7.

Environmental Assessment

Hemicellulase
(CAS No. 9025-56-3)

Hemicellulases are a group of enzymes that break down hemicellulose, which are polysaccharides that are present in cell walls of all terrestrial plants. These polysaccharides have a β-(1→4)-linked backbone and are composed of pentoses (xylose, arabinoses), hexoses (mannose, glucose, galactose), and sugar acids. Unlike cellulose which are polysaccharides consisting of linear chains of several hundred to over ten thousand β-(1→4) linked D-glucoses, hemicelluloses are not chemically homogeneous. The best characterized hemicellulases are the 1,4- β -D-xylanases and, in particular, those derived from fungal sources presumably because their substrates, xylans, constitute the largest proportion of hemicelluloses in pasture plants.

No toxicity information could be located on hemicellulases; however, mammalian toxicity information was found on the cellulase enzymes (HERA, 2005). Cellulases cleave the ß-1,4-glycosidic bonds in cellulose, and are used in the pulp and paper industry, the textile industry, and in detergents to remove deposits and stains. The molecular weight of cellulase is 20,000 to 80,000 daltons.

Enzymes are catalytic proteins or polypeptides and consist of amino acid residues coupled via peptide bonds. They are primarily characterized by their biocatalytic or enzymatic activity. There is a broad range of detergent cellulases used both from fungal as well as from bacterial origin; all are characterized by ß-1,4-endoglucanase activity. For the purposes of risk assessment, the structure of hemicellulases would be expected to be similar to that of cellulases, given that hemicellulases and cellulases are both enzyme families that hydrolyze polysaccharides, although differing in their substrates. Thus, the toxicity data on cellulases will be used as read-across to hemicellulases.

Biodegradation

A cellulase enzyme was readily biodegradable in an OECD 301F test. There was ~10% degradation after one day; ~60% after 5 days; and 129% after 28 days (ECHA). [Kl. score = 1]

Three different cellulase enzymes were considered readily biodegradable based on the results of OECD 301C and 301E tests (HERA, 2005) [Kl. scores = 1]. In an OECD 301E test, there was 84% DOC removal of the enzyme Carezyme after 28 days. In another OECD 301E test, there was 92% DOC removal of the enzyme Clazinase® after 28 days. In an OECD 301C test, BOD/COD was 78% after 28 days (HERA, 2005).

Bioaccumulation

No bioaccumulation studies have been conducted on cellulase enzymes. Cellulase enzymes are not expected to bioaccumulate due to their high molecular weight and their octanol-water partition coefficient (log K_{ow} is <1.3). Moreover, cellulases are rapidly biotransformed in an organism to lower molecular-weight protein fragments by proteolytic enzymes (proteases), and eventually to the basic amino acids by peptidase enzymes.

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies on cellulase enzyme.

Table 1: Acute Aquatic Toxicity Studies on Cellulase Enzyme

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Oncorhynchus mykiss	96-h LC_{50}	>100* >52.1**	1	ECHA
Brachydanio rerio	96-h LC_{50}	330*	4	HERA (2005)
Daphnia magna	48-h EC_{50}	>100* >52.1**	1	ECHA
Daphnia magna	48-h EC_{50}	>1,000**	4	HERA (2005)
Daphnia magna	48-h EC_{50}	1,000**	4	HERA (2005)
Pseudokirchneriella subcapitata	72-h EC_{50}	>100* >52.1**	1	ECHA
Scenedesmus subspicatus	72-h EC_{50}	>1,000**	4	HERA (2005)

*Total organic solids.
**Active enzyme protein.

No chronic studies are available.

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (>52.1 mg aep/L), *Daphnia* (>52.1 mg aep/L), and algae (>52.1 mg aep/L). No chronic toxicity studies are available. On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 100 has been applied to the lowest reported $E(L)C_{50}$ value of 52.1 mg aep/L for fish. The $PNEC_{aquatic}$ is 0.5 mg/L.

$PNEC_{sediment}$: There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 0.3 mg/kg sediment wet weight.

The calculations are as follows:

$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$
$= (0.825/1280) \times 1000 \times 0.5$
$= 0.3$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$K_{sed\text{-}water} = 0.8 + [0.2 \times Kp_{sed}/1000 \times BD_{solid}]$
$= 0.8 + [0.2 \times 0.052/1000 \times 2400]$
$= 0.825$

Where:
Kp_{sed} = solid-water partition coefficient (L/kg).
BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$Kp_{sed} = K_{oc} \times f_{oc}$
$= 1.3 \times 0.04$
$= 0.052$

Where:
K_{oc} = organic carbon normalized distribution coefficient (L/kg). The K_{oc} for cellulase enzymes is calculated to be <1.3 L/kg (HERA, 2005).
F_{oc} = fraction of organic carbon in sediment = 0.04 [default].

$PNEC_{soil}$: There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is <u>0.009 mg/kg soil dry weight</u>.

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
$= (0.026/1500) \times 1000 \times 0.5$
$= 0.009$

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
$= 1.3 \times 0.02$
$= 0.026$

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for cellulase enzymes is calculated to be <1.3 L/kg (HERA, 2005).
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

PBT Assessment

Hemicellulase enzyme is readily biodegradable; thus, it does not meet the screening criteria for persistence.

Hemicellulase enzyme has a high molecular weight (20 to 80 kD), hydrophilic properties (high water solubility, log K_{ow} <1.3), and is readily biotransformed in organisms by proteases and peptidases. Thus, hemicellulase enzyme does not meet the screening criteria for bioaccumulation.

There are no chronic toxicity studies on the cellulase enzyme. The acute E(L)C_{50} values for cellulase are >1 mg/L in fish, invertebrates, and algae. Thus, hemicellulase enzyme does not meet the criteria for toxicity.

The overall conclusion is that hemicellulase enzyme is not a PBT substance.

References

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

HERA (2005). Human and Environmental Risk Assessment (HERA) on Ingredients of Household Cleaning Products: α-amylase, CAS No. 9000-90-2; Cellulase (β-(1,4)-glucanase), CAS No. 9012-54-8; Lipase, 9001-62-1, 2005. http://www.heraproject.com.

Environmental Assessment

1,6-Hexanediol
(CAS No. 629-11-8)

Biodegradation

1,6-Hexanediol is readily biodegradable. In an OECD 301 C test, degradation was 98% (DOC removal) and 95% (O_2 consumption) after 28 days (ECHA) [Kl. score = 2]. In an OECD 301 A test, degradation was >90% (DOC removal) after 7 days (ECHA) [Kl. score = 2].

Bioaccumulation

No bioconcentration studies have been conducted on 1,6-hexanediol. 1,6-Hexanediol is not expected to bioaccumulate based on the experimental log K_{ow} of 0 (ECHA) [Kl. score = 2].

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies on salts of 1,6-hexanediol.

Table 1: Acute Aquatic Toxicity Studies on 1,6-Hexanediol

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Leuciscus idus	96-hr LC_{50}	4,640 – 10,000	2	ECHA
Daphnia magna	48-hr EC_{50}	>500	2	ECHA
Desmodesmus subspicatus	72-hr EC_{50}	5,940	2	ECHA

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (4,640 – 10,000 mg/L), *Daphnia* (>500 mg/L), and algae (5,940 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 100 has been applied to the lowest reported $E(L)C_{50}$ value of 500 mg/L for *Daphnia*. The $PNEC_{water}$ is 5.0 mg/L.

PBT Assessment

1,6-Hexanediol is readily biodegradable and thus does not meet the screening criteria for persistence.

No bioconcentration studies are available for 1,6-hexanediol. The measured log K_{ow} for 1,6-hexanediol is 0; thus, 1,6-hexanediol does not meet the screening criteria for bioaccumulation.

The acute E(L)C_{50} values for 1,6-hexanediol in fish, invertebrates, and algae are >1 mg/L. Thus, 1,6-hexanediol does not meet the screening criteria for toxicity.

The overall conclusion is that 1,6-hexanediol is not a PBT substance.

Reference

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

Environmental Assessment

Hydrochloric acid
(CAS No. 7647-01-0)

Hydrochloric acid can exist in a gaseous phase at room temperature and pressure. Hydrochloric acid is also very soluble in water and is a strong acid that dissociates completely in water to hydrogen (H^+) and chloride (Cl^-) ions.

Environmental Fate

Due to its high water solubility and low vapour pressure, hydrochloric acid will be found predominantly in the aquatic environment where it dissociates completely to hydrogen (H^+) and chloride (Cl^-) ions. Both ions are ubiquitous in the environment (UNEP, 1995).

The addition of hydrochloric acid to an aquatic ecosystem may decrease the pH depending on the buffer capacity of the receiving water. In general, the buffer capacity is regulated by the equilibria between CO_2, HCO_3^- and CO_3^{2-}:

$CO_2 + H_2O \leftrightarrow HCO_3^- + H^+$ ($pKa_1 = 6.35$)

$HCO_3^- \leftrightarrow CO_3^{2-} + H^+$ ($pKa_2 = 10.33$)

A release of hydrochloric acid into the aquatic environment from the use of HCl could potentially increase the chloride concentration and decrease the pH in the aquatic environment. Table 1 shows the amount of hydrochloric acid that would need to be added to bicarbonate solutions to obtain pH values of 6.0 and 4.0. The UNEP (1995) study reported that the 10th percentile, mean, and the 90th percentile of bicarbonate concentrations in 77 rivers in North America, South America, Asia, Africa, Europe, and Oceania were 20, 106, and 195 mg/L, respectively. The data show that the decrease in pH depends on the buffer capacity (bicarbonate concentration) of the receiving water. The calculated values in Table 2 were confirmed experimentally.

Table 1: Buffer capacity to maintain the pH based on bicarbonate concentration from UNEP monitoring data (de Groot and van Dijk, 2002; taken from OECD, 2002b)

Initial concentration of HCO_3^-	**Final pH**	**Concentration of HCl required to obtain the final pH value**
		Calculated [mg/L]
20 mg/LHCO_3^- (10th percentile 77 rivers)	6.0	8.28
	4.0	11.9
106 mg/L HCO_3^- (mean value of 77 rivers)	6.0	43.9
	4.0	63.2
195 mg/L HCO_3^- (90th percentile 77 rivers)	6.0	80.7
	4.0	116.3

H^+ and Cl^- ions will not adsorb on the particulate matter or surfaces and will not accumulate in living tissues (OECD, 2002a,b).

Aquatic Toxicity

The acute aquatic toxicity studies on hydrochloric acid are listed in Table 2.

Table 2: Acute Aquatic Toxicity Studies on Hydrochloric Acid

Test Species	Endpoint	Results	Klimisch score	Reference
Oncorhynchus mykiss	96-hr LC_{50}	pH 4.12 (hard water) pH 3.98 (soft water)	2	ECHA; OECD 2002a,b
Lepomis macrochirus	96-hr LC_{50}	pH 3.25 – 3.5	2	ECHA; OECD 2002a,b
Daphnia magna	48-hr EC_{50}	pH 4.92	1	ECHA
Chlorella vulgaris	72-hr EC_{50} 72-hr NOEC	pH 4.7 [growth rate] pH 4.82 [biomass] pH 5 [yield/growth rate	1	ECHA

No chronic studies are available.

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

PNEC values were not derived from hydrochloric acid because factors such as the buffer capacity, the natural pH, and the fluctuation of the pH are very specific for a certain ecosystem.

PBT Assessment

Hydrochloric acid is an inorganic salt that dissociates completely to hydrogen and chloride ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both hydrogen and chloride ions are also ubiquitous and are present in water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria are not considered applicable to this inorganic salt.

Hydrogen and chloride ions are essential to all living organisms, and their intracellular, and extracellular concentrations are actively regulated. Thus, hydrochloric acid is not expected to bioaccumulate.

No chronic toxicity data exist on hydrochloric acid; however, the acute $E(L)C_{50}$ values are >1 mg/L in fish, invertebrates and algae. Thus, hydrochloric acid does not meet the screening criteria for toxicity.

The overall conclusion is that hydrochloric acid is not a PBT substance.

References

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Environmental Assessment

Isopropanol
(CAS No. 67-63-0)

Biodegradation

Aerobic biodegradation of isopropanol has been shown to occur rapidly under non-acclimated conditions, based on a result of 49% biodegradation from a 5-day BOD test (Bridie *et al.*, 1979). Additional biodegradation data developed using standardized test methods show that isopropanol is readily biodegradable in both freshwater and saltwater media (72 to 78% biodegradation in 20 days) (Price *et al.*, 1974).

Adsorption/Desorption

No experimental data are available for isopropanol. Using KOCWIN in EPISUITE™ (EPA, 2017), the estimated K_{oc} value from log K_{ow} is 3.478 L/kg. The estimated K_{oc} value from the molecular connectivity index (MCI) is 1.53 L/kg.

Bioaccumulation

Bioconcentration of isopropanol in aquatic organisms is not expected to occur based on a measured log K_{ow} of 0.05 (ECHA).

Aquatic Toxicity

The 96-hour LC_{50} in *Pimephales promelas* is 9,640 mg/L (Veith *et al.*, 1983) [Kl score = 2]. The 24-hour EC_{50} in *Daphnia magna* is >10,000 mg/L (Brinkmann and Kuehn, 1977) [Kl. score = 2]. The 7-day toxicity threshold value for a freshwater algae was determined to be 1,800 mg/L (Brinkmann and Kuehn, 1980) [Kl. score = 2].

The 16- and 21-day NOEC values for *Daphnia magna* were 141 and 30 mg/L, respectively (Hermens *et al.*, 1985; OECD, 1977a,b) [Kl. score = 4].

Terrestrial Toxicity

An EC_{50} value of 2,100 mg/L was determined from a lettuce seed germination test (Reynolds, 1977) [Kl. score = 2].

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (9,640 mg/L) and invertebrates (>10,000 mg/L). Results from chronic studies are available for invertebrates (16- and 21-day NOECs for *Daphnia* are 141 and 30 mg/L, respectively). On the basis that the data consists of a chronic study on one trophic level, an assessment factor of 100 has been applied to the lowest reported NOEC of 30 mg/L for *Daphnia*. The $PNEC_{water}$ is 0.3 mg/L.

$PNEC_{sediment}$: There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 0.2 mg/kg sediment wet weight.

The calculations are as follows:

$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$
$= (0.87/1280) \times 1000 \times 0.3$
$= 0.2$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$K_{sed\text{-}water} = 0.8 + [0.2 \times Kp_{sed})1000 \times BD_{solid}]$
$= 0.8 + [0.2 \times 0.14/1000 \times 2400]$
$= 0.87$

Where:
Kp_{sed} = solid-water partition coefficient (L/kg).
BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$Kp_{sed} = K_{oc} \times f_{oc}$
$= 3.478 \times 0.04$
$= 0.14$

Where:
K_{oc} = organic carbon normalized distribution coefficient (L/kg). The K_{oc} for isopropanol calculated from EPISUITE™ using Log K_{ow} is 3.478.
F_{oc} = fraction of organic carbon in sediment = 0.04 [default].

$PNEC_{soil}$: There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is 0.014 mg/kg soil dry weight.

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
$= (0.07/1500) \times 1000 \times 0.3$
$= 0.014$

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
$= 3.478 \times 0.02$
$= 0.07$

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for isopropanol calculated from EPISUITE™ using K_{ow} is 3.478.
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

PBT Assessment

Isopropanol is readily biodegradable; thus, it does not meet the screening criteria for persistence.

Based on a measured log K_{ow} of 0.05 and a calculated BCF of 1, isopropanol does not meet the screening criteria for bioaccumulation.

The chronic toxicity data on isopropanol show a NOEC of >0.1 mg/L. The acute $E(L)C_{50}$ values for isopropanol in fish, invertebrates, and algae are >1 mg/L. Thus, isopropanol does not meet the screening criteria for toxicity.

The overall conclusion is that isopropanol is not a PBT substance.

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Environmental Assessment

Methanol
(CAS No. 67-56-1)

Biodegradation

Methanol is readily biodegradable. In a closed bottle test using seawater, there was 84% and 95% degradation after 10 and 20 days, respectively (Price et al., 1974; ECHA). [Kl. score = 2]

In a soil test using [^{14}C]-methanol, there was 53.4% degradation under aerobic conditions after 5 days, as measured by CO_2 evolution; and 46.3% degradation under anaerobic conditions after 5 days, as measured by CO_2 evolution (Scheunert et al., 1987; ECHA). [Kl. score = 2]

Adsorption/Desorption

The adsorption of methanol was investigated in three different soil types at 6°C (Lokke, 1984; ECHA). There was slight adsorption with the sandy soils tested (percentage organic matter of 0.09% and 0.1% in the samples) and with the clay soil (percentage organic matter was 0.22%). Methanol solutions of concentrations of 0.1, 1.0, 9, and 90 mg/L were used in one-hour exposure adsorption studies; the K_{oc} values were between 0.13 and 0.61 for all soil types and at all concentrations.

Bioaccumulation

The BCF of methanol in *Cyprinus carpio* was determined to be 1.0 (Gluth et al. 1985); in *Leuciscus idus*, the BCF was <10 (Hansch and Leo, 1985; Freitag et al. 1985).

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies conducted on methanol.

Table 1: Acute Aquatic Toxicity Studies on Methanol

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Bluegill	96-hr LC_{50}	15,400	1	Poirer et al. 1986
Salmo gairdneri	96-hr LC_{50}	20,100	1	Call et al., 1983
Pimphales promelas	96-hr LC_{50}	28,100	1	Call et al., 1983
Daphnia magna	96-hr EC_{50}	18,260	2	Dorn et al., 2012; ECHA
Daphnia magna	48-hr EC_{50}	>10,000	2	Kuehn et al., 1989

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Selenastrum capricornutum	96-hr EC_{50}	~22,000	2	Cho et al., 2008; ECHA
Chlorella pyrenoidosa	10-14 d EC_{50}	28,400	2	Stratton and Smith, 1988

No adequate chronic studies were identified.

Terrestrial Toxicity

The terrestrial toxicity studies on methanol are listed below in Table 2.

Table 2: Terrestrial Toxicity Studies on Methanol

Test Species (Method)	Endpoint	Results (mg/kg soil dw)	Klimisch score	Reference
Earthworm *Eisenia fetida* (OECD 222)	35-d EC_{50} 63-d EC_{50}	17,199 26,646	2	ECHA
Folsomia candida (OECD 232)	28-d EC_{25} 28-d NOEC* (reproduction)	2,842 1,000	1	ECHA
Hordeum vulgare (OECD 208)	14-d EC_{50} 14-d NOEC* (seedling emergence)	15,492 12,000	1	ECHA
	14-d EC_{25} 14-d NOEC* (shoot dry mass)	2,538 1,555		
	14-d EC_{25} 14-d NOEC* (root dry mass)	2,823 2,592		
	14-d EC_{25} 14-d NOEC* (shoot length)	4,885 2,592		
	14-d EC_{25} 14-d NOEC* (root length)	5,752 4,320		

* Since only EC_{25} values were available from the test results, NOECs were derived graphically from the representing treatment means.

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (15,400 mg/L), *Daphnia* (>10,000 mg/L), and algae (22,000 mg/L). There are no well-conducted long-term studies on methanol. Therefore, an assessment of 1,000 has been applied to the lowest reported effect concentration of 10,000 mg/L for *Daphnia*. The $PNEC_{water}$ is 10 mg/L.

$PNEC_{sediment}$: There are no adequate toxicity studies on sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 6.3 mg/kg wet weight.

The calculations are as follows:

$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$
$= (0.81/1280) \times 1000 \times 10$
$= 6.3$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$K_{sed\text{-}water} = 0.8 + [0.2 \times Kp_{sed}/1000 \times BD_{soilid}]$
$= 0.8 + [0.2 \times 0.02/1000 \times 2400]$
$= 0.81$

Where:
Kp = solid-water partition coefficient (L/kg).
BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$Kp_{sed} = K_{oc} \times f_{oc}$
$= 0.61 \times 0.04$
$= 0.02$

Where:
K_{oc} = organic carbon normalized distribution coefficient (L/kg). The K_{oc} for methanol is 0.61.
F_{oc} = fraction of organic carbon suspended sediment = 0.04 [default].

$PNEC_{soil}$: Experimental results from chronic studies are available for three trophic levels. The lowest NOEC is 1,000 mg/kg soil dry weight for the arthropod *Folsomia candida*. On the basis that the data consists of long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported long-term NOEC of 1,000 mg/kg soil dry weight. The $PNEC_{soil}$ is 100 mg/kg soil dry weight.

PBT Assessment

Methanol is readily biodegradable and thus it does not meet the screening criteria for persistence.

Based on an experimental BCF of <10 in fish, methanol does not meet the criteria for bioaccumulation.

There are no adequate chronic toxicity studies on methanol. The acute $E(L)C_{50}$ values of methanol in fish, invertebrates and algae is >1 mg/L; thus, it does not meet the screening criteria for toxicity.

The overall conclusion is that methanol is not a PBT substance.

References

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Environmental Assessment

N-benzyl-alkylpyridium chloride
(CAS No. 68909-18-2)

N-benzyl-alkylpyridium chloride is a UVCB substance.

Biodegradation

No data are available.

Bioaccumulation

No bioconcentration studies have been conducted on N-benzyl alkylpyridium chloride. N-benzyl alkylpyridium chloride is not expected to bioaccumulate based on the experimental log K_{ow} of 3 (ECHA) [Kl. score = 1].

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies on salts of N-benzyl-alkylpyridium chloride.

Table 1: Acute Aquatic Toxicity Studies on N-benzylalkylpyridium chloride

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Daphnia magna	48-hr EC_{50}	3.1	1	ECHA
Pseudokirchneriella subcapitata	72-hr EC_{50} NOEC	0.47 0.02	1	ECHA

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for two trophic levels. Acute $E(L)C_{50}$ values are available for *Daphnia* (3.1 mg/L), and algae (0.47 mg/L). On the basis that the data consists of short-term results from two trophic levels, an assessment factor of 1,000 has been applied to the lowest reported $E(L)C_{50}$ value of 0.47 mg/L for algae. The $PNEC_{water}$ is 0.005 mg/L.

PBT Assessment

No data are available on the persistence of N-benzyl alkylpyridium chloride.

No bioconcentration studies are available for N-benzyl alkylpyridium chloride. The measured log K_{ow} for N-benzyl alkylpyridium chloride is 3; thus, N-benzyl alkylpyridium chloride does not meet the screening criteria for bioaccumulation.

The acute E(L)C_{50} values for N-benzyl alkylpyridium chloride in algae is <1 mg/L. Thus, N-benzyl alkylpyridium chloride meets the screening criteria for toxicity.

The overall conclusion is that N-benzyl alkylpyridium chloride is not a PBT substance.

References

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

Environmental Assessment

Pine Oil
(CAS No. 8002-09-3)

Biodegradation

Pine oil is a UVCB substance. Based on data on its components, pine oil is expected to be readily biodegradable.

Bioaccumulation

No bioconcentration studies have been conducted on pine oil. Based on data on its components, bioaccumulation or bioconcentration (BCF values >2,000) in aquatic organisms is possible (EPA, 2006).

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies on pine oil.

Table 1: Acute Aquatic Toxicity Studies on Pine Oil

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Oncorhynchus mykiss	LC_{50}	18.4	-	EPA, 2006
Lepomis macrochirus	LC_{50}	54.8	-	EPA, 2006
Daphnia magna	EC_{50}	24.1	-	EPA, 2006

Terrestrial Toxicity

The acute LD_{50} to Bobwhite quail is >2,250 mg/kg (EPA, 2006). The LC_{50} to mallard ducks in a subacute dietary study is >5,620 ppm (EPA, 2006).

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for two trophic levels. Acute $E(L)C_{50}$ values are available for fish (18.4 mg/L) and *Daphnia* (24.1 mg/L). On the basis that the data consists of short-term results from two trophic levels, an assessment factor of 1,000 has been applied to the lowest reported $E(L)C_{50}$ value of 18.4 mg/L for fish. The $PNEC_{water}$ is 0.02 mg/L.

PBT Assessment

Pine oil is expected to be readily biodegradable based on data of its components. Thus, it does not meet the criteria for persistence.

No bioconcentration studies are available for pine oil. The estimated BCF values of some of its components suggest that bioaccumulation in aquatic organisms is possible. Thus, pine oil may meet the screening criteria for bioaccumulation.

The acute E(L)C_{50} values for pine oil in fish and invertebrates are >1 mg/L. Thus, pine oil does not meet the screening criteria for toxicity.

The overall conclusion is that pine oil is not a PBT substance.

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Environmental Assessment

Polyoxyethylene Nonylphenol Ether
[Nonylphenol, ethoxylated]
(CAS No. 9016-45-9)

Biodegradation

Nonylphenol ethoxylates (NPE) are readily biodegradable. There was 96% degradation of NPEs after 30 days, indicating substantial primary biodegradation. The biodegradation process generated degradants nonylphenol mono- and di-ethoxylates, nonylphenoxy acetate and nonylphenol mono-ethoxyacetate, some of which remained at the end of 30 days (Ying et al., 2002, NICNAS). These degradants are expected to be ultimately biodegraded in the environment (Hayashi et al., 2005; Lu et al., 2009; NICNAS).

Bioaccumulation

Nonylphenol ethoxylates (CAS No. 9016-45-9) are expected to have low bioaccumulation potential in aquatic organisms (NICNAS). The BCF in the fish *Cyprinus carprio* of nonylphenol ethoxylates (CAS No. 9016-45-9) was reported to be <0.2 L/kg at 2 mg/L and <1.4 L/kg at 0.2 mg/L (NITE, 2014; NICNAS).

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies on nonylphenol ethoxylates (CAS No. 9016-45-9).

Table 1: Acute Aquatic Toxicity Studies on Nonylphenol Ethoxylates (CAS No. 9016-45-9)

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Lepomis macrochirus	96-hr LC_{50}	1.3	-	NICNAS
Scenedesmus opoliensis	120-hr EC_{50}	37.4	-	NICNAS

The 7-d NOEC from a chronic study on *Ceriodaphnia dubia* is 0.285 mg/L. The data was conducted on a chemical with an average ethylene oxide chain (EO) of 1.5 and read-across to nonylphenol ethoxylates (CAS No. 9016-45-9).

The 96-hr NOEC from an algal (Pseudokirchneriella subcapitata) on a nonylphenol ethoxylate (CAS No. 9016-45-9) is 8 mg/L (NICNAS).

Both nonylphenols and short-chain NPEs have been reported to have endocrine activity, with NPEs having less activity than nonylphenols (NICNAS).

Terrestrial Toxicity

The 48-hr LC_{50} to the Gallery worm (*Capitella capitata*) is 3.26 mg/L (NICNAS).

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (1.3 mg/L) and *Daphnia* (37.4 mg/L). Results are available from chronic studies on two trophic levels, with NOEC values for invertebrate (0.285 mg/L) and algae (8 mg/L). On the basis that the data consists of short-term results from two trophic levels and long-term results from two trophic levels, an assessment factor of 50 has been applied to the lowest reported NOEC value of 0.285 mg/L for invertebrates. The $PNEC_{water}$ is 0.006 mg/L.

PBT Assessment

Nonylphenol ethoxylates are readily biodegradable and thus do not meet the screening criteria for persistence.

The measured BCF values in fish for nonylphenol ethoxylates are <1.4; thus, nonylphenol ethoxylates do not meet the screening criteria for bioaccumulation.

The lowest chronic NOEC value for nonylphenol ethoxylates is <1 mg/L. Thus, nonylphenol ethoxylates meet the screening criteria for toxicity.

The overall conclusion is that nonylphenol ethoxylates are not PBT substances.

References

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Environmental Assessment

Potassium carbonate
(CAS No.584-08-7)

Environmental Fate

Potassium carbonate is partially soluble in water, dissociating into potassium (K^+) and carbonate (CO_3^{2-}) ions. Both ions are ubiquitous in the environment.

The addition of potassium carbonate to an aquatic ecosystem could result in a shift towards in alkalinity and a tendency to increase the pH. The carbonate ions will react with water, forming bicarbonate (HCO_3^-) and hydroxide (OH^-) ions, until an equilibrium is reached. A re-equilibration takes place when carbonate (CO_3^{2-}) is dissolved in water according to the following equations:

$HCO_3^- \leftrightarrow CO_3^{2-} + H^+$ $pK_a = 10.33$
$CO_2 + H_2O \leftrightarrow HCO_3^- + H^+$ $pK_a = 6.35$

Only a small fraction of the dissolved CO_2 is present as H_2CO_3 (carbonic acid); the major part is present as CO_2. The amount of CO_2 in water is in equilibrium with the partial pressure of CO_2 in the atmosphere. The CO_2/ HCO_3^-/ CO_3^{2-} equilibria are the major buffer of the pH of freshwater.

Based on these equations, CO_2 is the predominant species at a pH smaller than 6.35, while HCO_3^- is the predominant species at a pH in the range of 6.35-10.33 and CO_3^{2-} is the predominant species at a pH higher than 10.33.

K^+ and CO_3^{2-} ions are not expected to adsorb on particulate matter or surfaces and will not accumulate in living tissues.

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies on potassium carbonate.

Table 1: Acute Aquatic Toxicity Studies on Potassium Carbonate

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Oncorhynchus mykiss	96-hr LC_{50}	68	2	ECHA
Lepomis macrochirus	96-hr LC_{50}	230	2	ECHA
Daphnia pulex	48-hr EC_{50}	200	2	ECHA
Daphnia magna	48-hr EC_{50}	430	2	ECHA

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

The natural pH, bicarbonate and the potassium concentration (and their fluctuations in time) vary significantly between aquatic ecosystems; so deriving generic PNEC values from aquatic toxicity results on potassium carbonate determined in an experimental system with a defined pH, buffered media and/or media composition to real world conditions is not useful. Therefore, PNEC values for freshwater, sediment, and soil were not derived for potassium carbonate.

PBT Assessment

Potassium carbonate is an organic salt that dissociates completely to potassium and carbonate ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both potassium and carbonate ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria are not considered applicable to this inorganic salt.

Potassium and carbonate ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, potassium carbonate is not expected to bioaccumulate.

No chronic aquatic toxicity data exist on potassium carbonate; however, the acute $E(L)C_{50}$ values are >1 mg/L in fish, invertebrates and algae. Thus, potassium carbonate does not meet the screening criteria for toxicity.

The overall conclusion is that potassium carbonate is not a PBT substance.

References

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

Environmental Assessment

Potassium chloride
(CAS No. 7447-40-7)

Environmental Fate

Potassium chloride (KCl) dissociates completely in aqueous solutions to potassium (K^+) and chloride (Cl^-) ions. Potassium chloride and its dissociated ions are ubiquitous in the environment.

The transport and/or leaching of potassium (K^+) and chloride (Cl^-) ions is affected by clay minerals (type and content), pH, and organic matter. Potassium ions are less mobile and less prone to leaching than anions in soil, such as chloride and nitrate (NO_3^-). Chloride binds only weakly to soil particles, and therefore follows water movement (OECD, 2001).

Potassium (K^+) and chloride (Cl^-) ions are essential to all living organisms, and their intracellular and extracellular concentrations are actively regulated (OECD, 2001; Ganong, 1995). Neither potassium chloride or its dissociated ions are expected to bioaccumulate.

Aquatic Toxicity

The results of the acute toxicity studies conducted on potassium chloride are presented in Table 1.

Table 1: Acute Aquatic Toxicity Studies on Potassium Chloride

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Pimephales promelas	96-h LC_{50}	880	2	Mount et al., 1997; ECHA
Daphnia magna	48-h EC_{50}	660	2	Mount et al., 1997; ECHA
Ceriodaphnia dubia	48-h EC_{50}	630	2	Mount et al., 1997; ECHA
Scenedesmus subspicatus	72-h EC_{50}	>100* (growth rate)	1	ECHA

*NOEC = >100 mg/L

In a fish early-life-stage test with the fathead minnow (*Pimephales promelas*), the 7-day NOEC was 500 mg/L (ECHA).

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (720 mg/L), *Daphnia* (177 mg/L), and algae (>100 mg/L). Although a chronic study was conducted on fish that fulfils the requirements in the OECD TG 210, it is not considered adequate for deriving a PNEC because of the short duration of the test. On the basis of the short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 100 mg/L for algae. The $PNEC_{water}$ is 0.1 mg/L.

$PNEC_{sediment}$: No reliable experimental toxicity data on sediment organisms are available. Potassium chloride dissociates completely in water with its environmental distribution is dominated by its high water solubility. K_{ow} and K_{oc} parameters do not readily apply to inorganics, such as potassium chloride. Therefore, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sed}$. Based on its properties, no adsorption of potassium chloride to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No reliable experimental toxicity data on terrestrial organisms are available. The environmental distribution of potassium chloride is dominated by its water solubility. Sorption of potassium chloride should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. K_{ow} and K_{oc} parameters do not readily apply to inorganics, such as potassium chloride. Therefore, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on its properties, potassium chloride is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Potassium chloride is an inorganic salt that dissociates completely to potassium and chloride ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both potassium and chloride ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria are not considered applicable to this inorganic salt.

Potassium and chloride ions are essential to all living organisms, and their intracellular, and extracellular concentrations are actively regulated. Therefore, potassium chloride is not expected to bioaccumulate.

There are no adequate chronic aquatic toxicity studies available on potassium chloride. The acute $E(L)C_{50}$ values for postassium chloride are >1 mg/L in fish, invertebrates and algae. Therefore, potassium chloride does not meet the screening criteria for toxicity.

The overall conclusion is that potassium chloride is not a PBT substance.

References

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances

Ganong, W.F. (1995). Review of Medical Physiology, 17th Edition, Appleton & Lange, Norwalk, Connecticut, USA.

Mount, D.R., Gulley, D.D., Hockett, J.R., Garrison, T.D., and Evans, J.M. (1997). Statistical models to predict the toxicity of major ions to *Ceriodaphnia dubia, Daphnia magna* and *Pimephales promelas* (fathead minnows). Environ. Toxicol. Chem. 16: 2009-2019.

OECD. (2001). Screening Information Assessment Report (SIAR) for Potassium chloride (CAS No. 7447-40-7), UNEP Publications. Available at: http://webnet.oecd.org/Hpv/UI/SIDS_Details.aspx?id=68BF142A-D550-432C-8C48-13883944BA1D.

Environmental Assessment

Potassium hydroxide
(CAS No. 1310-58-3)

Environmental Fate

Due to its high water solubility and low vapour pressure, potassium hydroxide will be found predominantly in the aquatic environment where it dissociates completely to potassium (K^+) and hydroxyl (OH^-) ions. Both ions are ubiquitous in the environment (UNEP, 1995).

Addition of potassium hydroxide to an aquatic ecosystem may increase the pH depending on the buffer capacity of the receiving water. In general, the buffer capacity is regulated by the equilibria between CO_2, HCO_3^- and CO_3^{2-}:

$CO_2 + H_2O \leftrightarrow HCO_3^- + H^+$ ($pKa_1 = 6.35$)

$HCO_3^- \leftrightarrow CO_3^{2-} + H^+$ ($pKa_2 = 10.33$)

A release of potassium hydroxide into the aquatic environment from the use of KOH could potentially increase the potassium concentration and the pH in the aquatic environment. Table 1 shows the concentration of potassium hydroxide needed to increase the pH to values of 9.0, 10.0, 11.0, and 12.0.

Table 1: Potassium Hydroxide Concentration (mg/L) Needed to Increase pH (DeGroot et al., 2002; taken from OECD, 2002).

Buffer capacity	[KOH] (mg/L)	[K] (mg/L)	[KOH] (mg/L)
0 mg/L HCO_3 (distilled water)	0.56	0.39	0.010
20 mg/L HCO_3 (10^{th} percentile of 77 rivers)	0.86	0.60	0.015
106 mg/L HCO_3^- (mean value of 77 rivers)	4.51	3.14	0.080
195 mg/L HCO_3^- (90^{th} percentile of 77 rivers)	8.30	5.78	0.148

K^+ and OH^- ions will not adsorb on particulate matter or surfaces and will not accumulate in living tissues (OECD, 2002).

Aquatic Toxicity

The OECD-SIDS SIAR on KOH states the following regarding the aquatic toxicity studies on KOH (OECD, 2002):

> At concentrations reported in publications and study reports, the toxicity has been assumed to be due to hydroxide only, because at these effect concentrations the concentration of potassium is too low to explain the effects. However, it should be realised that the results of toxicity tests with KOH depend on the buffer capacity of the test medium. In a highly buffered test medium the hydroxyl ion will be neutralised, and the observed toxicity will be low, while in a poorly buffered test medium the pH will increase rapidly and therefore the observed toxicity will be relatively high. Besides the

direct effects (pH change) KOH could also have indirect effects. The pH change could influence the speciation of other chemicals and therefore increase and/or decrease the toxicity e.g., NH_3 is more toxic than NH_4^+.

Acute Fish

The 96-hour LC_{50} of *Gambusia affinis* (mosquitofish) is 80 mg/L. At 56 mg/L, no effects on the fish were observed. The pH was 10.3 at 100 mg/L (OECD, 2002). [Kl. score = 3]

Acute Invertebrate

No studies are available.

Acute Algae

No studies are available.

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

The OECD-SIDS SIAR on KOH states the following regarding the aquatic toxicity studies on KOH (OECD, 2002):

> In many cases pH, buffer capacity and/or medium composition were not discussed in the publications, although this is essential information for toxicity tests with KOH. The observed variation in LC50 values can be explained by the buffer capacity of the testing water, which was used.
>
> Although valid acute ecotoxicity tests and chronic ecotoxicity tests with KOH or NaOH are not available there is no need for additional testing with KOH. Aquatic ecosystems are characterized by an alkalinity/pH and the organisms of the ecosystem are adapted to these specific natural conditions. Based on the natural alkalinity of waters, organisms will have different optimum pH conditions, ranging from poorly buffered waters with pH of 6 to very hard waters with pH values up to 9."
>
> Furthermore, acute toxicity data cannot be used to derive a PNEC or a PNEC added for sodium hydroxide. Aquatic ecosystems are characterised by an alkalinity/pH and the organisms of the ecosystem are adapted to these specific natural conditions. Based on the natural alkalinity of waters, organisms will have different optimum pH conditions, ranging from poorly buffered waters with a pH of 6 or less to very hard waters with pH values up to 9. A lot of information is available about the relationship between pH and ecosystem structure and also natural variations in pH of aquatic ecosystems have been quantified and reported extensively in ecological publications and handbooks.
>
> Based on the available data it is not considered useful to derive a PNEC or a PNEC added for KOH because:

- The natural pH of aquatic ecosystems can vary significantly between aquatic ecosystems,
- Also the sensitivity of the aquatic ecosystems to a change of the pH can vary significantly between aquatic ecosystems.
- The change in pH due to an anthropogenic KOH addition is influenced significantly by the buffer capacity of the receiving water.

Although a PNEC or a PNEC added was not calculated for KOH there is a need to assess the environmental effect of KOH (alkaline) discharge. Based on the pH and buffer capacity of effluent and receiving water and the dilution factor of the effluent, the pH of the receiving water after the discharge can be calculated. Of course the pH change can be measured also very easily via a laboratory experiment or by conducting field measurements. The change in pH should be compared with the natural variation in pH of the receiving water and based on this comparison it should be assessed if the pH change is acceptable.

Based on the information above, PNEC values for freshwater, sediment, and soil were not derived for potassium hydroxide.

PBT Assessment

Potassium hydroxide is an inorganic salt that dissociates completely to potassium and hydroxide ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both potassium and hydroxide ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria are not considered applicable to this inorganic salt.

Potassium and hydroxide ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, potassium hydroxide is not expected to bioaccumulate.

There are no chronic toxicity data available on potassium hydroxide. The acute $E(L)C_{50}$ values for potassium hydroxide are >1 mg/L in fish. Thus, potassium hydroxide does not meet the screening criteria for toxicity.

The overall conclusion is that potassium hydroxide is not a PBT substance.

References

De Groot et al. (2002). Addition of sodium hydroxide to a solution with sodium bicarbonate to a fixed pH. Solvay Pharmaceuticals Int. Doc. No. 8320/47/01; cited in OECD, 2002.

Ganong, W.F. (1995). Review of Medical Physiology, 17th Edition, Appleton & Lange, Norwalk, Connecticut, USA.

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UNEP. (1995). Water quality of world river basins. UNEP Environment Library No. 14, Nairobi, Kenya; cited in OECD, 2002.

Environmental Assessment

Potassium persulfate
(CAS No. 7727-21-1)

Environmental Fate

Potassium persulfate dissociates in aqueous media to the potassium cation (K^+) and persulfate anion ($S_2O_8^{2-}$) (OECD 2005; ECHA). The persulfate anion will readily hydrolyse (decompose) into sulfate ions.

The rates of hydrolysis are expected to be similar for sodium persulfate, potassium persulfate, and ammonium persulfate. The rates of decomposition (hydrolysis) was measured at 50°C at various pHs. The half-lives increased from 20 hours at pH 1 to 210 hours at pH 10 (Koltoff and Miller, 1951).

Biodegradation is not applicable to inorganic compounds. Potassium persulfate is not expected to bioaccumulate; it will dissociate (and decompose) to ions that are ubiquitous in the environment. Potassium persulfate is not expected to absorb to soil or sediment because of its dissociation properties, instability (hydrolysis), and high water solubility.

Aquatic Toxicity

There are no aquatic toxicity studies on potassium persulfate. Table 1 lists the results of acute aquatic toxicity studies on other similar persulfate compounds.

Table 1: Acute Aquatic Toxicity Studies on Sodium Persulfate and Ammonium Persulfate

Substance	Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Ammonium persulfate	*Oncorhynchus mykiss*	96-h LC_{50}	76.3	1	ECHA
Sodium persulfate	*Oncorhynchus mykiss*	96-h LC_{50}	163	1	ECHA
Ammonium persulfate	*Daphnia magna*	48-h EC_{50}	120	1	ECHA
Sodium persulfate	*Daphnia magna*	48-h EC_{50}	133	1	ECHA
Ammonium persulfate	*Selenastrum capricornutum*	72-h EC_{50}	83.7	1	ECHA
Sodium persulfate	*Selenastrum capricornutum*	72-h EC_{50}	116	1	ECHA

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (76.3 mg/L), *Daphnia* (120 mg/L), and algae (83.7 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 100 has been applied to the lowest reported $E(L)C_{50}$ value of 76.3 mg/L for fish. The $PNEC_{water}$ is 0.8 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Potassium persulfate dissociates completely in water; its environmental distribution is dominated by its high water solubility. K_{ow} and K_{oc} parameters do not readily apply to inorganics, such as potassium persulfate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of potassium persulfate to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The environmental distribution of potassium persulfate is dominated by its water solubility. Sorption of potassium persulfate should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. K_{oc} and K_{ow} parameters do not readily apply to inorganics, such as potassium persulfate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, potassium persulfate is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Potassium persulfate is an inorganic compound that dissociates completely to potassium and persulfate ions in aqueous solutions. Persulfate ions are further hydrolysed to sulphate ions. Biodegradation is not applicable to these compounds. For the purposes of this PBT assessment, the persistent criteria are not considered applicable to potassium persulfate or its dissociated compounds.

Potassium persulfate is an inorganic compound that dissociates completely in water to ionic compounds that are ubiquitous in the environment. Thus, potassium persulfate is not expected to bioaccumulate.

There are no chronic aquatic toxicity data on potassium persulfate. The acute $E(L)C_{50}$ values for fish, invertebrates, and algae are >1 mg/L. Thus, potassium persulfate does not meet the criteria for toxicity.

The overall conclusion is that potassium persulfate is not a PBT substance.

References

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

Koltoff, I., and Miller, I.K. (1951). The chemistry of persulfate. I. The kinetics and mechanism of the decomposition of the persulfate ion in aqueous medium. J. Am. Chem. Soc. 73: 3055-3059.

OECD (2005). IUCLID Data Set for Ammonium persulfate (CAS No. 7727-54-0); Potassium persulfate (CAS No. 7727- 27-1); Sodium persulfate (CAS No. 7775-27-1), UNEP Publications. Available at: http://webnet.oecd.org/Hpv/UI/SIDS_Details.aspx?id=5D4B16BE-8BA8-4BE4-8787-469DE31A76E9.

Environmental Assessment

Potassium sorbate
(CAS No. 24634-61-5)

Biodegradation

In an OECD 301 D test on sorbic acid, degradation was 74.9% after 28 days. Thus, potassium sorbate is expected to be readily biodegradable (ECHA) [Kl. score = 1].

Bioaccumulation

No bioconcentration studies have been conducted on potassium sorbate. Potassium sorbate is not expected to bioaccumulate based on the experimental log K_{ow} of -1.72 at pH 6.5 for sorbic acid (ECHA) [Kl. score = 1].

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies on potassium sorbate.

Table 1: Acute Aquatic Toxicity Studies on Potassium Sorbate

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Danio rerio	96-hr LC_{50}	500	2	ECHA
Daphnia magna	48-hr EC_{50}	982	1	ECHA
Desmodesmus subspicatus	72-hr EC_{50} NOEC	>85* 8.46*	3	ECHA

*Read-across from sorbic acid.

The 21-d NOEC from a chronic *Daphnia* study on sorbic acid is 50 mg/L (ECHA) [Kl. score = 1].

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (500 mg/L), *Daphnia* (982 mg/L), and algae (>85 mg/L). Results from chronic studies are available for invertebrates (50 mg/L) and algae (8.46 mg/L). On the basis that the data consists of short-term results from three trophic levels and long-term results from two trophic levels, an assessment factor of 50 has been applied to the lowest reported NOEC of 8.46 mg/L for *Daphnia*. The $PNEC_{water}$ is 0.17 mg/L.

PBT Assessment

Potassium sorbate is readily biodegradable and thus does not meet the screening criteria for persistence.

No bioconcentration studies are available for potassium sorbate. The measured log K_{ow} for sorbic acid is -1.72 at pH 6.5; thus, potassium sorbate does not meet the screening criteria for bioaccumulation.

The acute $E(L)C_{50}$ values for potassium sorbate in fish, invertebrates, and algae are >1 mg/L. Thus, potassium sorbate does not meet the screening criteria for toxicity.

The overall conclusion is that potassium sorbate is not a PBT substance.

References

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

Environmental Assessment

Quaternary Ammonium Compounds, bis(Hydrogenated Tallow Alkyl) Dimethyl, Salts with Bentonite
[Quaternium-18 Bentonite]
(CAS No. 68953-58-2)

Quaternary ammonium compounds, bis (hydrogenated tallow alkyl) dimethyl, salts with bentonite, also known as quaternium-18 bentonite, will be designated "2M(2Alk) bentonite".

2M(2Alk) bentonite is one of a group of organoclays composed of quaternary ammonium compounds (cations) that have the following general formula:

N+R1, R2, R3, R4

Where R1, R2, R3, and R4 are substitutions on the N (nitrogen atom) of the quaternary compound (salt) as follows:

Methyl – 1 or 2 substitutions
Benzyl – 0 or 1 substitutions
Alkyl (C14-22) – 1, 2 or 3 substitutions

The organoclays discussed in this dossier are hydrogenated tallowalkonium bentonites and are the product of the reaction of hydrogenated tallowalkonium chloride and bentonite. Bentonite is a widely distributed natural material consisting predominantly of the clay montmorillonite, a smectite clay. Bentonite is formed of highly colloidal and plastic clays and is produced by in-situ devitrification of volcanic ash (CIR, 2016).

Biodegradation

No biodegradation studies were located for 2M(2Alk) bentonite. Biodegradation studies are available for quaternary ammonium compounds, benzylbis(hydrogenated tallow alkyl)methyl, chlorides, compounds with bentonite: B(2Alk)M bentonite.

In three separate OECD TG 306 biodegradation tests using B(2Alk)M bentonite, biodegradation ranged from 4.7 to 33.4% in 28 days (OECD, 2007). Based on these data as well as the structural and chemical properties of these compounds, it is assumed that other organoclay category members will also show limited biodegradation. It should be noted that biodegradation relates only to the organic component of the organoclays (*i.e.*, the alkyl quaternary ammonium salts).

Bioaccumulation

Bioaccumulation is not expected due to the insolubility of 2M(2Alk) bentonite.

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies on 2M(2Alk) bentonite and similar organoclays.

Table 1: Acute Aquatic Toxicity Studies on B(Alk)2M Bentonite or similar organoclays

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Rainbow trout	96-h LC_{50}	> ca. 500*	4	OECD, 2007
Daphnia magna	96-h EC_{50}	>100	4	OECD, 2007
Daphnia magna	96-h EC_{50}	300*	4	OECD, 2007
Daphnia magna	96-h EC_{50}	300**	4	OECD, 2007
Skeletonema costatum	72-h EC_{50}	>1,000** (growth rate)	4	OECD, 2007

***B(Alk)2M Bentonite:** Quaternary ammonium compounds, benzyl(hydrogenated tallow alkyl)dimethyl, chlorides, compounds with bentonite.

****B(2Alk)M hectorite:** Quaternary ammonium compounds, benzylbis(hydrogenated tallow alkyl)methyl, salts with hectorite

There are no chronic aquatic toxicity studies on 2M(2Alk) bentonite. The 21-d NOEC in a *Daphnia* reproduction test on B(2Alk)M hectorite was 3.2 mg/L (OECD, 2007). The mortality of *Daphnia* seen at the LOEC of 32 mg/L was considered to be due, in part, to physical effects of the test material.

Terrestrial Toxicity

The 14-day NOEC of B(Alk)2M bentonite to earthworms is 1,000 mg/kg. Since 1,000 mg/kg is the limit dose, it is assumed that the LC_{50} is >1,000 mg/kg (OECD, 2007).

Terrestrial plant toxicity are available for B(2Alk)M hectorite. The EC_{50} values of B(2Alk)M hectorite for the emergence and early growth stages of wheat and radish seedlings (*Tritium aestivum* and *Raphanus sativus*, respectively) are >100 mg/kg; the NOEC are 100 mg/kg, the highest dose tested (OECD, 2007). The LC_{50} of B(2Alk)M hectorite was 9 mg/kg for the emergence and early growth stages of cress seedling (*Lepidum sativum*); the LOEC was 1 mg/kg and a NOEC was not established (OECD, 2007).

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (>500 mg/L), *Daphnia* (>100 mg/L), and algae (>1,000 mg/L). Results from chronic studies are also available for two trophic levels, with the lowest NOEC being 3.2 mg/L for invertebrates. On the basis that the data consists of short-term results from three trophic levels and long-term results from two trophic levels, an assessment factor of 50 has

been applied to the lowest reported long-term NOEC of 3.2 mg/L for *Daphnia*. The $PNEC_{aquatic}$ is 0.06 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The K_{ow} of 2M(2Alk) bentonite cannot be calculated because it is essentially insoluble in water. Thus, the equilibrium partition method cannot be used to determine a $PNEC_{sediment}$.

$PNEC_{soil}$: Experimental results are available for two trophic levels. An acute LC_{50} value is available for earthworms (>1,000 mg/kg). Results from the long-term studies are only available for terrestrial plants, which give widely divergent results. On the basis that the data consist of one short-term result from one trophic level, an assessment factor of 1,000 has been applied to the acute LC_{50} value of 1,000 mg/kg for earthworms. The $PNEC_{soil}$ is 1.0 mg/kg soil dry weight.

PBT Assessment

The clay component of 2M(2Alk) bentonite is not biodegradable, and the organic component is not readily biodegradable. Thus, it meets the criteria for persistence.

2M(2Alk) bentonite is insoluble in water and is not bioavailable. Thus, it is not expected to meet the screening criteria for bioaccumulation.

There are no chronic aquatic toxicity studies available on 2M(2Alk) bentonite; however, the NOEC from a chronic *Daphnia* study on a similar organoclay is >0.1 mg/L. The acute $E(L)C_{50}$ values for 2M(2Alk) bentonite and similar organoclays are >1 mg/L in fish, invertebrates, and algae. Thus, it does not meet the criteria for toxicity.

The overall conclusion is that 2M(2Alk) bentonite is not a PBT substance.

References

Cosmetic Ingredient Review [CIR] (2016). Safety assessment of alkonium clays as used in cosmetics. Available at: http://online.personalcarecouncil.org/ctfa-static/online/lists/cir-pdfs/FR698.pdf.

OECD (2007). SIDS Initial Assessment Profile on Organoclays Category. Available at: http://webnet.oecd.org/hpv/ui/handler.axd?id=b8b51b84-081c-444c-bb95-fb7f41c859c1.

Environmental Assessment

Sodium benzoate
(CAS No. 532-32-1)

Biodegradation

In a biotic degradation: closed bottle test, degradation was 111% of ThOD after 330 days with a medium containing high ammonium content. In medium containing low ammonium content, degradation was 92% of ThOD. There was slightly lower degradation (75%) with medium with no nitrification. It can be concluded that sodium benzoate is readily biodegradable but failing the 10-day window (ECHA) [Kl. score = 2].

In an OECD 301 CO_2 evolution test, degradation ranged from 85 to 94% after 28 days (ECHA) [Kl. score = 2].

Bioaccumulation

No bioconcentration studies have been conducted on sodium benzoate. Sodium benzoate is not expected to bioaccumulate based on a calculated log K_{ow} of -2.269 (ECHA) [Kl. score = 2].

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies on sodium benzoate.

Table 1: Acute Aquatic Toxicity Studies on Sodium Benzoate

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Pimephales promelas	96-hr LC_{50}	484	2	ECHA
Pimephales promelas	96-hr LC_{50}	>100	2	ECHA
Daphnia magna	48-hr EC_{50}	>100	2	ECHA
Pseudokirchneriella subcapitata	72-hr EC_{50} EC_{10}	>30.5 6.5	1	ECHA

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (>100 mg/L), *Daphnia* (>100 mg/L), and algae (>30.5 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 100 has been applied to the lowest reported $E(L)C_{50}$ value of 30.5 mg/L for algae. The $PNEC_{water}$ is 0.3 mg/L.

PBT Assessment

Sodium benzoate is readily biodegradable and thus does not meet the screening criteria for persistence.

No bioconcentration studies are available for sodium benzoate. The measured log K_{ow} for benzoate is -2.269; thus, sodium benzoate does not meet the screening criteria for bioaccumulation.

The acute $E(L)C_{50}$ values for sodium benzoate in algae is >1 mg/L. Thus, sodium benzoate does not meet the screening criteria for toxicity.

The overall conclusion is that sodium benzoate is not a PBT substance.

References

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

Environmental Assessment

Sodium bisulfite
(CAS No. 7631-90-5)

Environmental Fate

At environmental pHs, sodium bisulfite dissociates in water to form sodium (Na^+) ions, bisulfite ions (HSO_3^-), sulfite (SO_2^{3-}) ions, and sulfur dioxide (SO_2) which is a gas (OECD, 2001).

Sodium bisulfite is not expected to bioaccumulate in the environment because of its dissociation to ionic species and a gas. Furthermore, sulfite will oxidize to sulfate, which is ubiquitous in the environment (OECD, 2001).

Sodium bisulfite and its dissociated species are expected to have a low potential to adsorb to soil and sediment.

Aquatic Toxicity

No acute aquatic studies are available on sodium bisulfite; however, studies are available on other inorganic sulfite compounds. The studies on these inorganic sulfite compounds can used to read-across to sodium bisulfite since sulfite ions are formed in water upon dissociation of sodium bisulfite. Table 1 lists the results of acute aquatic toxicity studies on the structural analogues of sodium bisulfite.

Table 1: Acute Aquatic Toxicity Studies on the Structural Analogues of Sodium Bisulfite

Test Species	Test Substance	Endpoint	Results (mg/L)	Klimisch score	Reference
Leuciscus idus	Potassium sulfite	96-hr LC_{50}	316	2	ECHA
Salmo gairdneri	Sodium pyrosulfite	96-hr LC_{50}	147-215 (177.8*)	2	ECHA
Brachydanio rerio	Potassium metabisulfite	96-hr LC_{50}	464-1,000 (681.2*)	1	ECHA
Daphnia magna	Sodium disulfite	48-hr EC_{50}	88.8	2	ECHA
S. subspicatus	Sodium disulfite	96-hr EC_{50} 72-hr EC_{10}	43.9 33.3	2	ECHA

*Geometric mean.

No chronic studies are available on sodium bisulfite; however, studies are available on sodium sulfite. Table 2 lists the results of chronic aquatic toxicity studies conducted on sodium sulfite.

Table 2: Chronic Aquatic Toxicity Studies on Sodium Sulfite (CAS No. 7757-83-7)

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Danio rerio	34-d NOEC	>316	1	ECHA
Daphnia magna	21-d NOEC	>10	2	ECHA

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

$PNEC_{water}$: No studies have been conducted on sodium bisulfite; however, the results from studies conducted on other inorganic sulphite compounds can be used to read-across to sodium bisulfite. Hence, experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (177.8 mg/L for sodium pyrosulfite), invertebrates (88.8 mg/L for sodium sulfite), and algae (43.9 mg/L for sodium disulfite). Results from chronic studies on sodium sulfite are also available for all three trophic levels, with the lowest NOEC being 10 mg/L for invertebrates. Using the molecular weights of sodium sulfite (126 g/mol) and sodium bisulfite (104.1 g/mol), the NOEC of 10 mg/L for sodium sulfite is converted to 8.3 mg/L. On the basis that the data consist of short-term and long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported NOEC of 8.3 mg/L for invertebrates. The $PNEC_{water}$ is 0.8 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Sodium bisulfite dissociates completely in water; its environmental distribution is dominated by its high water solubility. K_{ow} and K_{oc} parameters do not readily apply to inorganics, such as sodium bisulfite. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sed}$. Based on its properties, no adsorption of sodium bisulfite to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on soil organisms are available. Sodium bisulfite dissociates completely in water; its environmental distribution is dominated by its high water solubility. K_{ow} and K_{oc} parameters do not readily apply to inorganics, such as sodium bisulfite. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on its properties, no adsorption of sodium bisulfite to soil is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Sodium bisulfite is an inorganic compound that dissociates completely to ionic species and sulfur dioxide gas. Biodegradation is not applicable to these compounds. For the purposes of this PBT assessment, the persistent criterion is not considered applicable to sodium bisulfite or its dissociated compounds.

Sodium bisulfite is not expected to bioaccumulate because its dissociated species are inorganic ions and a gas.

There are no aquatic toxicity data on sodium bisulfite. The lowest NOEC from chronic aquatic toxicity studies on sodium sulfite, a structural analogue of sodium bisulfite, is >0.1 mg/L. Thus, sodium bisulfite is not expected to meet the criteria for toxicity.

The overall conclusion is that sodium bisulfite is not a PBT substance.

References

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

OECD (2001). OECDS-SIDS: Disodium disulphite (CAS No. 7657-4). UNEP Publications. Available at: http://www.inchem.org/documents/sids/sids/DISODIUM.pdf.

Environmental Assessment

Sodium erythrobate
(CAS No. 6381-77-7)

Biodegradation

In an OECD 301E test, biodegradation was 56% after 28 days, indicating that sodium erythrobate is not readily biodegradable (ECHA) [Kl. score = 2].

Bioaccumulation

No bioconcentration studies have been conducted on sodium erythrobate. Sodium erythrobate is not expected to bioaccumulate based on the experimental log K_{ow} of -3.29 (ECHA).

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies on sodium erythrobate.

Table 1: Acute Aquatic Toxicity Studies on Sodium Erythrobate

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Oncorhynchus mykiss	96-hr LC_{50}	>100	1	ECHA
Daphnia magna	48-hr EC_{50}	>100	1	ECHA
Pseudokirchneriella subcapitata	72-hr EC_{50}	>100	1	ECHA

Terrestrial Toxicity

No studies are available.

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (>100 mg/L), *Daphnia* (>100 mg/L), and algae (>100 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 100 has been applied to the lowest reported $E(L)C_{50}$ value of 100 mg/L for fish, invertebrates, and algae. The $PNEC_{aquatic}$ is 1.0 mg/L.

PBT Assessment

Sodium erythrobate is not readily biodegradable; thus, it meets the screening criteria for persistence.

No bioconcentration studies are available for sodium erythrobate. The measured log K_{ow} for sodium erythrobate is -3.29; thus, sodium erythrobate does not meet the screening criteria for bioaccumulation.

The acute E(L)C_{50} values for sodium erythrobate in fish, invertebrates, and algae are >1 mg/L. Thus, sodium erythrobate does not meet the screening criteria for toxicity.

The overall conclusion is that sodium erythrobate is not a PBT substance.

References

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances.

Environmental Assessment

Sodium hydroxide
(CAS No. 1310-73-2)

Sodium hydroxide (NaOH) is a strong alkaline substance that dissociates completely in water to sodium (Na^+) and hydroxyl (OH^-) ions.

Environmental Fate

Due to its high water solubility and low vapour pressure, sodium hydroxide will be found predominantly in the aquatic environment where it dissociates completely to sodium (Na^+) and hydroxyl (OH^-) ions. Both ions are ubiquitous in the environment (UNEP, 1995).

The addition of sodium hydroxide to an aquatic ecosystem may increase the pH depending on the buffer capacity of the receiving water. In general, the buffer capacity is regulated by the equilibria between CO_2, HCO_3^- and CO_3^{2-}:

$CO_2 + H_2O \leftrightarrow HCO_3^- + H^+$ ($pKa_1 = 6.35$)
$HCO_3^- \leftrightarrow CO_3^{2-} + H^+$ ($pKa_2 = 10.33$)

A release of sodium hydroxide into the aquatic environment from the use of NaOH could potentially increase the sodium concentration and the pH in the aquatic environment. Table 1 shows the concentration of sodium hydroxide needed to increase the pH to values of 9.0, 10.0, 11.0, and 12.0.

Table 1: Sodium Hydroxide Concentration (mg/L) Needed to Increase pH (DeGroot et al., 2002; taken from OECD, 2002b).

Buffer capacity*	Final pH			
	9.0	**10.0**	**11.0**	**12.0**
0 mg/L HCO_3 (distilled water)	0.4	4.0	40	400
20 mg/L HCO_3 (10^{th} percentile of 77 rivers)	1.0	8.2	51	413
106 mg/L HCO_3^- (mean value of 77 rivers)	3.5	26	97	468
195 mg/L HCO_3^- (90^{th} percentile of 77 rivers)	6.1	45	145	525

*The initial pH of a bicarbonate solution with a concentration of 20-195 mg/L was 8.25 to 8.35.

Na^+ and OH^- ions will not adsorb on the particulate matter or surfaces and will not accumulate in living tissues (OECD, 2002b).

Aquatic Toxicity

The OECD-SIDS SIAR on NaOH states the following regarding the aquatic toxicity studies on NaOH (OECD, 2002b):

> "At concentrations reported in publications and study reports, the toxicity has been assumed to be due to hydroxide only, because at these effect concentrations the concentration of sodium is too low to explain the effects. However, it should be realised that the results of toxicity tests with NaOH depend on the buffer capacity of the test medium. In a highly buffered test medium, the hydroxyl ion will be neutralised, and the observed toxicity will be low, while in a poorly buffered test medium the pH will increase rapidly and therefore the observed toxicity will be relatively high. Besides the direct effects (pH change) NaOH could also have indirect effects. The pH change could influence the speciation of other chemicals and therefore increase and/or decrease the toxicity, e.g.; NH_3 is more toxic than NH_4^+."

There are no guideline studies on NaOH; the studies summarised below have Klimisch scores of 3 or 4.

Acute Fish

The 24-hour LC_{50} to *Carassius auratus* (goldfish) is 160 mg/L. At 100 mg/L, which was equivalent to a pH of 9.8, no mortality was observed. The 48-hour LC_{50} to *Leuciscus idus melanotus*, is 189 mg/L. The 96-hour LC_{50} of *Gambusia affinis* (mosquitofish) is 125 mg/L. At 84 mg/L, no effects on the fish were observed. The pH was 9 at 100 mg/L.

Acute Invertebrate

The 48-hour LC_{50} is 40 mg/L for *Ceriodaphnia cf. dubia*. The toxicity threshold concentration of NaOH for *Daphnia magna* was reported to range from 40 to 240 mg/L.

Acute Algae

No studies were identified.

<u>Terrestrial Toxicity</u>

No studies are available.

<u>Derivation of PNECs</u>

The OECD-SIDS SIAR on NaOH states the following regarding the aquatic toxicity studies on NaOH (OECD, 2002b):

> "In many cases pH, buffer capacity and/or medium composition were not discussed in the publications, although this is essential information for toxicity tests with NaOH. This is the most important reason why most of the studies, mentioned above were considered invalid. Although valid acute ecotoxicity tests and chronic ecotoxicity tests with NaOH are not available, there is no need for additional testing with NaOH. A significant number of acute toxicity tests are available, and the results of the tests are more or less consistent. Altogether they give a sufficient indication of acute toxicity levels of sodium hydroxide."

> "Furthermore, acute toxicity data cannot be used to derive a PNEC or a PNEC added for sodium hydroxide. Aquatic ecosystems are characterised by an alkalinity/pH, and

the organisms of the ecosystem are adapted to these specific natural conditions. Based on the natural alkalinity of waters, organisms will have different optimum pH conditions, ranging from poorly buffered waters with a pH of 6 or less to very hard waters with pH values up to 9. A lot of information is available about the relationship between pH and ecosystem structure and also natural variations in pH of aquatic ecosystems have been quantified and reported extensively in ecological publications and handbooks."

"Normally a PNEC or a PNEC added has to be derived from the available ecotoxicity data. A PNEC added is a PNEC which is based on added concentrations of a chemical (added risk approach). Based on the available data it is not considered useful to derive a PNEC or a PNEC added for NaOH because:

- The natural pH of aquatic ecosystems can vary significantly between aquatic ecosystems,
- Also, the sensitivity of the aquatic ecosystems to a change of the pH can vary significantly between aquatic ecosystems and
- The change in pH due to an anthropogenic NaOH addition is influenced significantly by the buffer capacity of the receiving water."

"Although a PNEC or a PNEC added was not calculated for NaOH, there is a need to assess the environmental effect of a NaOH (alkaline) discharge. Based on the pH and buffer capacity of effluent and receiving water and the dilution factor of the effluent, the pH of the receiving water after the discharge can be calculated. Of course, the pH change can also be measured very easily via a laboratory experiment or by conducting field measurements. The change in pH should be compared with the natural variation in pH of the receiving water and based on this comparison it should be assessed if the pH change is acceptable."

Based on the information above, PNEC values for freshwater, sediment, and soil were not derived for sodium hydroxide.

PBT Assessment

Sodium hydroxide is an inorganic salt that dissociates completely to sodium and hydroxide ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both sodium and hydroxide ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria are not considered applicable to this inorganic salt.

Sodium and hydroxide ions are essential to all living organisms, and their intracellular, and extracellular concentrations are actively regulated. Thus, sodium hydroxide is not expected to bioaccumulate.

No chronic toxicity data exist on sodium hydroxide; however, the acute $E(L)C_{50}$ values are >1 mg/L in fish, invertebrates and algae. Thus, sodium hydroxide does not meet the screening criteria for toxicity.

The overall conclusion is that sodium hydroxide is not a PBT substance.

References

De Groot et al. (2002). The addition of sodium hydroxide to a solution with sodium bicarbonate to a fixed pH. Solvay Pharmaceuticals Int. Doc. No. 8320/47/01; cited in OECD, 2002a,b.

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UNEP. (1995). Water quality of world river basins. UNEP Environment Library No. 14, Nairobi, Kenya; cited in OECD, 2002a,b.

Environmental Assessment

Sodium Polyacrylate
(CAS No. 9003-04-7)

Sodium polyacrylates are polymers that range in molecular weight (MW) from 1,000 to 78,000 (HERA, 2014). The sodium polyacrylates mostly used in detergents have a typical molecular weight of approximately 4,500 (HERA, 2014).

Biodegradation

Sodium polyacrylates are not readily biodegradable but are partly accessible to ultimate biodegradation particularly under long incubation conditions. Sodium polyacrylates with MW of <2,000 are partly biodegradable under the conditions of soil and sediment inoculation. Test results with activated sludge inoculum indicate different elimination degrees, apparently due to adsorption and precipitation processes. The removal degrees of different sodium polyacrylates show no clear relationship between elimination extent and molecular weight (HERA, 2014).

Bioaccumulation

No experimental studies are available on sodium polyacrylates. Estimated bioconcentration factors based on octanol-water coefficients are not appropriate since the molecular weights of these polymers are higher than the molecular weight range for the QSAR models. Due to their high molecular weights, sodium polyacrylates are not expected to bioaccumulate. In addition, these water-soluble polymers can form insoluble calcium salts in natural waters, suggesting that bioaccumulation is unlikely.

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies on sodium polyacrylates.

Table 1: Acute Aquatic Toxicity Studies on Sodium Polyacrylates

Mean MW	Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
1,000	*Brachydanio rerio*	96-hr LC_{50}	>200	1	HERA, 2014
1,000	*Salmo gairdneri*	96-hr LC_{50}	>1,000	1	HERA, 2014
1,200	*Leuciscus idus*	96-hr LC_{50}	>500	1	HERA, 2014
2,000	*Brachydanio rerio*	96-hr LC_{50}	>200	1	HERA, 2014
2,500	*Leuciscus idus*	96-hr LC_{50}	>500	1	HERA, 2014
4,500	*Lepomis macrochirus*	96-hr LC_{50}	>1,000	1	HERA, 2014
4,500	*Lepomis macrochirus*	96-hr LC_{50}	>1,000	1	HERA, 2014
8,000	*Leuciscus idus*	96-hr LC_{50}	>500	1	HERA, 2014
10,000	*Lepomis macrochirus*	96-hr LC_{50}	>1,000	1	HERA, 2014

Mean MW	Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
15,000	*Leuciscus idus*	96-hr LC_{50}	>10,000	1	HERA, 2014
78,000	*Brachydanio rerio*	96-hr LC_{50}	>400	2	HERA, 2014
1,000	*Daphnia magna*	48-hr EC_{50}	>200	1	HERA, 2014
1,000	*Daphnia magna*	48-hr EC_{50}	>1,000	1	HERA, 2014
2,000	*Daphnia magna*	48-hr EC_{50}	>200	1	HERA, 2014
4,500	*Daphnia magna*	48-hr EC_{50}	>200	1	HERA, 2014
4,500	*Daphnia magna*	48-hr EC_{50}	>1,000	1	HERA, 2014
78,000	*Daphnia magna*	24-hr EC_{50}	276	2	HERA, 2014
8,000	*Selenastrum capricornutum*	72-hr EC_{50}	40	1	HERA, 2014
78,000	*Scenedesmus subspicatus*	96-hr EC_{50}	44	2	HERA, 2014

Table 2 lists the results of chronic aquatic toxicity studies on sodium polyacrylates.

Table 2: Chronic Aquatic Toxicity Studies on Sodium Polyacrylates (HERA, 2014)

Mean MW	Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
4,500	*Pimephales promelas*	32-d NOEC	56	2	HERA, 2014
4,500	*Brachydanio rerio*	28-d NOEC	>450	1	HERA, 2014
78,000	*Brachydanio rerio*	14-d NOEC	>400	2	HERA, 2014
4,500	*Daphnia magna*	21-d NOEC	450	1	HERA, 2014
4,500	*Daphnia magna*	21-d NOEC	58	1	HERA, 2014
4,500	*Daphnia magna*	21-d NOEC	12	2	HERA, 2014
78,000	*Daphnia magna*	21-d NOEC	100	2	HERA, 2014
4,500	*Scenedesmus subspicatus*	96-hr NOEC	180	2	HERA, 2014
78,000	*Scenedesmus subspicatus*	96-hr NOEC	32.8	2	HERA, 2014

There is considerable variability in the chronic aquatic toxicity results for *Daphnia magna* for sodium polyacrylates with the same molecular weight of 4,500. This was discussed in HERA (2014) and was explained by the solubility of sodium polyacrylates in water. In distilled water, the solubility of sodium polyacrylates with the molecular weight of 4,500 is >400 mg/L;

however, under test conditions water solubility will decrease due to the presence of Ca^{++} and Mg^{++} (as measured by water hardness). In a study by BASF (reviewed in HERA, 2014), the water solubility of sodium polyacrylate (MW 4,500) was determined with radiolabelled compounds in a test system with a calcium concentration of 70 mg/L, which corresponds to the mean water hardness to the media used in an OECD TG 202 test. Under these conditions, the water solubility of sodium polyacrylate was 1.3 mg/L after 24 hours. So, one explanation for the variability of the chronic *Daphnia* studies may be due to differences in water hardness.

Toxicity to Sediment Organisms

The 96-hr EC_0 to *Chironomus riparius* (larvae) is >4,500 mg/kg sediment dry weight (HERA, 2014).

Terrestrial Toxicity

The results of terrestrial toxicity studies on sodium polyacrylate polymers are listed below in Table 3.

Table 3: Terrestrial Toxicity Studies on Sodium Polyacrylates (HERA, 2014)

Mean MW	Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
4,500	*Eisenia foetida foetida*	14-d EC_0	1,000	1	HERA, 2014
78,000	*Eisenia foetida andrei*	14-d EC_0	1,000	2	HERA, 2014
78,000	*Brassica rapa*	21-d NOEC	1,000	2	HERA, 2014
4,500	Nitrogen transformation*	28-d EC_{10}	>2,500	1	HERA, 2014
4,500	Carbon transformation*	28-d EC_{10}	>2,500	1	HERA, 2014

*Soil organisms.

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (>200 mg/L), invertebrates (>200 mg/L), and plants (40 mg/L). Results from chronic studies are also available for all three trophic levels, with the lowest NOEC being 12 mg/L for invertebrates. On the basis that the data consists of short-term and long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported NOEC of 12 mg/L for invertebrates. The $PNEC_{water}$ is 1.2 mg/L.

$PNEC_{sediment}$: Experimental results are available for one trophic level. There were no visual signs of toxicity to *Chironomus riparius* (larvae) at the highest concentration tested (>4,500 mg/kg sediment dry weight) (HERA, 2014). The EC_0 is considered to be above 4,500 mg/kg and an assessment factor cannot apply. Thus, the equilibrium partitioning method will be used

to determine the $PNEC_{sed}$. The HERA (2014) risk assessment calculated a $PNEC_{sed}$ of 130 mg/kg sediment wet weight using the default of 0.05 as the weight fraction of organic carbon in sediment according to the EU Technical Guidance Document (TGD) (EC, 2003).

$PNEC_{soil}$: Experimental results are available for three trophic levels. An acute LC_{50} value is available for earthworms (1,000 mg/kg soil dry weight). A 21-day NOEC for *Brassica rapa* was reported to be 1,000 mg/kg soil dry weight. Results from two long-term studies are available for soil microorganisms, with the NOECs for nitrogen and carbon transformation being >2,500 mg/kg soil dry weight. On the basis that the data consists of short-term tests, as well as one long-term test from one trophic level, an assessment factor of 100 has been applied to the lowest reported long-term NOEC of >2,500 mg/kg soil dry weight. The $PNEC_{soil}$ is 25 mg/kg soil dry weight.

PBT Assessment

The sodium polyacrylates are not readily biodegradable; thus, they meet the screening criteria for persistence.

The sodium polyacrylates are expected to have high molecular weights and are not expected to be bioavailable. Thus, these polymers do not meet the criteria for bioaccumulation.

Chronic NOECs for fish, daphnia and algae are available for sodium polyacrylates, and the NOEC values are >0.1 mg/L. Thus, sodium polyacrylates do not meet the screening criteria for toxicity.

The overall conclusion is that sodium polyacrylates are not PBT substances.

References

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Environmental Assessment

Sodium tetraborate decahydrate
[Disodium tetraborate decahydrate; Borax]
(CAS No. 1303-96-4)

Environmental Fate

Many minerals contain boron, which is present as the sodium or calcium borate salt. Thus, boron is ubiquitous and widely distributed in the environment. It is present in rocks, soil and water and is released into the environment primarily from the weathering of rock and soil, volatilization of sea water, and anthropogenic activity.

Sodium tetraborate tetrahydrate ($Na_2B_4O \bullet 10H_2O$) is very soluble in water, with the main species in freshwater being the borate ion $[B(OH)_4]^-$ and boric acid $B(OH)_3$, depending on the pH. The relative proportion of boric acid and borate ions is controlled by pH: $B(OH)_3 + 2H_2O \Leftrightarrow [B(OH)_4]^- + H_3O^-$. In dilute aqueous solutions, boric acid does not dissociate at pH <7; at pH values between 7 and 11, both boric acid and borate ions are present. In dilute aqueous solutions and physiological conditions, the predominant species present is un-dissociated boric acid. So, the consideration of boric acid addresses the relevant environmental stability properties for borates.

In natural waters, boron forms stable species and exists primarily as un-dissociated boric acid $[B(OH)_3]$ and complex polyanions (*e.g.,* $[B(OH)_4]^-$). These forms of boron are highly soluble and not easily removed from solution by natural mechanisms. Borate and boric acid are in equilibrium depending on the pH of the water. At an acidic pH, boron exists in solution mainly as un-dissociated boric acid, whereas at alkaline pH it is present as borate ions.

Degradation is not applicable to inorganic borates, such as sodium tetraborate decahydrate. It is not subject to hydrolysis, photodegradation, or biodegradation (ECHA). Inorganic borates are subject to chemical transformation processes (adsorption, complexation, precipitation, fixation) once released into the environment (ECHA).

The WHO review of boron (WHO, 1998) noted that "highly water soluble materials are unlikely to bioaccumulate to any significant degree and that borate species are all present essentially as un-dissociated and highly soluble boric acid at neutral pH". A BCF of <0.1 was reported in Chinook salmon fed boron-supplemented diets for 60 to 90 days (Hamilton and Wiedmeyer, 1990).

Exposure to borates are often expressed in terms of boron (B) equivalents based on the fraction of boron in the source substance on a molecular weight basis. The B equivalents used are a generic designation rather than a designation of the element boron. The factor for converting sodium tetraborate decahydrate to B-equivalents is 0.1134.

Aquatic Toxicity

The summary of the data used by ANZECC to develop a water quality guideline for boron is as follows:

Freshwater Fish

The chronic values for four species ranged from 40 µg/L (32-day LOEC in *O. mykiss*) to 27,600 µg/L (32-day LOEC in *O. mykiss*). Other *O. mykiss* data were order of magnitude higher than 40 µg/L, including those from the same paper (2,100 µg/L for an 87-day NOEC and 27,600 µg/L for a 32-day LC_{50}). All other geometric means were >4,000 µg/L.

Freshwater Crustaceans

The chronic data ranged from a 21-day MATC value of 4,665 µg/L for *Daphnia magna* based on growth to an LC_{50} value of 54,200 µg/L from a 21-day *Daphnia* study. A measured NOEC of 6,000 µg/L based on reproduction was also reported.

Freshwater Algae

The data ranged from a 14-day NOEC of 400 µg/L for *Chlorella pyrenoidosa* to a NOEC of 5,200 µg/L for *Chlorella vulgaris*. Both values are based on population growth.

Terrestrial Toxicity

There are considerable number of terrestrial toxicity studies on borates. See the ECHA REACH database (ECHA) for summaries of the relevant studies.

Derivation of PNECs

$PNEC_{water}$: The ANZECC water quality guideline (2000) used a "freshwater high reliability trigger value for boron of 370 µg/L was calculated using the statistical distribution method at 95% protection."

"Although the 95% protection level is higher than the 32-day LOEC of 100 µg/L for *O. mykiss*, this figure appeared anomalous and other data on this species showed much less toxicity. The low figure may need to be checked. The 95% figure is considered sufficiently protective for slightly-moderate disturbed ecosystems" (ANZECC, 2000).

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Sodium tetraborate, anhydrous dissociates completely in water and its environmental distribution is dominated by its high water solubility. K_{ow} and K_{oc} parameters do not readily apply to inorganics, such as sodium tetraborate, anhydrous. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sed}$. Based on the its properties, no adsorption of sodium tetraborate, anhydrous to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: In the ECHA REACH database (ECHA), a $PNEC_{soil}$ was derived for boron using the species sensitivity distribution method and an assessment factor of 2. The $PNEC_{soil}$ was determined to be 5.7 mg/kg soil dry weight.

PBT Assessment

Sodium tetraborate decahydrate is an inorganic compound that dissociates completely to boric acid and the borate anion in aqueous media. Biodegradation is not applicable to these inorganic compounds; both boric acid and borate are also ubiquitous and are present in most water, soil

and sediment. For the purposes of this PBT assessment, the persistent criteria are not considered applicable to sodium tetraborate decahydrate.

Sodium tetraborate decahydrate is a water-soluble substance that is not expected to bioaccumulate. Limited data indicate that bioaccumulation (BCF values are low) is not significant in aquatic and terrestrial food chains. Thus, it does not meet the criteria for bioaccumulation.

Boric acid and inorganic borates are reproductive toxicants and have been classified under GHS as known or presumed human reproductive toxicants (Category 1B). Thus, sodium tetraborate decahydrate meets the PBT criteria of toxicity.

The overall conclusion is that sodium tetraborate decahydrate is not a PBT substance.

References

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ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances

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APPENDIX G.11 HALLIBURTON HYBOR-DELTA HYDRAULIC FRACTURING FLUID SYSTEMS

ACETIC ACID

This dossier on acetic acid does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of acetic acid in its use in drilling muds and hydraulic fracturing fluids. The majority of information presented in this dossier was obtained from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC): Acetic acid

CAS RN: 64-19-7

Molecular formula: $C_2H_4O_2$

Molecular weight: 60.1

Synonyms: Acetic acid, ethanoic acid, ethylic acid, methane carboxylic acid, vinegar acid

SMILES: CC(=O)O

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Acetic Acid

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Colorless liquid with a pungent odor.	2	ECHA
Melting Point	16.64°C	2	ECHA
Boiling Point	117.9°C	2	ECHA
Density	1.04 g/cm^3	2	ECHA
Vapor Pressure	20.79 hPa @ 25°C	2	ECHA
Partition Coefficient (log K_{ow})	-0.17	2	ECHA

Water Solubility	602.9 g/L	2	ECHA
Flash Point	39ºC @ 101.3 kPa	2	ECHA
Auto flammability	463ºC	2	ECHA
Viscosity	1.056 mPa s @ 25ºC	2	ECHA
Dissociation constant	4.756 @ 25ºC	2	ECHA

Acetic acid readily dissociates in aqueous media to the acetate ($H_3C2O_2^-$) and hydrogen (H^+) ions.

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

The acetate ion of acetic acid is readily biodegradable, is not expected to bioaccumulate, and has a low potential to adsorb to soil.

B. Biodegradation

Acetic acid was readily biodegradable a non-acclimated freshwater study. Degradation was 96% after 20 days (Price et al., 1974; ECHA) [Kl. score = 2]. Acetic acid is also readily biodegradable under anaerobic conditions (Kameya et al., 1995) [Kl. score = 2].

C. Environmental Distribution

Adsorption/desorption

No experimental data are available for acetic acid. Using KOCWIN in EPISUITE™ (EPA, 2017), the estimated K_{oc} values from log K_{ow} and the molecular connectivity index (MCI) are 1.153 and 1.0 L/kg ,respectively.

D. Bioaccumulation

There are no bioaccumulation studies on acetic acid. Bioaccumulation of acetic acid is not expected to occur because acetic acid dissociates completely in aqueous solution to acetate and its hydrogen ion. Both ions are ubiquitous in the environment. Acetate is naturally found in eukaryotic and prokaryotic cells and is involved in their biochemical pathways.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Acetic acid is a corrosive liquid. Depending on the concentration, aqueous solutions of acetic acid are either corrosive, irritating, or non-irritating to the skin, eyes, and gastrointestinal tract. Vapours from aqueous solutions of acetic acid can cause respiratory irritation. There are no adequate repeated dose toxicity studies on acetic acid. Acetic acid is not genotoxic. Positive findings have been reported in some *in vitro* genotoxicity studies, and are considered to be the result of the pH change in the test system. Animals studies have shown no developmental toxicity from ingestion of acetic acid.

B. Acute Toxicity

The oral LD_{50} of the sodium salt of acetic acid in rats is 3,310 mg/kg (Woodard et al., 1941; ECHA) [Kl. score =2]. The oral LD_{50} of the acetic acid in unfasted rats is 3,530 mg/kg (ECHA) [Kl. score =4]. The oral LD_{50} of the sodium salt of acetic acid in mice is 4,960 mg/kg (Smyth et al., 1951; ECHA) [Kl. score =2].

The 4-hour inhalation LC_{50} in rats for acetic acid vapor is 11.4 mg/L. There were clinical signs that were indicative of corrosion (ECHA) [Kl. score = 2].

C. Irritation

Application of a 3.3% or a 10% aqueous solution of acetic acid to the skin of rabbits for 4 hours was slightly irritating. The Primary Dermal Irritation Index scores were 0.5 and 1.1, respectively (Nixon et al., 1990; ECHA) [Kl. score = 2]. Application of a 10% solution of acetic acid to the skin of rabbits for 4 hours under semi-occlusive conditions was slightly irritating (ECHA) [Kl. score = 2].

Instillation of 0.1 mL of a 10% solution of acetic acid to the eyes of rabbits was considered irritating. The mean of the 24, 48, and 72 hours scores were: 2.67 for erythema; 1.67 for chemosis; 1.72 for corneal opacity; and a mean of 87% corneal swelling (Jacobs and Martens, 1989; ECHA) [Kl. score = 2]

D. Sensitization

No studies are available.

E. Repeated Dose Toxicity

<u>Oral</u>

No adequate studies for human health risk assessment are available.

Inhalation

No studies are available.

Dermal

No adequate studies for human health risk assessment are available.

F. Genotoxicity

In Vitro Studies

The *in vitro* genotoxicity studies on acetic acid are presented below in Table 2.

Table 2: *In vitro* Genotoxicity Studies on Acetic Acid

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* strains)	NC	-	2	Ishidate et al. (1984); ECHA
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	Zeiger et al. (1992); ECHA
Chromosomal aberrations (CHO cells)	-**	-**	2	Morita et al. (1990); ECHA
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	-***	-***	2	Seifried et al. (2006); ECHA

*+, positive; -, negative; NC, not conducted.
**A dose-dependent increase in chromosomal aberrations was observed with 10 mM acetic acid (-S9) and 8 mM acetic acid (+S9). These concentrations were close to the cytotoxic limit at which the cells could no longer be evaluated. These effects were abolished by neutralizing the test medium or increasing the buffer capacity. These results suggest that the positive findings are due to the acidic pH of the incubation medium rather than a consequence of an intrinsic clastogenic potential of acetic acid.
***Acetic anhydride (hydrolyzes to acetic acid in aqueous media).

In vivo Studies

No studies are available on acetic acid.

A bone marrow micronucleus study has been conducted on acetic anhydride (which hydrolyses to acetic acid). Male and female SD rats were exposed by inhalation to 0, 1, 5, or 20 ppm acetic anhydride, 6 hours/day, 5 days/week for 13 weeks. The incidence of micronucleated immature erythrocytes was not increased at any exposure concentration (ECHA) [Kl. score = 1]

G. Carcinogenicity

No oral or inhalation studies are available.

No deaths and no skin tumors were seen when acetic acid was applied dermally once a week to CD-1 mice for 32 weeks (Slaga et al., 1975; ECHA) [Kl. score = 4].

H. Reproductive Toxicity

No studies are available.

I. Developmental Toxicity

Pregnant female Wistar rats were dosed by oral gavage with 0 or various concentrations up to 1,600 mg/kg apple cider vinegar (5% acetic acid) on gestational days 6 to 15. There were no maternal or developmental toxicity at any dose level. The NOAEL for maternal and developmental toxicity is 1,600 mg/kg-day (ECHA). [Kl. score = 2]

Pregnant female CD-1 mice were dosed by oral gavage with 0, 16, 74.3, 345, or 1,600 mg/kg apple cider vinegar (5% acetic acid) on gestational days 6 to 15. There were no treatment-related effects on maternal or fetal survival, or on soft or skeletal tissues. There was no effect on the fetal development in the presence of slight maternal toxicity (reduced body weight gain) at 345 mg/kg. At 1,600 mg/kg, there was an increase in the number of litters containing a dead fetus and some reductions in ossification. The NOAELs for maternal and developmental toxicity are 74.3 and 345 mg/kg-day, respectively (ECHA). [Kl. score = 2]

Pregnant female Dutch-belted rabbits were dosed by oral gavage with 0, 16, 74.3, 345, or 1,600 mg/kg apple cider vinegar (5% acetic acid) on gestational days 6 to 18. There were no treatment-related effects on maternal or fetal survival, or on soft or skeletal tissues. There was a reduction in the pregnancy rate in the high-dose group; and a dose-dependent decrease in maternal body weights at $\geq$74.3 mg/kg. Some deaths or abortions occurred in all treated groups and some litter losses were reported at $\geq$345 mg/kg. Maternal effects were much more noticeable than the effects on fetal development. These findings have been considered a consequence of the bactericidal properties of orally administered acetic

acid within the gastrointestinal tract of female rabbits, and not a direct effect on embryonic implantation and development of acetic acid (EU, 2008). It is likely that this accounts for the apparent increased sensitivity of this species to oral administration of acetic acid. The NOAEL for developmental toxicity is 1,600 mg/kg-day; a NOAEL for maternal toxicity was not identified (ECHA). [Kl. score = 2]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for acetic acid follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

There are no repeated dose toxicity studies that were considered adequate for human health risk assessment.

The Joint FAO/WHO Expert Committee on Food Additives (JECFA) has maintained a group ADI of "not limited" for acetic acid and its potassium and sodium salts (JECFA).

The Australian drinking water guidance value for pH may apply to acetic acid.

B. Cancer

There are no carcinogenicity studies by the oral or inhalation route. A dermal carcinogenicity study in mice showed no carcinogenic activity when acetic acid was applied to the skin for 32 weeks. Thus, a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Acetic acid is a flammable liquid.

Acetic acid does not exhibit the following physico-chemical properties:

- Explosivity
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Acetic acid is of moderate acute toxicity concern to aquatic organisms, in part because of the effect of pH changes from the dissociated hydrogen ion. The acetate ion is of low acute toxicity concern to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

Table 3 presents the results of acute aquatic toxicity studies on acetic acid and potassium acetate.

Table 3: Acute Aquatic Toxicity Studies on Acetic acid and Potassium Acetate

Test Substance	Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Potassium acetate	*Oncorhynchus mykiss*	96-h LC_{50}	>300.82*	2	ECHA
Potassium acetate	*Danio rerio*	96-h LC_{50}	>300.82*	2	ECHA
Acetic acid	*Oncorhynchus mykiss*	96-h LC_{50}	64.8 (measured)	4	ECHA
Acetic acid	*Oncorhynchus mykiss*	96-h LC_{50}	31.3 – 67.6	4	ECHA
Potassium acetate	*Daphnia magna*	48-h EC_{50}	>300.82*	2	ECHA
Acetic acid	*Daphnia magna*	48-h EC_{50}	79.5 (measured)	4	ECHA
Acetic acid	*Daphnia magna*	48-h EC_{50}	18.9 (measured)	4	ECHA
Acetic acid	*Desmodesmus subspicatus*	72-h EC_{50}	486.5	4	ECHA

*As the acetate ion.

Chronic Studies

In a 21-day fish (*Oncorhynchus mykiss*) chronic study, the measured NOEC values for 60% and 100% acetic acid were 57.2 and 34.3 mg/L, respectively (ECHA). [Kl. score = 4]

In a 21-day *Daphnia* reproduction study, the measured NOEC for 60% and 100% acetic acid were 80 and 31.4 mg/L, respectively (ECHA). [Kl. score = 4]

In a 21-day *Daphnia* reproduction study, the measured NOEC for 100% acetic acid was 22.7 mg/L (ECHA). [Kl. score = 4]

C. Terrestrial Toxicity

No data are available.

D. Calculation of PNEC

The PNEC calculations for acetic acid follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. For the acute toxicity studies, data are available on both acetic acid and potassium acetate; both substances dissociate completely in aqueous media to the acetate anion and the corresponding cations (H^+ and K^+). The toxicity of these substances is expected to be driven by the acetate ion, with the cations having a minor role. The toxicity data on potassium acetate are preferred because of the absence of a potential pH change from the dissociated H^+ ion of acetic acid. For the chronic toxicity studies, only acetic acid has been tested for two trophic levels: fish and invertebrates. These studies will not be used to derive the PNEC value; however, an assessment factor of 100 will be applied to the lowest acute $E(L)C_{50}$ values.

From the potassium acetate studies, acute $E(L)C_{50}$ values (adjusted for acetic acid) are available for fish (300.82 mg/L) and *Daphnia* (300.82 mg/L). By applying an assessment factor of 100 to the $E(L)C_{50}$ value of 300.82 mg/L from either fish or *Daphnia*, the $PNEC_{aquatic}$ for acetic acid is 3.0 mg/L.

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 1.9 mg/kg sediment wet weight.

The calculations are as follows:

$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$
$= (0.82/1280) \times 1000 \times 3.0$
$= 1.9$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$K_{sed\text{-}water} = 0.8 + [(0.2 \times Kp_{sed})/1000 \times BD_{solid}]$
$= 0.8 + [(0.2 \times 0.04/1000 \times 2400]$
$= 0.82$

Where:
Kp_{sed} = solid-water partition coefficient (L/kg).
BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$Kp_{sed} = K_{oc} \times f_{oc}$
$= 1.0 \times 0.04$
$= 0.04$

Where:
K_{oc} = organic carbon normalized distribution coefficient (L/kg). The K_{oc} for acetic acid calculated from EPISUITE™ using the MCI is 1.0 L/kg .
F_{oc} = fraction of organic carbon in sediment = 0.04 [default].

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is 0.04 mg/kg soil dry weight.

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
$= (0.02/1500) \times 1000 \times 3.0$
$= 0.04$

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$

= 1.0 x 0.02
= 0.02

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for aceti acid calculated from EPISUITE™ using the MCI is 1.0 L/kg .
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Acetic acid is readily biodegradable; thus, it does not meet the screening criteria for persistence.

Bioaccumulation of acetic acid is not expected to occur because acetic acid dissociates completely in aqueous media to acetate and its hydrogen ion. Both ions are ubiquitous in the environment. Acetate is naturally found in eukaryotic and prokaryotic cells and is involved in their biochemical pathways. The log K_{ow} for acetic acid is -0.17. Thus, acetic acid does not meet the screening criteria for bioaccumulation.

The NOECs from the chronic aquatic toxicity studies on acetic acid are >0.1 mg/L. The $E(L)C_{50}$ values for potassium acetate are > 1 mg/L. Thus, acetic acid does not meet the criteria for toxicity.

The overall conclusion is that acetic acid is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Flammable Liquid Category 3
Skin Corrosion Category 1A

EU:
≥90%: Skin Corrosion 1A
≥25% to <90%: Skin Corrosion 1B
≥10% to <25%: Skin irritant Category 2; Eye irritant Category 2

In addition to the hazard statements corresponding the GHS classifications (if Skin Corrosion 1A or 1B is included), the following non-GHS hazard statement is to be added to the SDS: AUH071: Corrosive to the Respiratory Tract.

B. Labelling

Danger

C. Pictogram



X. SAFETY AND HANDLING

Eye Contact
Immediately flush open eyes with plenty of water for at least 15 minutes. Remove contacts, if present and easy to do. Get medical attention immediately, preferably a physician for an ophthalmologic examination.

Skin Contact
For minor skin contact, avoid spreading material on unaffected skin. Remove and isolate contaminated clothing. Wash the contaminated area of body with soap and fresh water. Get medical attention immediately.

Inhalation
Move person to fresh air. Administer oxygen if breathing is difficult. Do not use mouth-to-mouth method if victim inhaled the substance; give artificial respiration with the air of a pocket mask equipped with a one-way valve or other proper respiratory medical device. Give artificial respiration if victim is not breathing. Get medical attention immediately.

Ingestion
Rinse mouth and lips with plenty of water if person is conscious. Do not induce vomiting. Do not use mouth-to-mouth method if victim had ingested the substance. Obtain medical attention immediately if ingested.

Notes to Physician
Treat as a corrosive due to pH of the material. All treatments should be based on observed signs and symptoms of distress in the patient.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Use water spray or fog, foam, dry chemical or carbon dioxide. Do not use straight streams of water.

Specific Exposure Hazards
Flammable liquid and vapor. Vapors are flammable and heavier than air. Vapors may travel across the ground and reach remote ignition sources causing a flashback fire danger. Emits toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: carbon dioxide, carbon monoxide.

Special Protective Equipment for Firefighters
Structural firefighter's protective clothing provides limited protection in fire situations only; it is not effective in spill situations where direct contact with the substance is possible. Wear chemical protective clothing that is specifically recommended by the manufacturer. It may provide little or no thermal protection. Wear positive pressure self-contained breathing apparatus (SCBA). Move containers from fire area if you can do it without risk.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Isolate area. Keep unnecessary and unprotected personnel from entering the area. Use personal protective clothing. Ensure adequate ventilation. Wear respiratory protection if ventilation is inadequate. Do not breath mist, vapors, or spray Avoid contact with skin, eye, and clothing. Eliminate all sources of ignition.

Environmental Precautions
Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled
Eliminate all sources of ignition. All equipment used when handling the material must be grounded. A vapor suppressing foam may be used to reduce vapors. Use clean non-sparking tools to collect absorbed material. Pick up with suitable absorbent material and transfer to a container for chemical waste. For large amounts: dike spillage and pump off product into container for chemical waste. Dispose of contaminated material as prescribed.

D. STORAGE AND HANDLING

General Handling

Prevent exposure to ignition sources (i.e., use non-sparking tools and explosion-proof equipment). Avoid contact with eyes, skin, and clothing. Avoid breathing vapor. Wash thoroughly after handling. Keep container closed. Use with adequate ventilation. Use proper bonding and/or ground procedures. However, bonding and grounds may not eliminate the hazard from static accumulation. Peroxides may form upon prolonged storage. Exposure to light, heat or air significantly increases peroxide formation. If evaporated to a residue, the mixture of peroxides residue and material vapor may explode when exposed to heat or shock.

Storage

Keep container tightly closed. Store in a cool, well-ventilated area away from heat and light. Storage containers should be grounded and bonded. Fixed storage containers, transfer containers and associated equipment should be grounded and bonded to prevent accumulation of static charge.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards

The workplace exposure standard for acetic acid in Australia is 10 ppm (25 mg/m^3) as a 8-hr TWA and 15 ppm (37 mg/m^3) as a 15-min STEL.

Engineering Controls

Good general ventilation should be used. Ventilation rates should be matched to conditions. If applicable, use process enclosures, local exhaust ventilation, or other engineering controls to maintain airborne levels below recommended exposure limits. If exposure limits have not been established, maintain airborne levels to an acceptable level.

Personal Protection Equipment

Respiratory Protection:

If workers are exposed to concentrations above the exposure limit, they must use appropriate, certified respirators. If there are no applicable exposure limit requirements or guidelines, use an approved respirator. Selection of air-purifying or positive pressure supplied-air will depend on the specific operation and the potential airborne concentration of the product. For emergency conditions, use an approved positive-pressure self-contained breathing apparatus.

Hand Protection:

Use gloves chemically resistant to this material. Consult the SDS for appropriate glove barrier materials.

Skin Protection:

Use protective clothing chemically resistant to the this material. Selection of specific items such as face shield, boots, apron, or full body suit will depend on the task.

Eye protection*:*
Use chemical goggles.

Other Precautions:
Wash hands, forearms, and face thoroughly after handling chemical products, before eating, smoking, and using the lavatory and at the end of the working period. Appropriate techniques should be used to remove potentially contaminated clothing. Wash contaminated clothing before reusing. Ensure that eyewash stations and safety showers are close to the workstation location.

F. TRANSPORT INFORMATION

For glacial acetic acid or >80% acetic acid solutions:

UN 2789 (ACETIC ACID, GLACIAL or ACETIC ACID SOLUTION)
Class: 8
Packing Group: II

For ≥50% to 80% acetic acid solutions:

UN 2790 (ACETIC ACID SOLUTION)
Class: 8
Packing Group: II

For >10% to <50% acetic acid solutions:

UN 2790 (ACETIC ACID SOLUTION)
Class: 8
Packing Group: III

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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ALCOHOLS, C12-15, ETHOXYLATED

This dossier on alcohols, C12-15, ethoxylated does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of alcohols, C12-15, ethoxylated in its use in drilling muds and hydraulic fracturing fluids. The information presented in this dossier was obtained primarily from the Human & Environmental Risk Assessment on Ingredients of European Household Cleaning Products: Alcohol Ethoxylates (HERA, 2009), and from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA).. Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name: Alcohols, C12-15, ethoxylated

CAS RN: 68131-39-5

Molecular formula: Not available (UVCB substance)

Molecular weight: Not available (UVCB substance)

Synonyms: Alcohols, C12-15, ethoxylated

SMILES: Not available (UVCB substance)

Alcohol ethoxylates (AE) are a class of non-ionic surfactants that have the basic structure $C_{x-y}AE_n$. The subscript (x-y) following the 'C' indicates the range of carbon chain units. The hydrocarbon chain can be either linear or branched. AEs also contain an ethylene oxide (E) chain attached to the alcohol. The degree of ethylene oxide polymerization is indicated by the subscript (n) which indicates the average number of ethylene oxide units. Alcohols, C12-15, ethoxylated (CAS No. 68131-39-5) has an average number of 1 to 2.5 moles of ethylene oxide units.

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Alcohols, C12-15, Ethoxylated (1 to 2.5 moles ethoxylated)

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Clear liquid with a rancy odor*	2	ECHA
Melting Point	7.22°C	2	ECHA
Boiling Point	ca. 287°C	1	ECHA
Density	0.926 g/cm^3 @ 15.56°C	1	ECHA

Vapor Pressure	Negligible	-	ECHA
Partition coefficient (log K_{ow})	5.06* @ 25°C	2	ECHA
Water Solubility	7 – 63 mg/L @ 25°C	2	ECHA
Flash Point	165.56°C	2	ECHA
Auto flammability	235°C	2	ECHA
Viscosity	28.1 mPA s (dynamic) @ 20°C	2	ECHA

*Based on alcohols, C12-14, ethoxylated (1 to 2.5 EO) [CAS No. 68439-50-9]
**Weight-averaged log K_{oc} of whole substance based on normalized composition

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Alcohols, C12-15, ethoxylated is readily biodegradable. It has a low potential for bioaccumulation and a moderate potential for absorption to soil and sediment.

B. Biodegradation

Alcohols, C12-15, ethoxylated is readily biodegradable. In an OECD 301B test, degradation was 72% in 28 days, but failed the 10-day window (ECHA) [Kl. score = 1].

An alcohol, C12-15, ethoxylated (7 EO) degraded 80 to 88% in 28 days when tested using a shake-flask CO_2-evolution test method (ECHA) [Kl. score = 2].

C. Environmental Distribution

Adsorption/desorption

No experimental data are available for alcohols, C12-15, ethoxylated. Using KOCWIN in EPISUITE™ (EPA, 2019), the estimated K_{oc} values for surrogates of alcohols, C12-15, ethoxylated are:

C12 linear alcohol, ethoxylated (2 EO): 279.5 L/kg (MCI) and 464.2 L/kg (K_{ow})

C15 linear alcohol, ethoxylated (2 EO): 1,691 L/kg (MCI) and 3,018 L/kg (K_{ow})

E. Bioaccumulation

The BCF values for alcohol ethoxylates in fathead minnows have been reported to range from <5 to 387.5 (Toll et al., 2000). The uptake rates varied from 330 to 1660 (L x kg/d) and elimination rates varied from 3.3 to 59 per day (Toll et al., 2000). The high concentrations in fish is thought

to be prevented by an efficient biotransformation of the alcohol ethoxylates, leading to a high elimination rate.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

The acute toxicity of alcohols, C12-15, ethoxylated is low by the oral and dermal routes. The skin irritation rabbit studies on alcohols, C12-15, ethoxylated have shown mixed results, but human patch studies on these alcohol ethoxylates do not support a skin irritant classification. Alcohols, C12-15, ethoxylated is expected to be irritating to the eyes of rabbits. Alcohols, C12-15, ethoxylated is not a skin sensitizer. Repeated dose toxicity studies on alcohol ethoxylates similar to alcohols, C12-15, ethoxylated in rats do not indicate any target organ effects. These alcohol ethoxylates are not genotoxic, carcinogenic, and have a low potential for reproductive and developmental toxicity.

B. Acute Toxicity

No acute toxicity studies are available on alcohols, C12-15, ethoxylated.

The oral LD_{50} in rats for $C_{12\text{-}15}AE_3$ is >5,000 mg/kg (ECHA) [Kl. score = 2]. The oral LD_{50} in rats for $C_{12\text{-}15}AE_7$ is 1,700 mg/kg (HERA, 2009) [Kl. score = 2]. The oral LD_{50} value in rats for $C_{12\text{-}13}AE_{6.5}$ is 2,100 mg/kg (HERA, 2009) [Kl. score = 2]. The oral LD_{50} value in rats for $C_{12\text{-}15}AE_{11}$ is >2,000 mg/kg in males and between 1,000 and 2,000 mg/kg in females (HERA, 2009) [Kl. score = 2]. The oral LD_{50} values in rats for $C_{14\text{-}15}AE_{13}$ in two separate studies are 1,100 and 1,000 mg/kg (HERA, 2009) [Kl. score = 2]. The relative number of EO units, but not the carbon chain length, appears to influence acute oral toxicity (HERA, 2009).

An acute dermal LD_{50} values of >2,000 mg/kg were determined for $C_{12\text{-}14}AE_3$ and $C_{12\text{-}14}AE_6$ in two separate studies (HERA, 2009) [Kl. score = 2]. The acute dermal LD_{50} of $C_{12\text{-}15}AE_7$ is >2,000 mg/kg (HERA, 2009) [Kl. score = 2].

C. Irritation

Skin
Application of 0.5 mL isotridecanol, ethoxylated (3 EO) to the skin of rabbits for 4 hours under occlusive conditions was considered irritating (ECHA) [Kl. score = 2].

Application of 0.5 mL isotridecanol, ethoxylated (3 EO) to the skin of rabbits for 4 hours under semi-occlusive conditions was not considered irritating (ECHA) [Kl. score = 2].

In a 24-hour human patch test, there was some short-lived redness in some individuals from the application of $C_{12\text{-}14}AE_3$, but there was no scaling or edema in any subjects (HERA, 2009) [Kl. score = 2].

In a standard 4-hour human patch test, the irritation potential of $C_{12\text{-}15}AE_5$ and $C_{12\text{-}15}AE_5$ were compared to 20% sodium dodecyl sulfate (which is classified a skin irritant under GHS). The results showed that neither alcohol ethoxylate should be classified as a skin irritant (Basketter et al., 2004) [Kl. score = 2].

Eye

Most alcohol ethoxylates tested as the undiluted neat test material are moderately to severely irritating to the eyes of rabbits, with an eye irritation index (EII) ranging from >25 to 50 (HERA, 2009). The alcohol ethoxylates $C_{12\text{-}14}AE_3$, $C_{12\text{-}14}AE_6$, $C_{13}AE_6$, and $C_{12\text{-}14}AE_{10}$ were found to be moderately to severely irritating to the eyes of rabbits (HERA, 2009). In another study, $C_{12\text{-}15}AE_{11}$ was considered moderately to severely irritating to the eyes of rabbits (HERA, 2009).

Some alcohol ethoxylates were reported to be practically or minimally irritating to the eyes of rabbits with EII scores of 0.5 to 15. These alcohol ethoxylates include: $C_{12\text{-}15}AE_3$, $C_{14\text{-}15}AE_7$, $C_{12\text{-}14}AE_{15}$, $C_{14\text{-}15}AE_{18}$, and $C_{13}AE_{20}$ (HERA, 2009).

D. Sensitization

No sensitization studies are available on alcohols, C12-15, ethoxylated.

In a guinea pig maximization test, $C_{12\text{-}13}AE_{<2.5}$ (CAS No. 66455-14-9) was not considered a skin sensitizer (ECHA) [Kl. score = 2].

In a guinea pig maximization tests, $C_{12\text{-}15}AE_3$, $C_{12\text{-}15}AE_7$, and $C_{14\text{-}15}AE_7$ were not considered skin sensitizers (HERA, 2009) [Kl. scores = 2].

E. Repeated Dose Toxicity

Oral

Rats were given in their diet 0%, 0.0313%, 0.0625%, 0.125, 0.25, 0.5 or 1.0% $C_{12\text{-}15}AE_7$ for 90 days. The animals in the $\geq$0.25% groups showed significantly reduced body weight gain, which was associated with marked decreases in food and water consumption. Relative liver weights were significantly increased in the $\geq$0.5% male rats and $\geq$0.25% females. Histopathologic examination showed hepatocytic enlargement in the $\geq$0.125% groups, suggesting increased liver metabolism on the basis of increased alkaline phosphatase activity at the higher dose levels. The NOAEL was established at 0.0625% in the diet or 102 mg/kg-day (HERA, 2009) [Kl. score = 2].

Rats were fed $C_{12\text{-}14}AE_7$ in the diet at concentrations of 0%, 0.0313%, 0.0625%, 0.125%, 0.25%, 0.5% and 1.0% for 90 days. The animals in the $\geq$0.25% groups showed significantly reduced body weight gain, which was associated with marked decreases in food and water consumption. Relative liver weights were significantly increased in the $\geq$0.5% male rats and $\geq$0.25% females. Histopathologic examination showed hepatocytic enlargement in the $\geq$0.125% groups, suggesting increased liver metabolism on the basis of increased alkaline phosphatase activity at the higher dose levels. The NOAEL was established at 0.0625% in the diet or 110 mg/kg-day (HERA, 2009) [Kl. score = 2].

Male and female Wistar rats given in their diet 0, 300, 1,000, 3,000, and 10,000 ppm $C_{14\text{-}15}AE_7$ for 90 days. There were no deaths during the study. Mean body weights and feed were lower in 10,000 ppm males and the 3,000 ppm females. Feed consumption was lower in the 10,000 ppm animals and the 3,000 ppm females. Relative liver weights were increased in the $\geq$3,000 ppm

animals, and relative spleen weights were increased in the 10,000 ppm males. Clinical chemistry changes were noted in the 10,000 ppm group and consisted of significantly higher urea, chloride and potassium levels in males; significantly higher urea, chloride and cholesterol in females. Increased total leucocytes and lymphocytes were seen in the 10,000 ppm animals and in the 3,000 ppm males. The 10,000 ppm females showed lower numbers of neutrophils; mean cell volume and mean cell hemoglobin were identified in one or both sexes fed in the ≥3,000 ppm dose groups. In the 1,000 ppm females, there were minor, but statistically significant changes in the liver and kidney weights and plasma urea concentration; these effects were considered to be of no toxicological significance. Histopathologic examination showed no treatment-related effects at any dose level. The NOAEL for this study is 1,000 ppm in the diet, which corresponded to 50 mg/kg-day (HERA, 2009) [Kl. score = 2].

Rats were given in their diet 0, 0.1, 0.5, or 1% $C_{14\text{-}15}AE_7$ for 90 days. Body weights, food intake, organ weights, and hematology and clinical chemistry parameters were similar across groups. The NOAEL for this study is 1% in the diet, which corresponded to 700 and 785 mg/kg-day for males and females, respectively (HERA, 2009) [Kl. score = 2].

Rats were given in their diet 0, 0.1, 0.5 or 1% $C_{12\text{-}13}AE_{6.5}$ or $C_{14\text{-}15}AE_7$ for two years. Body weight gain was reduced in the 1% males and ≥0.5% females, which was likely due to the reduced food consumption in these animals. At study termination, organ to body weight ratios were increased in the ≥0.5% females (liver, kidney and brain), 1% females (heart), and 1% males (liver). A dose-related focal myocarditis was observed in males. While focal myocarditis is commonly observed in non-treated aging rats, the incidence in the treated animals were higher than in the controls. The NOAEL was established at 0.1% or 50 mg/kg-day (HERA, 2009) [Kl. score = 2].

Male and female CR rats were given in their diet $C_{14\text{-}15}AE_7$ at 0.1, 0.5 and 1% for two years. A treatment-related body weight depression was observed in females at the two highest treatment levels and in males at the 1% dose level, probably due to the poor palatability of the diet. Relative liver, kidney, heart, and thyroid/parathyroid gland weights were increased in the 1% dietary group at study termination. Histopathological examination showed a dose-related increase in the incidence of focal myocarditis at the 12-month time point, but not at the end of the study at two years. The NOAEL for this study was considered to be 0.5% in the diet, which corresponded to 162 and 190 mg/kg-day for males and females, respectively (HERA, 2009) [Kl. score = 2].

Inhalation

No studies are available.

Dermal

No adequate studies are available.

F. Genotoxicity

In Vitro Studies

The genotoxicity studies conducted on alcohol ethoxylates are reviewed in HERA (2009). The results of few of the *in vitro* studies on similar alcohol ethoxylates to alcohols, C12-15,

ethoxylated are presented below in Table 2.

Table 2: *In Vitro* Genotoxicity Studies on Selected Alcohol Ethoxylates

Test Substance	Test System	Results*		Klimisch Score	References
		-S9	+S9		
$C_{14-15}AE_7$	Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	HERA, 2009
$C_{14-15}AE_7$	Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	HERA, 2009
$C_{14}AE_{12}$	Chromosomal aberrations (CHO cells)	-	-	2	HERA, 2009

*+, positive; -, negative

In Vivo Studies

In two separate studies, CD-1 mice were given an intraperitoneal dose of 0, 50, or 100 mg/kg $C_{12-15}AE_3$ or $C_{12-14}AE_9$. There were no increases in the frequency of micronuclei in the bone marrow cells (Talmage, 1994) [Kl. score = 2].

Male and female Tunstall rats were given a single oral gavage dose of 0, 250, 500, or 1,000 mg/kg $C_{14-15}AE_7$. There were no increases in chromosomal aberrations in the bone marrow cells (HERA, 2009 [Kl. score = 2].

G. Carcinogenicity

No studies are available on alcohols, C12-15, ethoxylated.

Male and female Sprague-Dawley rats were given in their diet $C_{12-13}AE_{6.5}$ in the diet at doses up to 1% (500 mg/kg-day). Reduced food consumption was noted at the higher dose levels (*i.e.*, 0.5 and 1% for females and 1% for males), resulting in a lower body weight gain compared to the control group. No treatment-related histopathology was found and no increase in tumor incidence was observed (HERA, 2009) [Kl. score = 2].

Male and female Charles River rats were given in their diet 0, 0.1, 0.5 or 1% $C_{14-15}AE_7$ for two years. There were no treatment-related changes in general behavior and appearance. The survival rate of the test animals was comparable if not better than the controls. Body weights of the 0.5% females and the 1% males and females had significantly lower weight gains than the control. There were no treatment-related effects on organ weights and tumor incidence (HERA, 2009) [Kl. score = 2].

Male and female Sprague-Dawley rats were given in their diet $C_{14-15}AE_7$ at 0.1, 0.5 and 1% for two years. A treatment-related body weight depression was observed in females at the two highest treatment levels and in males at the 1% dose level, probably due to the poor palatability of the diet. There was no evidence for any carcinogenic activity (HERA, 2009) [Kl. score = 2].

H. Reproductive Toxicity

No studies are available on alcohols, C12-15, ethoxylated.

CD rats were given in their diet 0, 0.05, 0.1 or 0.5% (approximately 0, 25, 50 or 250 mg/kg-day) $C_{12}AE_6$ in a two-generation reproductive toxicity study. There were no treatment related effects in the parents or pups on general behavior, appearance or survival. At 0.5%, there was reduced weight gain in both the parental animals and the pups compared to the controls. Fertility was unaffected by treatment. The NOAEL for reproductive toxicity is 0.5% in the diet, which corresponds to 250 mg/kg-day (HERA, 2009) [Kl. score = 2].

In a two-generation developmental and teratogenicity study, CD rats were given in their diet 0, 0.05, 0.1 or 0.5% $C_{14\text{-}15}AE_7$ (approximately 0, 25, 50 or 250 mg/kg-day). Three of the treated groups were given the test substance continuously throughout the study; in the other three groups the females received the test substance on GD 6-15 and the males were untreated. None of the deaths of parental rats during the study was considered to be compound-related. There were no treatment-related changes in behavior or appearance in the parental rats or pups. Slightly lower body weight gain was noted in the 0.5% continuously treated females. Food consumption was similar for control and treated rats. Fertility, gestation and viability indices were similar across groups. The average 21-day body weights for the 0.5% continuous treated pups were significantly lower than that of the control. Relative liver weights of the 0.5% continuously treated F_1 parental animals were increased at the 91-day sacrifice; relative liver weights of the 0.5% continuously treated males were also increased at the 60-day and caesarean section sacrifices. There were no treatment-related histopathological lesions in any of the tissues from the F_0 and F_1 generations. The NOAEL for reproductive toxicity is 0.5% in the diet or 250 mg/kg-day (HERA, 2009) [Kl. score = 2].

I. Developmental Toxicity

No studies are available on alcohols, C12-15, ethoxylated.

In a two-generation reproductive toxicity study, Charles River rats were given in their diet 0, 0.05, 0.1 or 0.5% (about 0, 25, 50 or 250 mg/kg-day) $C_{12}AE_6$. General behavior, appearance and survival were unaffected by treatment. At the 0.5% dose level, adults and pups gained less weight than the control rats. In the 0.5% dose group, there was a statistical increase in embryo lethality and soft tissue anomalies and at the 0.1% there was a statistical decrease in mean fetal liver weight. Neither of these effects was considered to be treatment-related by the authors as they showed no dose response characteristics. The NOAEL for maternal toxicity is 50 mg/kg-day. The NOAEL for developmental and teratogenicity is 0.1% in the diet or 50 mg/kg-day (HERA, 2009) [Kl. score = 2].

Pregnant rabbits were given by oral gavage 0, 50, 100 or 200 mg/kg $C_{12}AE$ from gestational days 2 to 16. Nine control rabbits and 31 treated rabbits died during the study. Surviving rabbits at the 200 mg/kg dose group generally showed slight losses of body weight. At 100 and 200 mg/kg, ataxia and a slight decrease in body weight was observed in the pregnant animals. In seven treated and two control rabbits, early deliveries were recorded. There were no treatment-related effects on corpora lutea, implantations, number of live fetuses and spontaneous abortions. The NOAEL for maternal toxicity is 50 mg/kg-day; the NOAEL for developmental toxicity is 200 mg/kg-day (HERA, 2009) [Kl. score = 2].

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for alcohols, C12-15, ethoxylated follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

Two-year dietary studies in rats have been conducted on alcohol ethoxylates $C_{12\text{-}13}AE_{6.5}$ and $C_{14\text{-}15}AE_{7}$ (HERA, 2009). The lowest NOAEL from these studies is 50 mg/kg-day based on increased organ weights. The NOAEL of 50 mg/kg-day will be used to derive an oral reference dose and drinking water guidance value for alcohols, C12-15, ethoxylated.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 50/(10 x 10 x 1 x 1 x 1) = 50/100 = 0.5 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (0.5 x 70 x 0.1)/2 = 1.8 mg/L

B. Cancer

Several alcohol ethoxylates similar to alcohols, C12-16, ethoxylated were not carcinogenic to rats in a two-year dietary study. Thus, a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Alcohols, C12-15, ethoxylated does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Alcohol, C12-15, ethoxylated has moderate chronic toxicity concern to aquatic life.

B. Aquatic Toxicity

In developing a water quality guideline for alcohol ethoxylates (ANZECC, 2000), the toxicity data was normalized for a specific alkyl chain length or a specific number of ethoxylate (EO) groups. The NOECs listed below were normalized to an alkyl chain length of C13.3 and EO of 8.2.

Freshwater fish: 2 species, 720 to 1,500 μg/L.

Freshwater crustaceans: 2 species, 590 to 860 μg/L.

Freshwater rotifers: 1 species, *Brachionus calyciflorus*, 1,300 μg/L

Freshwater algae, diatoms and blue-green algae: 6 species, 200 to 8,700 μg/L.

Freshwater mesocosms: 4 NOEC data for multiple species tests were 80, 80, 320, and 330 μg/L, although replication was insufficient to meet OECD (1992) requirements. Normalized data were 380, 380, 320, and 1,520 μg/L.

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

$PNEC_{water}$: The ANZECC water quality guideline (2000) for freshwater is: **"A high reliability trigger value of 140 μg/L was derived for AE (normalized data) using the statistical distribution method with 95% protection."**

For the purposes of calculating the PNEC values for sediment and soil, the $PNEC_{water}$ will be 0.14 mg/L.

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ values are 0.9 to 5.6 mg/kg soil dry weight.

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
$= (9.28/1500) \times 1000 \times 0.14$
$= 0.87$

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
$= (60.36/1500) \times 1000 \times 0.14$
$= 5.63$

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
$= 464 \times 0.02$
$= 9.28$

$Kp_{soil} = K_{oc} \times f_{oc}$
$= 3{,}018 \times 0.02$
$= 60.36$

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} values for alcohols, C12-15, ethoxylated based on K_{ow} values range from 464 to 3,018 L/kg (see section III.C)
.
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Alcohols, C12-15, ethoxylated is readily biodegradable and thus does not meet the screening criteria for persistence.

The bioconcentration factors (BCF) in fish for ethoxylated alcohols (which includes alcohols, C12-15, ethoxylated) have been reported to range from <5 to 387.5. Thus, alcohols, C12-15, ethoxylated does not meet the screening criteria for bioaccumulation.

The chronic NOEC values for alcohols ethoxylates are >0.1 mg/L. Thus, alcohols, C12-15, ethoxylated do not meet the criteria for toxicity.

The overall conclusion is that alcohols, C12-15, ethoxylated is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Acute Toxicity Category 4 [Oral]
Eye Irritant Category 2
Aquatic Chronic Toxicity Category 3

B. Labelling

Warning

C. Pictogram



X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
Rinse immediately with plenty of running water. If easy to do, remove contact lenses. Get medical attention.

Skin Contact
Wash with soap and water. Get medical attention if symptoms occur.

Inhalation
Treat symptomatically. Move to fresh air. Get medical attention.

Ingestion
Rinse mouth with water and then drink plenty of water. Never give anything by mouth to an unconscious person. Seek medical attention.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, dry chemical, foam. Do not use water jet.

Specific Exposure Hazards
May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: carbon monoxide, carbon oxides.

Special Protective Equipment for Firefighters
Self-contained breathing apparatus and full protective clothing must be worn in case of fire.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Wear appropriate personal protective equipment. Do not breath mist or aerosol.

Environmental Precautions
Prevent from entering sewers, waterways, or low area

Steps to be Taken if Material is Released or Spilled
Absorb spill with inert absorbent material, then place in a container for chemical waste.

D. STORAGE AND HANDLING

General Handling
Protect against moisture. Shut containers immediately after taking product because product takes up the humidity of air. No special precautions are necessary beyond normal good hygiene practices.

Other Handling Precautions
Wash hands thoroughly after handling. Avoid breathing mists or aerosols.

Storage
Keep container closed.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards

Workplace Australia has not established an occupational exposure standard for isotridecanol, ethoxylated.

Engineering Controls
Good general ventilation should be used.

Personal Protection Equipment

Respiratory Protection:
Wear respiratory protection if ventilation is inadequate.

Hand Protection:
Chemical resistant protective gloves.

Skin Protection:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Chemical safety goggles.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible.

F. TRANSPORT INFORMATION

Isotridecanol, ethoxylated is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

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AMIDES, TALL OILS FATTY, N,N-BIS(HYDROXYETHYL)

This dossier on amides, tall oils fatty, N,N-bis(hydroxyethyl) does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of amides, tall oils fatty, N,N-bis(hydroxyethyl) in its use in drilling muds and hydraulic fracturing fluids. The information presented in this dossier was obtained from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997; Kl).

I. SUBTANCE IDENTIFICATION

Chemical Name: Amides, tall oils fatty, N,N-bis(hydroxyethyl)

CAS RN: 68155-20-4

Synonyms:

Synonyms for oleamide DEA listed below.

While no specific composition data are available on amides, tall oils fatty, N,N-bis(hydroxyethyl), it is expected to be a mixture of diethanolamides of the fatty acids that constitute tall oil, which is composed of predominantly C18 unsaturated fatty acids: 48% oleic acid, 35% linoleic acid, 7% conjugated linoleic acid (REF).

This dossier is based on information on Amides, C18-unsatd, N,N-bis(hydroxyethyl) [CAS No. 93-83-4]. This is justified because amides, tall oils fatty, N,N-bis(hydroxyethyl) is predominantly diethanolamides of unsaturated C18 fatty acids and there are no available studies on this substance.

AMIDES, C18-UNSATD., N,N-BIS(HYDROXYETHYL)

Chemical Name: Oleamide DEA

CAS RN: 93-83-4

Molecular formula: UVCB substance

Molecular weight: UVCB substance

Synonyms for oleamide DEA:
Oleyl diethanolamide;(9Z)-N,N-Bis(2-hydroxyethyl)-9-octadecenamide; (z)-n,n-bis(2-hydroxyethyl)-9-octadecenamide; 9-Octadecenamide, N,N-bis(2-hydroxyethyl)-, (Z)-; Alkamide DO-280;

N,N-Bis(2-hydroxyethyl)-9-octadecenamide; Alrosol O; Amisol ode; Clindrol 2000; Clindrol 2020, Comperlan OD; Diethanololeamide; EMID 6545; Emulsifier WHC; Lauridit OD; Mackamide O, Marlamid D 1885, N,N-Diethanololeamide, Nitrene NO, Oleamide, N,N-bis(2-hydroxyethyl)-, Oleic acid diethanolamide, Oleic acid diethanolamine condensate, Oleic diethanolamide, Schercomid ODA, Stafoam DO, Steinamid DO 280SE, Witcamide 511C

SMILES: Not applicable.

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Amides, C18-unsatd, N,N-bis(hydroxyethyl) [CAS No. 93-83-4]

Property	Value	Klimisch score	Reference
Physical state at 20ºC and 101.3 kPa	Liquid	2	ECHA
Melting point	ca. -80ºC	1	ECHA
Boiling point	>300ºC	1	ECHA
Density	0.967 g/cm^3@ 20ºC	1	ECHA
Vapor pressure	0 Pa @ 25ºC	1	ECHA
Partition coefficient (log K_{ow})	>6 (experimental)	1	ECHA
Water solubility	<1 mg/L @ 20ºC	1	ECHA
Flash point	218ºC	1	ECHA
Auto flammability	350ºC	1	ECHA
Viscosity	805.87 mPa s @ 20ºC	1	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

According to ECHA, hydrolysis studies were not conducted; “the study does not need to be conducted because the substance is readily biodegradable.” (ECHA)

B. Biodegradation

Amides, C18-unsatd, N,N-bis(hydroxyethyl) is readily biodegradable. In an OECD 301 D test, degradation was 70% after 28 days (ECHA) [Kl. score = 1]. In an OECD 301 B test, degradation was 79% after 14 days and 86% after 28 days (ECHA) [Kl. score = 1].

C. Environmental Distribution

Adsorption/desorption

No experimental data are available for amides, C18-unsatd, N,N-bis(hydroxyethyl). Using KOCWIN v2.00, the estimated K_{oc} values for the individual components were calculated using the molecular connectivity index (MCI) approach. The final K_{oc} value was calculated on a weighted-average basis using the mole fractions of the individual components. The final K_{oc} value is 1,717 L/kg.

D. Bioaccumulation

There are no bioaccumulation studies on amides, C18-unsatd, N,N-bis(hydroxyethyl). The bioaccumulation potential of amides, C18-unsatd, N,N-bis(hydroxyethyl) was estimated using BCFBAF v3.01. The final BCF was calculated on a weighted-average basis using the mole fractions of all individual components. The calculated BCF was 112.53 L/kg, indicating a low potential for bioaccumulation (ECHA).

IV. HUMAN HEALTH HAZARD ASSESSMENT

Human health toxicity data were obtained from ECHA, unless another source is explicitly cited.

A. Summary

Amides, C18-unsatd, N,N-bis(hydroxyethyl) are considered acutely toxic and an skin and eye irritant. It is not considered a skin sensitizer or toxic via repeated doses, and has no reported reproductive or developmental effects. It is not considered genotoxic or carcinogenic.

B. Acute Toxicity

Amides, C18-unsatd, N,N-bis(hydroxyethyl) is considered acutely toxic via oral route of exposure, with an LD50 of 10,000 mg/kg in male Sprague-Dawley rats (Kl = 2).

C. Irritation

Based on the available data, the test substance is considered irritating to both the skin and eyes. The available in vivo studies demonstrate:

- Clear irritation response following semi-occlusive exposure to the test substance for 24 h. The data support a classification as Skin Irrit. 2 - H315 (causes skin irritation) according to CLP (EC 1272/2008) criteria (Kl =1).

- Undiluted test substance showed irritation to rabbit eyes and supports classification as Eye Irrit. 2 – H319 (causes serious eye irritation) according to CLP (EC 1272/2008) criteria (Kl = 1).

D. Sensitization

The test substance is not expected to be a skin sensitiser based on a negative in vivo skin sensitisation study conducted on a structurally similar substance (Kl=1). Therefore no classification is required for sensitisation according to CLP (EC 1272/2008) criteria. There are no data on the respiratory sensitization potential of the substance.

E. Repeated Dose Toxicity

Based on the NOAEL derived from an oral subacute study in rat (>750 mg/kg bw/day) in which no treatment-related effects were observed, and observed effects in a chronic dermal study in rat (NOAEL of 50 mg/kg bw/day for systemic effects and LOAEL of 50 mg/kg bw/day for local effects), the test substance is not considered to meet the requirements for repeated dose toxicity classification according to CLP (EC 1272/2008) criteria. There are no data to evaluate the repeated dose toxicity classification for the inhalation exposure route.

F. Genotoxicity

The test substance and read across substance (amides, C8-18 (even numbered) and C18-unsatd. N,N bis(hydroxyethyl) were negative in short-term in vitro and in vivo genotoxicity tests. Therefore no classification is required for this endpoint according to CLP (EC 1272/2008) criteria.

In Vitro Studies

The *in vitro* studies conducted for this substance are described in Table 2. The referenced studies indicate that the substance is not mutagenic or genotoxic *in vitro.*

Table 2: *In vitro* Genotoxicity Studies

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
In vitro gene mutation study in bacteria (*S. typhimurium* TA97, TA98, TA100 and TA1535)	-	-	2	Irwin, 1999**
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	-	-	1	Irwin, 1999**
Bacterial reverse mutation (S. typhimurium and E. coli strains)	-	-	1	Verspeek-Rip, 2014**

*+, positive; -, negative. ** As cited in ECHA.

In Vivo Studies

A study was conducted to evaluate the potential of the test material to induce micronuclei in B6C3F1 mice. Under the conditions of the study, the test substance did not increase the frequencies of micronucleated normochromatic erythrocytes (NCEs) in peripheral blood of both male and female mice at the end of 13 weeks (Kl =1).

G. Carcinogenicity

No studies are available for assessing the carcinogenicity of this substance via the oral or inhalation routes of exposure.

Rodent tests indicate that the substance is not carcinogenic by the dermal route. A study was conducted to evaluate the effects of chronic exposure to the test substance in B6C3F1 mice. Under the test conditions, no evidence of carcinogenic activity was observed with the test substance at any tested dose levels in mice (Kl =1). A study was conducted to evaluate the effects of chronic exposure to the test substance in F344/N rats. Under the test conditions, no evidence of carcinogenic activity was observed with the test substance at any tested dose levels in rats (Kl =1).

H. Reproductive and Developmental Toxicity

No studies were available to assess the effects of the substance on reproduction. No adverse developmental effects were observed following administration of 1,000 mg/kg bw day to pregnant Sprague-Dawley rats (Kl = 2).

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

The lowest NOAEL from these studies is a 750 mg/kg bw/day based on bodyweight, hematology, clinical chemistry, urinalysis, gross and microscopic pathology in male and female rats from a 28-day oral gavage study (Potokar, 1983). The NOAEL of 750 mg/kg-day will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10

UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 10
UF_D (database uncertainty) = 1

Oral RfD = 750/(10 x 10 x 1 x 10 x 1) = 750/1000 = 7.5 mg/kg-day

Drinking water guidance value

The drinking water guidance value is calculated as:

(animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD, the drinking water guidance value is calculated as:

(oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:

Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (7.5 x 70 x 0.1)/2 = 26.3 mg/L

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies conducted on amides, C18-unsatd, N,N-bis(hydroxyethyl).

Table 3: Acute Aquatic Toxicity Studies on Amides, C18-unsatd, N,N-bis(hydroxyethyl)

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Danio rerio	96-hr LC_{50}	5.1	1	ECHA
Daphnia magna	48-hr EC_{50}	3.2	2	ECHA
Desmodesmus subspicatus	72-hr EC_{50}	18.6	2	ECHA

Chronic Studies

The 28-day NOEC to *Oncorhynchus mykiss* in a fish chronic toxicity study is 0.32 mg/L [nominal] and 0.26 mg/L [measured] (ECHA) [Kl. score = 2].

The 21-d NOEC in a *Daphnia* reproduction test is 0.1 mg/L [nominal] and 0.07 mg/L [measured] (ECHA) [Kl. score = 2].

The 72-hr EC_{10} to *Desmodesmus subspicatus* is 1.4 mg/L (ECHA) [Kl. score = 2].

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for amides, C18-unsatd, N,N-bis(hydroxyethyl) follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (5.1 mg/L), invertebrates (3.2 mg/L), and algae (18.6 mg/L). Results from chronic studies are available for fish (0.26 mg/L), invertebrates (0.07 mg/L), and algae (1.4 mg/L). On the basis that the data consists of short-term and long-term results for three trophic levels, an assessment factor of 10 has been applied to the lowest reported NOEC or EC_{10} value of 0.07 mg/L for invertebrates. The $PNEC_{water}$ is 0.007 mg/L.

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is 0.16 mg/kg soil dry weight.

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
$= (34.34/1500) \times 1000 \times 0.007$
$= 0.16$

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
$= 1717 \times 0.02$
$= 34.34$

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for Amides, C18-unsatd, N,N-bis(hydroxyethyl) based on the molecular connectivity index (MCI) is 1,717 L/kg (ECHA).
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Amides, C18-unsatd, N,N-bis(hydroxyethyl) is readily biodegradable; thus, it does not meet the screening criteria for persistence.

Based on an estimated BCF value of 113 L/kg, amides, C18-unsatd, N,N-bis(hydroxyethyl) does not meet the criteria for bioaccumulation.

The lowest chronic NOEC or EC_{10} value for amides, C18-unsatd, N,N-bis(hydroxyethyl) is <0.1 mg/L. Thus, amides, C18-unsatd, N,N-bis(hydroxyethyl) meets the criteria for toxicity.

The overall conclusion is that amides, C18-unsatd, N,N-bis(hydroxyethyl) is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Skin Irritant Category 2
Eye Irritant Category 2
Aquatic Chronic Toxicity Category 2

May cause respiratory tract irritation.

B. Labelling

Warning

C. Pictogram



X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
Rinse thoroughly for at least 15 minutes and consult a physician.

Skin Contact
Remove contaminated clothing. Wash with soap and plenty of water. Consult a physician immediately.

Inhalation
Move the person to fresh air.

Ingestion
Rinse mouth with water; consult a physician immediately. Do not induce vomiting.

Notes to Physician
No data available

Medical Conditions Aggravated by Exposure

No data available

Emergency Personnel Protection
No additional notes

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, alcohol-resistant foam, dry chemical, or carbon dioxide.

Specific Exposure Hazards
May be combustible at high temperatures; container explosion may occur under fire conditions or if heated. Hazardous combustion products include carbon oxides and nitrogen oxides.

Special Protective Equipment for Firefighters
As in any fire, wear self-contained breathing apparatus and full protective gear.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Remove all sources of ignition. Ensure adequate ventilation. Use personal protective equipment. Avoid dust formation. Avoid breathing vapours, mist, or gas. Evacuate unprotected persons.

Environmental Precautions
Stop the spill if possible and safe. Prevent from reaching drains, sewers, or waterways.

Steps to be Taken if Material is Released or Spilled
Contain spill material by diking or using inert absorbent such as vermiculite, dry sand, or earth. Transfer to a disposal or recovery container.

D. STORAGE AND HANDLING

General Handling
Avoid contact with skin and eyes. Avoid formation of dust and aerosols.

Other Handling Precautions
Provide appropriate exhaust ventilation at places where dust is formed. Do not eat or drink while working with chemical substances.

Storage

Store in a cool, dry, well-ventilated place. Keep container tightly closed.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
No data available.

Engineering Controls
Provide ventilation.

Personal Protection Equipment

Respiratory Protection:
Wear dust mask when handling large quantities

Hand Protection:
Wear impervious gloves, inspect gloves before use.

Skin Protection:
Wear impervious clothing; PPE is to be selected according to the concentration and amount of the substance to be handled.

Eye protection*:*
Safety glasses with side-shields conforming to EN166. Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

Other Precautions:
No data available

F. TRANSPORT INFORMATION

UN Number: Not regulated

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

XIII. REFERENCES

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

Department of the Environment, Water, Heritage and the Arts [DEWHA] (2009). Environmental risk assessment guidance manual for industrial chemicals, Department of the Environment, Water, Heritage and the Arts, Commonwealth of Australia.

ECHA. ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances

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European Chemicals Agency [ECHA] (2008). Guidance on Information Requirements and Chemical Safety Assessment, Chapter R11: PBT Assessment, European Chemicals Agency, Helsinki, Finland.

Klimisch, H.J., Andreae, M., and Tillmann, U. (1997). A systematic approach for evaluating the quality of experimental and toxicological and ecotoxicological data. Regul. Toxicol. Pharmacol. 25:1-5.

U.S. Environmental Protection Agency [EPA] (2019). EPISuite™ v. 4.11, United States Environmental Protection Agency, Office of Pollution Prevention and Toxics and Syracuse Research Corporation. Available at: https://www.epa.gov/tsca-screening-tools/epi-suitetm-estimation-program-interface.

BUTYL ALCOHOL (1-BUTANOL)

This dossier on butyl alcohol (1-butanol) does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of 1-butanol in its use in drilling muds and hydraulic fracturing fluids. The information presented in this dossier was obtained from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997; Kl).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC): Butan-1-ol

CAS RN: 71-36-3

Molecular formula: C4H10O

Molecular weight: 74.123

Synonyms: 1-Butanol, 1-Butyl alcohol, 1-hydroxybutane, Butan-1-ol, butyl alcohol, Butyl hydroxide, Butylalcohol, CCS 203, ET5740PTB, Hemostyp, Methylolpropane, n-Butanol, n-Butyl alcohol, N300PTB, Nacol 4, PP100, Propylcarbinol

SMILES: CCCCO

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of 1-Butanol

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Clear, colorless liquid with an alcoholic odor	2	ECHA
Melting point	<-90°C	2	ECHA
Boiling point	119°C	2	ECHA
Density	0.81 g/cm^3 @ 20°C	2	ECHA
Vapor pressure	< 10 hPa @20°C	2	ECHA
Partition coefficient (log K_{ow})	1 @ 25°C	1	ECHA

Property	Value	Klimisch score	Reference
Water solubility	66 g/L @ 20°C	1	ECHA
Flash point	35°C	2	ECHA
Auto flammability	355°C	1	ECHA
Viscosity	2.947 mPa s @ 20°C	2	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

1-Butanol is readily biodegradable and not expected to bioaccumulate. No experimental data are available for adsorption/desorption; the estimated Koc value is 3.471 L/kg.

A calculated logKoc of 0.54 is available, suggesting a high mobility of 1-butanol in soil.

B. Biodegradation

1-Butanol is readily biodegradable. In a BOD test, degradation was 87% after 10 days and 92% after 20 day, meeting the 10-day window (ECHA) [Kl. score = 2].

C. Environmental Distribution

Adsorption/desorption

No experimental data are available for 1-butanol. Using KOCWIN in EPISUITE™ (EPA, 2019), the estimated K_{oc} value from log K_{ow} is 10.01 L/kg. The estimated K_{oc} value from the molecular connectivity index (MCI) is 3.471 L/kg.

D. Bioaccumulation

There are no bioaccumulation studies on 1-butanol. 1-Butanol is not expected to bioaccumulate based on a log K_{ow} of 1.0 (ECHA).

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Butyl alcohol is slightly acutely toxic to experimental animals via the oral and dermal routes of exposure; a low acute toxicity was observed after inhalative exposure. The chemical is classified in Australia as respiratory system and skin irritant but is not

considered a skin sensitiser. Butyl alcohol is not expected to be genotoxic; although there are no data on the carcinogenicity of butyl alcohol, based on the lack of genotoxicity, it is not expected to be. Few studies have evaluated reproductive or developmental toxicity but the available studies do not indicate reproductive or developmental effects. Any developmental toxicity is expected to be secondary to maternal toxicity.

B. Acute Toxicity

Butyl alcohol is slightly acutely toxic to experimental animals via the oral and dermal routes of exposure; a low acute toxicity was observed after inhalative exposure.

Oral

The most sensitive LD50 value was provided by a study comparable to OECD TG 401 (Union Carbide Corporation 1967). Here, 60 -day-old female Harlan Wistar rats were dosed with butan-1 -ol at various dose levels per gavage. The acute LD50 value was 2.83 mL/kg bw in female rats, corresponding to 2290 mg/kg bw (calculated with a density of 0.81 g/mL). No further data were available.

A comparable LD50 level was observed in a study following the standard acute method with acceptable restrictions (Jenner et al.1967). In this study, 5 young adult Osborne-Mendel rats per sex were dosed with butan-1-ol at different, but unspecified doses. The rats were observed for 14 days and the LD50 values were calculated. After 14 d observation period, the LD50 was 2510 mg/kg bw in rats. Mortality occurred within 4 -18 h after dosing, and depression and coma were reported as clinical signs. Weighing and performance of necropsy was not reported.

In another oral acute study, groups of 10 female rats were orally gavaged with 3160, 3980, 5000 or 6300 mg/kg and observed for 14 days after dosing. Here, 0, 3, 8 and 10 rats died at dose levels of 3160, 3980, 5000 or 6300 mg/kg, respectively. Deaths following oral doses occurred in many cases within 4 hours and in all but one instance within 24 hours. The LD50 was 4360 mg/kg/bw for female rats (Union Carbide Corporation 1951).

For other common test species oral LD50 values were reported with limited details: 2680 mg/kg bw for mice (Rumyanstev et al., 1979, Val. 4), 3500 mg/kg bw for rabbits (Munch, 1972; Munch and Schwarze, 1925, Val. 4), 1200 mg/kg bw for Golden hamsters (Dubina and Maksimov, 1976, Val. 4), and a minimum lethal dose of 1782 mg/kg bw for dogs (Von Oettingen, 1943, Val. 4). In the ECETOC JACC (2003) document also one publication with an oral LD50 in rats below 2000 mg/kg (790 mg/kg) is reported.

Dermal

The most reliable data were provided by a study comparable to OECD TG 402 (Union Carbide Corporation 1951). Here, butan-1 -ol was applied to the shaved skin of rabbits for 24 hours under occlusive conditions. Four doses of 1.26 to 10 ml/kg were applied to groups of four male rabbits and a LD50 value of 4.24 ml/kg bw (corresponding to ca. 3434 mg/kg bw; calculated with a density of 0.81 g/mL) was determined after an observation period of 14 days. Three rabbits of the 5 mL/kg bw group and all rabbits of

the 10 ml/kg bw group died; all deaths occurred on the day of application. Body weight gain during the observation period was highly variable in the sublethal dose groups and negative in the survivor of the 5 mL/kg bw group. No information regarding clinical signs or local effects was available. In the ECETOC JACC (2003) document further dermal LD50 values in rabbits of 7600, 5300 and 4200 mg/kg are reported.

Inhalation

In a study similar to OECD TG 403, 10 Sprague-Dawley rats per sex per dose were whole-body exposed to vapour atmospheres of butan-1-ol for 4 h and observed for 14 d. The LC0 is >17.76 mg/L; no mortality or clinical signs were observed at 17.76 mg/L; only slightly reduced body weight gain was observed. Therefore, the LD50 level is considered to be > 20 mg/L (BASF 1979).

In another study, which was similar to the inhalation hazard test of OECD TG 403, 12 Sprague-Dawley rats of both sexes were exposed to a vapour saturated butan-1-ol atmosphere for 7 h. None of the animals died (BASF 1980).

Additionally, in a further study comparable to OECD TG 403 no mortalities were observed after exposure to a substantially saturated vapour for 8 hours in male rats and after exposure to 8000 ppm (ca. 24 mg/L) for 4 h in female rats, respectively. Poor coordination or prostration was observed in both trials (Union Carbide Corporation 1951).

C. Irritation

Respiratory Irritation

The chemical is classified in Australia as hazardous with the risk phrase ‘Irritating to respiratory system’ (Xi; R37) in HSIS (Safe Work Australia). The available data from observations in animals and humans support this classification.

Based on an inhalation study in mice, it was reported that 1268 ppm (3909 mg/ m^3) of the chemical was predicted to be intolerable in humans, 127 ppm (390.9 mg/ m^3) would be uncomfortable in humans and 13 ppm (40 mg/ m^3) was expected to have no effect on humans (OECD 2001).

Skin Irritation

The chemical is classified in Australia as hazardous with the risk phrase ‘Irritating to skin’ (Xi; R38) in HSIS (Safe Work Australia). The available data from observations in animals and humans support this classification.

Moderate irritation was reported in a 24 hour patch test (non-guideline study) where 405 or 500 mg of the chemical was applied to the skin of the rabbits. It was reported that these effects may be due to the chemical's defatting (chemical dissolving of dermal lipids from the skin) and drying characteristics (OECD 2001).

Another non-guideline study reported the chemical was a skin irritant in several Vienna white rabbits exposed to 0.5 mL of the chemical for five minutes, one hour or two hours under occlusive conditions. The animals were observed for eight days. The authors concluded that exposure for two hours under occlusive conditions resulted in higher Draize scores and observed superficial necrosis (death of tissue). However, there was no full thickness destruction of the skin (REACH).

Eye Irritation

The chemical is classified in Australia as hazardous with the risk phrase 'Risk of serious damage to the eyes' (Xi; R41) in HSIS (Safe Work Australia). The available data from observations in animals and humans support this classification.

The chemical was reported to be a severe eye irritant when tested according to OECD Test Guideline (TG) 405 using 0.1 mL of the chemical applied to three New Zealand white rabbits. Severe ocular lesions were present at the end of the seven-day observation period, indicating severe eye damage and irreversible effects on the eye (REACH).

The chemical was reported to be a severe eye irritant in rabbits in non-guideline studies where 1.62 or 20 mg of the chemical was applied into rabbit eyes over a 24 or 72 hour period (OECD 2001). An additional non-guideline study reported severe corneal irritation when 0.005 mL of the chemical was applied into rabbit eyes.

D. Sensitization

Based on available repeat dose dermal studies, the chemical is not expected to be a skin sensitiser. OECD (2001) reported that human studies and experience show that the chemical is not likely to be a skin sensitiser.

E. Repeated Dose Toxicity

Oral

A no observed adverse effect level (NOAEL) of 125 mg/kg bw/day and a lowest observed adverse effect level (LOAEL) of 500 mg/kg bw/day in male and female CD rats was reported based on results from a repeat dose oral study (Kl = 1) using the chemical (OECD 2001). Groups of male and female rats (30/sex/group) were administered the chemical via gavage at 0, 30, 125 or 500 mg/kg/day for 13 weeks. It was reported that ataxia (impaired muscle coordination) and hypoactivity were observed at the highest dose during the final six weeks of the study. No treatment related effects were reported in the 30 and 125 mg/kg/ bw/day dose groups (OECD 2001).

Inhalation

In a non-guideline study, the chemical was applied to the skin of rabbits under occlusive conditions over a period of 21 days. Local effects were reported such as drying of the skin, cracking, wrinkling and exfoliation of the epidermis. However, no systemic toxicity was reported (REACH). In another non-guideline repeat dose dermal study on rabbits, 42 to 55 mL/kg of the chemical applied to the skin of rabbits over four consecutive days

resulted in 100 % mortality. However, the same study reported that 30 applications of 20 mL/kg of the chemical over six weeks did not produce any deaths (OECD 2001).

Dermal
No data are available.

F. Genotoxicity
The chemical is not expected to be genotoxic.

The chemical tested negative in a number of tests for genotoxicity. These included several in vitro tests (OECD Guideline 473: mammalian chromosome aberration test on Chinese hamster lung fibroblasts V79; OECD Guideline 471: bacterial reverse mutation assay on *S. typhimurium* TA 98, TA 100, TA 98, TA 1535 and TA 1537; OECD Guideline 476: mammalian cell gene mutation test on Chinese hamster lung fibroblasts V79) and in vivo tests (OECD Guideline 474: mouse micronucleus) (OECD 2001, REACH).

In Vitro Studies

Table 2: *In vitro* Genotoxicity Studies on

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (S. typhimurium strain TA 98, TA 100, TA 98, TA 1535 and TA 1537)	-	-	2	Jung et al., 1992
Mammalian cell gene mutation (Chinese hamster lung fibroblasts (V79))	-	-	1	REACH

*+, positive; -, negative

In Vivo Studies
Fewer studies are available for in vivo testing but are also negative for genotoxicity. According to the results of a reliable mouse study conducted according to OECD Guideline 474 (Mammalian Erythrocyte Micronucleus Test) (Kl =1), the single oral administration of butan-1-ol did not lead to any increase in the number of polychromatic erythrocytes containing either small or large micronuclei. The rate of micronuclei was always in the same range as that of the negative control in all dose groups and at all sacrifice intervals. No inhibition of erythropoiesis determined from the ratio of polychromatic to normochromatic erythrocytes was detected.

G. Carcinogenicity
OECD (2001) reported that based on the number of negative mutagenicity and clastogenicity findings, the chemical is not expected to be a carcinogen. A weight of

evidence study reported that the chemical is not expected to have carcinogenic potential as it does not contain structural components to support carcinogenicity (REACH, HSDB).

H. Reproductive and Developmental Toxicity

The chemical is not expected to be toxic to reproduction (OECD 2001). In a non-guideline study, male and female Sprague Dawley (SD) rats were exposed to the chemical via inhalation at 0, 3000 or 6000 ppm for seven hours/day. Female rats were exposed to the chemical throughout gestation, while males were exposed to the chemical for six weeks prior to mating. No harmful effects on fertility or pregnancy rate were reported at any of the dose levels. In another non-guideline study, no testicular toxicity (effect on testes weight or histopathology) was reported in SD male rats that were administered the chemical via oral intubation at 533 mg/kg bw/day over six days (OECD 2001).

Any developmental effects were only reported to be observed secondary to maternal toxicity, so the chemical is not expected to be a developmental toxin. OECD (2001) reported that the chemical showed mild foetotoxicity and developmental variations in offspring only at or near the maternally toxic and, in some cases, lethal dose of 8000 ppm. Offspring of female SD rats exposed via inhalation to 0, 3500, 6000 or 8000 ppm of the chemical on gestations days 1 to 19, reported a reduction of foetal weights at 6000 and 8000 ppm and a slight increase in skeletal malformations at 8000 ppm but not at the lower dosage levels. At a maternally toxic dose of 8000 ppm, decreased weight gain, food consumption and dam deaths were reported. The NOAEL for offspring and dams was 3500 ppm as there was a slight decrease in foetal weight at the 6000 ppm dose level.

In another 20 day study in male and female SD rats exposed to 0, 3000 or 6000 ppm of the chemical via inhalation, a small number of behavioural and neurochemical variations in offspring at 6000 ppm were reported. No maternal toxicity was reported throughout gestation for females or for six weeks prior to mating for males as a result of maternal or paternal exposure. However, the effects observed in offspring were not regarded as biologically significant by the authors due to inconsistences between dose-response patterns.

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for butyl alcohol follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

<u>Oral</u>

The lowest NOAEL from these studies is 125 mg/kg-day based on CNS effects in rats from a 90-day oral gavage study (Kl = 1; REACH). The NOAEL of 125 mg/kg-day will

be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 3
UF_D (database uncertainty) = 1

Oral RfD = 125/(10 x 10 x 1 x 3 x 1) = 125/300 = 0.4 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:

Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (0.4 x 70 x 0.1)/2 = 1.4 mg/L

B. Cancer

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

1-Butanol is a flammable liquid.

1-Butanol does not exhibit the following physico-chemical properties:

- Explosivity
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies conducted on 1-butanol.

Table 3: Acute Aquatic Toxicity Studies on 1-Butanol.

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Pimephelas promelas	96-hr LC_{50}	1,376	1	ECHA
Daphnia magna	48-hr EC_{50}	1,328	1	ECHA
Pseudokirchneriella subcapitata	72-hr EC_{50}	225	1	ECHA

Chronic Studies

The 21-d NOEC from a *Daphnia* reproduction test is 4.1 mg/L (ECHA) [Kl. score = 2].

96-hr EC_{10} to *Pseudokirchneriella subcapitata* is 134 mg/L (ECHA) [Kl. score = 1].

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for 1-butanol follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (1,376 mg/L), invertebrates (1,328 mg/L), and algae (225 mg/L). Results from chronic studies are available for invertebrates (4.1 mg/L) and algae (124 mg/L). On the basis that the data consists of short-term studies for three trophic levels and long-term studies for two trophic levels, an assessment factor of 50 has been applied to the lowest reported EC_{10} value of 4.1 mg/L for fish. The $PNEC_{water}$ is 0.08 mg/L.

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is 0.004 mg/kg soil dry weight.

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
$= (0.07/1500) \times 1000 \times 0.08$
$= 0.004$

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
$= 3.471 \times 0.02$
$= 0.07$

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for 1-butanol based on the molecular connectivity index (MCI) is 3.471 L/kg (EPA, 2019).
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

1-Butanol is readily biodegradable; thus, it does not meet the screening criteria for persistence.

Based on a measured log K_{ow} of 1.0, 1-butanol does not meet the screening criteria for bioaccumulation.

The lowest chronic EC_{10} or NOEC value for 1-butanol is >0.1 mg/L. The acute $E(L)C_{50}$ values are >1 mg/L. Thus, 1-butanol does not meet the criteria for toxicity.

The overall conclusion is that 1-butanol is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification
Flammable liquid Category 3

Acute toxicity Category 4
Specific target organ toxicity Category 3
Skin irritation Category 2
Eye damage Category 1

B. Labelling

Danger

C. Pictogram



X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
Rinse continuously with water for several minutes. Remove contact lenses if present and easy to do so. Continue rinsing. Call physician or poison center.

Skin Contact
Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower.

Inhalation
Remove victim to fresh air and keep at rest in a position comfortable for breathing.

Ingestion
Call physician or poison center.

Notes to Physician
May cause drowsiness or dizziness

Irritating to eyes, respiratory system and skin. Central nervous system effects. Hearing impairment Treat symptomatically.

Medical Conditions Aggravated by Exposure
No data available

Emergency Personnel Protection

First-Aid Providers: Avoid exposure to blood or body fluids. Wear gloves and other necessary protective clothing. Dispose of contaminated clothing and equipment as bio-hazardous waste.

B. FIRE FIGHTING INFORMATION

Extinguishing Media

Use foam, dry chemical, CO2 or water spray for extinction. Alcohol-resistant Foam; butanol is an alcohol. Do not use a solid (straight) water stream as it may scatter and spread fire.

Specific Exposure Hazards

Combustion products include carbon monoxide and carbon dioxide. Flammable. May be ignited by heat, sparks or flames. Material can burn with invisible flame. Vapor may travel considerable distance to source of ignition and flash back.
Vapors may form explosive mixtures with air. Most vapors are heavier than air. They will spread along the ground and collect in low or confined areas (sewers, basements, tanks). Container explosion may occur under fire conditions or when heated. Fire may produce irritating, corrosive and/or toxic gases.

Special Protective Equipment for Firefighters

Wear SCBA and fully encapsulating, gas-tight suit when handling these substances. Structural firefighter's uniform is NOT effective for these materials.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions

Ensure adequate ventilation. Keep people away from and upwind of spill/leak. Avoid contact with skin, eyes and clothing. Use personal protective equipment. Remove all sources of ignition. Pay attention to flashback. Take precautionary measures against static discharges. All equipment used when handling the product must be grounded. Use spark-proof tools and explosion-proof equipment. In case of large spill, water spray or vapor-suppressing foam may be used to reduce vapors, but may not prevent ignition in closed spaces.

Environmental Precautions

Prevent further leakage or spillage if safe to do so. Prevent product from entering drains. Prevent entry into waterways, sewers, basements or confined areas. In case of large spill, dike if needed. Dike far ahead of liquid spill for later disposal.

Steps to be Taken if Material is Released or Spilled

Stop leak if you can do it without risk. Absorb spill with inert material (e.g. vermiculite, dry sand or earth).
Use appropriate tools to put the spilled material in a suitable chemical waste disposal container. Use clean non-sparking tools to collect absorbed material.
Clean contaminated surface thoroughly.

D. STORAGE AND HANDLING

General Handling
Wear personal protective equipment. Use only in well-ventilated areas. Avoid contact with skin, eyes and clothing.
Keep away from heat and sources of ignition. Do not breathe vapors or spray mist. Do not ingest. When using do not smoke. Handle in accordance with good industrial hygiene and safety practice.

Other Handling Precautions
Remove all sources of ignition. To avoid ignition of vapors by static electricity discharge, all metal parts of the equipment must be grounded. Keep away from incompatible materials.

Storage
Keep container tightly closed in a dry and well-ventilated place. Store at room temperature in the original container. Keep away from heat and sources of ignition. Store in a segregated and approved area. Store away from incompatible materials.
Incompatible Materials: Oxidizing agents, Acids, Alkali Metals, Halogens, Aluminum, Caustics, isocyanates

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
The workplace exposure standard for butanol in Australia is 152 mg/m3 as an 8-hr TWA. No STEL is listed.

Engineering Controls
Ensure adequate ventilation. Provide exhaust ventilation or other engineering controls to keep the airborne concentrations of vapors and mist below their respective threshold limit value.

Personal Protection Equipment

Respiratory Protection:
Where ventilation is not adequate, respiratory protection may be required. Avoid breathing vapours or mists. Select and use respirators appropriately. When mists or vapours exceed the exposure standards then the use of the following is recommended: Approved respirator with organic vapour and dust/mist filters. Filter capacity and respirator type depends on exposure levels.

Hand Protection: Use appropriate, impervious gloves. Inspect gloves before use.

Skin Protection:
Chemical resistant apron, long sleeved clothing

Eye protection*:*
Use face shield, chemical goggles or safety glasses with side shield protection as appropriate.

Other Precautions:
No additional notes available.

F. TRANSPORT INFORMATION

UN Number 1120
Hazard class 3

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

AICS: Listed

XIII. REFERENCES

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CHLOROUS ACID, SODIUM SALT

This dossier on chlorous acid, sodium salt does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of chlorous acid, sodium salt in its use in drilling muds and hydraulic fracturing fluids. The majority of information presented in this dossier was obtained from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC): Sodium chlorite

CAS RN: 7758-19-2

Molecular formula: $ClHO_2.Na$

Molecular weight: 90.44

Synonyms: Chlorous acid, sodium salt; sodium chlorite

SMILES: [O-]Cl=O.[Na+]

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Chlorous Acid, Sodium Salt

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	White solid, slightly hydroscopic crystals or flakes. Aqueous solutions are colorless to greenish yellow with a slight chlorine-like odor	2	ECHA
Melting Point	180 – 200°C; decomposes at 200°C	2	ECHA
Density	2.432 g/mL	1	ECHA
Vapor Pressure	1.1×10^{-7} Pa @ 25°C	1	ECHA

Partition Coefficient (log K_{ow})	<-2.7	1	ECHA
Water Solubility	Very soluble (572 g/L @ 20°C)	1	ECHA
Oxidizing Properties	25.6% aq. solution – not an oxidizing liquid	1	ECHA

Chlorous acid, sodium salt in its dry form is a strong oxidizer.

Chlorous acid, sodium salt readily dissociates in aqueous solutions to the sodium (Na^+) and chlorite (ClO_2^-) ion. The chlorite (ClO_2^-) ion is in equilibrium with chlorous acid ($HClO_2$) in water. The chemical reaction is as follows:

$ClO_2^- + H^+ \rightleftharpoons HClO_2$

At pH values found in environmental media or physiological fluids, the chlorite ion will be the predominant form (pK_a of chlorous acid is 1.94).

Under acidic conditions, chlorous acid ($HClO_2$) will predominate and will disintegrate to chlorine dioxide (ClO_2). Chlorine dioxide (ClO_2) will degrade further to chlorite (ClO_2^-), and, ultimately, the chloride ion (Cl^-) is formed. The proportion of each oxy-chlorine species depends in part on the pH of the solution.

III. ENVIRONMENTAL FATE PROPERTIES

Chlorous acid, sodium salt readily dissociates in aqueous solutions to the sodium (Na^+) and chlorite (ClO_2^-) ion. The chlorite ion will ultimately degrade to chloride ions. Both sodium and chloride ions are ubiquitous in the environment. Biodegradation is not applicable to sodium chlorite. Neither sodium chlorite nor its dissociated ions are expected to adsorb to soil or sediment, or bioaccumulate.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Chlorous acid, sodium salt (sodium chlorite) in solution is moderately-to-highly toxic by the oral route, but has low acute toxicity by the dermal route. It is corrosive the skin and eyes. It is not a skin sensitizer. The critical effect seen in rodents given repeated oral administration of sodium chlorite is hemolytic anemia. Sodium chlorite was not mutagenic in a bacterial reverse mutation (Ames) test; however, chlorine dioxide (which breaks down to chlorite) was mutagenic in the mouse lymphoma assay in the absence and presence of metabolic activation. *In vivo* genotoxicity studies on sodium chlorite were generally negative. No reproductive toxicity was seen in male or female rats given sodium chlorite

in drinking water. There was, however, an effect on post-natal development in pups from the first generation; the effect was not seen in the pups from the second generation. There was no developmental toxicity in pregnant female rabbits given sodium chlorite in drinking water.

B. Acute Toxicity

The oral LD_{50} in rats is 284 mg/kg (ECHA) [Kl. score = 1]. The oral LD_{50} in rats of a 31% aqueous solution of chlorous acid, sodium salt is 390 mg/kg (ECHA) [Kl. score = 2).

There are no acute inhalation toxicity studies.

The dermal LD_{50} in rabbits is 134 mg/kg (ECHA) [Kl. score = 1]. The dermal LD_{50} in rabbits of a 31% aqueous solution of chlorous acid, sodium salt is >2,000 mg/kg (ECHA) [Kl. score = 2).

C. Irritation

Application of 0.5 mL of undiluted chlorous acid, sodium salt to the skin of rabbits for 4 hours under occlusive conditions was corrosive (ECHA) [Kl. score = 2]. Application of 0.5 mL of a 34.5% solution of chlorous acid, sodium salt to the skin of rabbits for four hours under semi-occlusive conditions was essentially non-irritating (ECHA) [Kl. score = 1].

Instillation of 0.1 mL of a 31% aqueous solution of chlorous acid, sodium salt to the eyes of rabbits was severely irritating (ECHA) [Kl. score = 2].

D. Sensitization

Chlorous acid, sodium salt was not considered to be a skin sensitizer when tested in a mouse local lymph node assay (ECHA). [Kl. score = 1]

E. Repeated Dose Toxicity

<u>Oral</u>

Male and female Crj:CD(SD) rats were dosed by oral gavage with 0, 10, 25, or 80 mg/kg chlorous acid, sodium salt for 13 weeks. Five animals died during the study: one in the 25 mg/kg group and five in the 80 mg/kg group subsequent to blood sampling. The deaths in the 80 mg/kg group were likely treatment-related; the animals were anemic and blood sampling may have exacerbated this problem, contributing to their death. Clinical signs were noted in the 25 and 80 mg/kg animals, the most notable being salivation. Body weights and feed consumption were similar across all groups. Hematological effects were

noted in the 80 mg/kg animals. The group mean erythrocyte count was significantly lower (both sexes). In males, hematocrit and hemoglobin levels were significantly lower, and methemoglobin levels and neutrophils counts were significantly higher than controls. The reticulocyte count was increased, but was not statistically significant. Two of the 80 mg/kg rats that prematurely died had marked changes in these hematological parameters. Morphological changes were also seen in the blood smears of three 80 mg/kg females: these were polychromasia, poikilocytosis, macrocytosis, and neutrophilia. Lymphocyte counts were significantly lower than controls in the 80 mg/kg males, and was likely due to the increased neutrophil count. Where the primary red blood cell parameters (mean erythrocyte count, hemoglobin, and hematocrit) were affected, there were also associated changes in mean cell volume, mean cell hemoglobin, and mean cell hemoglobin concentration. In the 25 mg/kg animals (both sexes) and the 10 mg/kg males, statistical trends highlighted a dose-dependent downward trend for erythrocyte counts. Statistical significance was not confirmed by direct comparison with the control group, and group mean values were within background range. Urine volume was unusually high in four 80 mg/kg females, and urinary specific gravity was reduced. There were no histopathologic changes seen in the kidneys of these animals. Absolute and relative spleen weights were increased in the 80 mg/kg males. Absolute spleen weights were increased in the 10 and 80 mg/kg females; relative spleen weights were increased in the 25 and 80 mg/kg females. Relative adrenal weights were increased in the 80 mg/kg males. Absolute adrenal weights were increased in the 80 mg/kg females; relative adrenal weights were increased in the 25 and 80 mg/kg females. Histopathologic changes indicative of chronic irritation were seen in the stomachs of many of the 80 mg/kg animals and a few of the 25 mg/kg males. Extramedullary hematopoiesis was seen in the spleen of a few 80 mg/kg animals and one animal each in the lower two dose groups. The NOAEL for this study is 10 mg/kg-day (ECHA). [Kl. score = 1]

Male C/J and C57L/L mice were given in their drinking water 0, 0.75, 7.5, or 75 mg/L chlorous acid, sodium salt (0, 0.19, 1.9, or 19 mg/kg-day chlorite ion) for 30 days. There were slight signs of oxidative stress of red blood cells at the high-dose. Glucose-6-phosphate dehydrogenase (G6PD) activity and osmotic fragility were slightly increased. Erythrocytes with irregular shapes were also observed. It was suggested that the primary effect of chlorous acid, sodium salt was a disruption of the erythrocyte cell membrane. However, the glutathione level in the erythrocyte was not affected and there were no associated signs of hemolytic anemia, suggesting that the slight increase in G6PD activity acted as a sufficient compensatory mechanism to limit the oxidative stress. The NOAEL for this study is considered to be 7.5 mg/L chlorous acid, sodium salt or 1.9 mg/kg-day chlorite (Moore and Calabrese, 1980). [Kl. score = 2]

Male C57L/J mice were given chlorous acid, sodium salt in their drinking water for 30, 90, or 180 days. The doses were 0, 3, 15, or 75 mg/L expressed as chlorite ion. The average daily doses were estimated to be: 0, 0.74, 3.57, and 17.23 mg/kg-day for the 30-day period; 0, 0.64, 3.15, and 16.2 mg/kg-day for the 90-day period; and 0, 0.69, 3.71, and 17.11 mg/kg-day for the 180-day period. There were no significant changes in body weight gain, absolute or relative kidney weights, water consumption, or histopathologic changes in the

kidney. The NOAELs for this study are: 17.23, 16.20, and 17.11 mg/kg-day for the 30-, 90-, and 180-day exposure periods, respectively (Connor et al., 1985). [Kl. score = 2]

Inhalation

No studies are available.

Dermal

No adequate studies are available.

F. Genotoxicity

In Vitro Studies

Table 2 lists the results of the *in vitro* genotoxicity studies on chlorous acid, sodium salt.

Table 2: *In vitro* Genotoxicity Studies on Chlorous Acid, Sodium Salt

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* TA97, TA102 strains)	-	-	4	ECHA
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	+**	+**	2	ECHA

*+, positive; -, negative
**Test material: chlorine dioxide (chlorite is a breakdown product)

In Vivo Studies

Male and female CD-1 mice were given by oral gavage a single dose of 0, 0.2, 0.5, or 1 mg/day (0, 10, 25, or 59 mg/kg-day) chlorous acid, sodium salt. Chromosomal aberrations were not increased in bone marrow cells of treated mice compared to those in the controls (Meier et al., 1985; ECHA).

Male and female CD-1 mice were given by oral gavage 0, 0.2, 0.5, or 1 mg/day (0, 10, 25, or 59 mg/kg-day) chlorous acid, sodium salt for five consecutive days. There were no significant differences between treated and control mice in the frequency of micronuclei or chromosomal aberrations in bone marrow cells (Meier et al., 1985; ECHA).

Male ddY mice were given a single intraperitoneal injection of 0, 7.5, 15, 30, or 60 mg/kg chlorous acid, sodium salt. Micronucleated polychromatic erythrocytes were statistically significantly increased at all dose levels. The increase was dose-dependent, but the frequency of micronucleated polychromatic erythrocytes decreased at the highest dose level (Hiyashi et al., 1988; ECHA). [Kl. score = 2]

Male ddY mice were given a single intraperitoneal injection of 0 or 15 mg/kg chlorous acid, sodium salt for four consecutive days. The frequency of micronucleated polychromatic erythrocytes were similar between treated and control mice (Hiyashi et al., 1988; ECHA). [Kl. score = 2]

Male ddY mice were given a single oral dose of 0, 37.5, 75, 150, or 300 mg/kg chlorous acid, sodium salt. There was no significant increases in the frequency of micronucleated polychromatic erythrocytes in the bone marrow of the treated mice compared to the controls (Hiyashi et al., 1988; ECHA). [Kl. score = 2]

G. Carcinogenicity

No studies are available.

H. Reproductive Toxicity

A two-generation reproductive toxicity study has been conducted on chlorous acid, sodium salt. Male and female SD rats were given in their drinking water 0, 35, 70, or 300 ppm chlorous acid, sodium salt. The average daily intakes are: 0, 4, 8, and 30 mg/kg-day for males ; and 0, 5, 10, and 39 mg/kg-day for females. The average daily intakes for chlorite are: 0, 2.9, 6, and 22 mg/kg-day for males; and 0, 4, 7.5, and 29 mg/kg-day for females. During lactation, the drinking water levels were reduced 50% to 17.5, 35, and 150 ppm chlorous acid, sodium salt. Water consumption was reduced in all treated groups. Body weights and feed consumption were reduced in the 70 and 300 ppm groups. There was no evidence of reproductive toxicity at any dose level. In the 300 ppm group, pup weights were reduced at birth and on PND 11 (-14%) compared to the controls. There was a decrease in the percent of the 300 ppm F_{2a} pups with eyes open on PND15 compared to the control group; this effects was not observed for the F_1 or F_{2b} pups. There was a small, but statistically significant, increase in the average time to preputial separation for the 70 and 300 ppm F_1 pups and in the vaginal opening for the 300 ppm F_1 pups. Similar changes were not observed for the F_2-generation pups. All of the high-dose animals exhibited mild methemoglobinemia. Thyroid levels were unaffected by treatment. There was a small decrease in the amplitude of auditory startle responses in the 70 and 300 ppm pups on PND 25; the toxicological significance of this effect is questionable. The NOAEL for reproductive toxicity is 300 ppm chlorous acid, sodium salt, the highest dose tested. The NOAEL for developmental toxicity is 35 ppm (4 and 5 mg/kg-day chlorous acid, sodium salt for males and females, respectively) based on the increase in the average time to preputial separation in the $\geq$70 ppm F_1 pups. The NOAELs for hematological effects is 70

ppm (8 and 10 mg/kg-day chlorous acid, sodium salt for males and female, respectively). The NOAEL for neurotoxicity is 300 ppm (30 and 39 mg/kg-day chlorous acid, sodium salt for males and females, respectively) (ECHA) [Kl. = 2].

I. Developmental Toxicity

Pregnant New Zealand White rabbits were given 0, 200, 600, or 1,200 mg/L (0, 12.2, 36.6, or 58.8 mg/kg-day) chlorous acid, sodium salt in their drinking water during GD 7 to PND 19. The animals in the mid- and high-dose groups showed reduced water consumption, along with reduced feed consumption, production of fecal pellets, and body weight gain. There was no evidence of embryotoxicity or teratogenicity at any dose level. The NOAELs for maternal and developmental toxicity are 12.2 and 58.8 mg/kg-day, respectively (ECHA). [Kl. score = 1]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for chlorous acid, sodium salt follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

The lowest NOAEL values from key toxicity studies on chlorous acid, sodium salt are listed below in Table 3.

Table 3: Lowest NOAEL Values from Key Toxicity Studies on Chlorous Acid, Sodium Salt by the Oral Route

Species/sex	Study Duration	mg/kg-day	Endpoint	Reference
Male/female rats	13 weeks	10	Clinical signs, stomach irritation	ECHA
Male pups	2-generation reproductive	4	↑ average time to preputial separation	ECHA
Male parental rats	2-generation reproductive	8	Hematological effects	ECHA

Female pregnant rabbits	Developmental (GD 6 to PND 17)	12.2	↓ Body weight gain, feed consumption	ECHA

The lowest NOAEL is 4 mg/kg-day based on increased average time to preputial separation in F_2 male pups from a two-generation reproductive toxicity study (ECHA). The NOAEL of 4 mg/kg-day will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Derivation of an Oral Reference Dose

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 10
UF_D (database uncertainty) = 1

Oral RfD = 4/(10 x 10 x 1 x 10 x 1) = 4/1000 = <u>0.004 mg/kg-day</u>

Derivation of a drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (0.004 x 70 x 0.1)/2 = <u>0.014 mg/L</u>

Australian Drinking Water Guidelines

The Australian drinking water guideline value for chlorite is 0.3 mg/L (ADWG, 2011).

The Australian drinking water guideline value for sodium is 180 mg/L based on aesthetics (ADWG, 2011).

B. Cancer

No carcinogenicity studies were found on chlorous acid, sodium salt. Thus, a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Chlorous acid, sodium salt in solution does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing Potential

[It should be noted that chlorous acid, sodium salt as a solid is a strong oxidizer.]

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Chlorous acid, sodium salt has a high acute toxicity concern to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies conducted on chlorous acid, sodium salt.

Table 3: Acute Aquatic Toxicity Studies on Chlorous Acid, Sodium Salt

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Oncorhynchus mykiss	96-h LC_{50}	149	2	ECHA
Daphnia magna	48-h EC_{50}	<1	2	ECHA

Peudokirchneriella subcapitata	96-h EC_{50}	1	1	ECHA

Chronic Studies

No studies are available.

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for chlorous acid, sodium salt follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (149 mg/L), invertebrates (<1 mg/L), and plants (1 mg/L). On the basis that the data consists of short-term studies from three trophic levels, an assessment factor of 1,000 has been applied to the EC_{50} value of 1 mg/L for algae. The $PNEC_{aquatic}$ is 0.001 mg/L.

PNEC sediment

No reliable experimental toxicity data on sediment organisms are available. Chlorous acid, sodium salt dissociates completely in water with its environmental distribution is dominated by its high water solubility. K_{ow} and K_{oc} parameters do not readily apply to inorganics, such as chlorous acid, sodium salt. Therefore, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sed}$. Based on its properties, no adsorption of chlorous acid, sodium salt to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

PNEC soil

No reliable experimental toxicity data on terrestrial organisms are available. The environmental distribution of chlorous acid, sodium salt is dominated by its water solubility. Sorption of chlorous acid, sodium salt should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. K_{oc} and K_{ow}

parameters do not readily apply to inorganics, such as chlorous acid, sodium salt. Therefore, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on its properties, chlorous acid, sodium salt is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Chlorous acid, sodium salt is an inorganic salt that dissociates completely in water to sodium (Na^+) and chlorite (ClO_2^-) ions. Chlorite will ultimately degrade to chloride (Cl^-) ions. Biodegradation is not applicable to these inorganic ions. For the purposes of this PBT assessment, the persistent criteria is not considered applicable to this inorganic salt.

As an inorganic compound, neither chlorous acid, sodium salt nor its dissociated ions are expected to accumulate. Thus, chlorous acid, sodium salt does not meet the criteria for bioaccumulation.

There are no chronic toxicity studies on chlorous acid, sodium salt. The acute $E(L)C_{50}$ values for chlorous acid, sodium salt are $\leq$1 mg/L in invertebrates and algae. Thus, chlorous acid, sodium salt meets the criteria for toxicity.

The overall conclusion is that chlorous acid, sodium salt is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification (Chlorous acid, sodium salt solutions)

Acute Toxicity Category 3 [Oral]
Skin Corrosive Category 1B
STOT RE Category 2 [Target organ: blood]
Aquatic Acute Category 1
Aquatic Chronic Category 3

B. Labelling

Danger

C. Pictogram



In addition to the hazard statements corresponding to the GHS classifications, the following non-GHS hazard statement is to be added to the SDS: AUH031: Contact with acids liberates toxic gas.

X. SAFETY AND HANDLING

Eye Contact
Immediately flush open eyes with plenty of water for at least 15 minutes. Remove contacts, if present and easy to do. Get medical attention immediately, preferably a physician for an ophthalmologic examination.

Skin Contact
Remove and isolate contaminated clothing. Rinse skin immediately with water for at least 15 min. Get medical attention immediately.

Inhalation
Move person to fresh air. Administer oxygen if breathing is difficult. Do not use mouth-to-mouth method if victim inhaled the substance; give artificial respiration with the air of a pocket mask equipped with a one-way valve or other proper respiratory medical device. Give artificial respiration if victim is not breathing. Get medical attention immediately.

Ingestion
Rinse mouth with water and then drink plenty of water. Get medical attention. Do not induce vomiting. Never give anything by mouth to an unconscious person.

Notes to Physician
Chlorine dioxide vapors are emitted when this product contacts acids or chlorine. If these vapors are inhaled, monitor patient closely for delayed development of pulmonary edema which may occur up to 48-72 hours post-inhalation Following ingestion, neutralization and use of activated charcoal is not indicated (OxyChem, 2015).

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Use dry chemical, carbon dioxide, water spray or fog, or foam.

Specific Exposure Hazards

Dried material can ignite upon contact wit combustibles. This product may represent an explosion hazard if it contacts acids, chlorine, or organic materials. Emits toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: chlorine and sodium oxides.

Special Protective Equipment for Firefighters

Structural firefighter's protective clothing provides limited protection in fire situations only; it is not effective in spill situations where direct contact with the substance is possible. Wear chemical protective clothing that is specifically recommended by the manufacturer. It may provide little or no thermal protection. Wear positive pressure self-contained breathing apparatus (SCBA). Move containers from fire area if it can be done without risk.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions

Ventilate enclosed areas. Do not walk through spilled material. Do not touch damaged containers or spilled material unless wearing appropriate protective clothing. Wear appropriate personal protective equipment, avoid direct contact. Do not breath mist, vapors, or spray. Do not get in eyes, on skin, or on clothing.

Environmental Precautions

Prevent entry into waterways, sewers, basements or confined areas.

Steps to be Taken if Material is Released or Spilled

As an immediate precautionary measure, isolate spill or leak area for at least 50 meters in all directions. Keep unauthorized personnel away. Remove all sources of ignition. Absorb or cover with dry earth, sand, or other non-combustible material and transfer to containers. Dike to collect large liquid spills. Every attempt should be made to avoid mixing spilled material with other chemicals or debris when cleaning up. Dried material can ignite upon contact with combustibles. Dispose immediately.

D. STORAGE AND HANDLING

General Handling

Do not get in eyes, on skin, or on clothing. Do not ingest or taste. Wear appropriate personal protective equipment, avoid direct contact. Do not breath mist, vapours, or spray. Use caution when combining with water. DO NOT add water to corrosive liquid, ALWAYS add corrosive liquid to water while stirring to prevent release of heat, steam, and fumes. This product becomes a fire hazard if allowed to dry. Remove and wash contaminated clothing to avoid fire.

Storage

Keep contain tightly closed. Store in a cool, dry, well-ventilated place. Keep from direct

sunlight. Avoid exposure to sunlight or ultraviolet light. Keep separated from acids, reducing agents, combustible material, oxidizing agents, hypochlorite, organic solvents and compounds, garbage, dirt, organic materials, household products, chemicals, soap products, paint products, vinegar, oils, pine oil, dirty rags, sulfur-containing rubber, or any other foreign matter.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards

Workplace Australia has not established an occupational exposure standard for chlorous acid, sodium salt.

Engineering Controls

Good general ventilation should be used. Localized ventilation should be used where vapours, mist, or aerosols may be generated.

Personal Protection Equipment

Respiratory Protection:

Wear an approved acid gas respirator with dust/mist pre-filters if any exposure to dust of mist is possible.

Hand Protection:

Wear appropriate chemical-resistant gloves.

Skin Protection:

Wear protective clothing to minimize skin contact.

Eye protection*:*

Wear chemical splash goggles and face shield.

Other Precautions:

Wash hands, forearms, and face thoroughly after handling chemical products, before eating, smoking, and using the lavatory and at the end of the working period. Appropriate techniques should be used to remove potentially contaminated clothing. Wash contaminated clothing before reusing. Ensure that eyewash stations and safety showers are close to the workstation location.

F. TRANSPORT INFORMATION

Sodium chlorite (dry)

UN1496 (SODIUM CHLORITE)
Class: 5.1
Packing Group: II

Environmentally Hazardous Substance

Sodium chlorite (liquid)
UN1908 (CHLORITE SOLUTION)
Class: 8
Packing Group: II
Contains Sodium chlorite

Environmentally Hazardous Substance

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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CHOLINE CHLORIDE

This dossier on choline chloride does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of choline chloride in its use in hydraulic fracturing fluids. The majority of information presented in this dossier was obtained from the OECD-SIDS documents on choline chloride (OECD, 2004), and the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC): 2-Hydroxy-N,N,N-trimethylethanaminium chloride

CAS RN: 67-48-1

Molecular formula: $C_5H_{14}NO.Cl$
$C_5H_{14}NO^+$ (choline)

Molecular weight: 139.6
104.2 (choline)

Synonyms: Choline chloride; 2-hydroxy-N,N,N-trimethylethanaminium chloride; trimethyl(2-hydroxyethyl)ammonium chloride; cholinium chloride; 2-hydroxyethyl(trimethyl)azanium chloride

SMILES: C[N+](C)(C)CCO.[Cl-]
C[N+](C)(C)CCO (choline)
OCCN(C)(C)C (choline)

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Choline Chloride

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa*	White crystalline solid*	2	OECD (2004)
Melting Point	ca. 200°C	1	ECHA
Boiling Point	Decomposition at 305°C prior to boiling.	2	ECHA
Density	70% aq. solution: 1.10 g/cm^3	4	OECD (2004)

Partition Coefficient (log K_{ow})	75% aq. solution: -3.77	1	ECHA
Water Solubility	Powder containing 50% choline chloride: 650 g/L	4	OECD (2004)
Auto flammability	330°C	2	ECHA
Viscosity	75% aq. solution: 26.2 mPa.s @ 20°C; 14.1 mPa.s @ 40°C	1	ECHA
Henry's Law Constant	2.06 x 10^{-11} Pa.m^3/mole @ 25°C (estimated using HENRYWIN v3.10)	-	OECD (2004)

*Choline chloride is a white crystalline solid; it is marketed as an aqueous solution (70-75% w/w in water), which is colorless with an amine-like odor.

Choline chloride is a quaternary amine salt that will dissociate in water into choline ($C_5H_{14}NO^+$) and chloride (Cl^-) ions.

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Choline chloride is readily biodegradable. Distribution modeling using Mackay Level 1 shows choline to be distributed completely into water. Choline chloride will not adsorb on soil and sediments. It is not expected to bioaccumulate.

B. Biodegradation

Choline chloride is readily biodegradable (93% within 14 days) in a MITI-I test (MITI, 1992; OECD, 2004). In another MITI-I test, biodegradation was $\geq$60%, indicating ready biodegradation (Tunkel *et al.*, 2000; OECD, 2004). A $BOD_5/ThOD_5$ ratio of 75% was obtained in a BOD_5 test performed according to DIN 38409 part 43 (BASF AG, 1984; OECD, 2004).

C. Environmental Distribution

Adsorption/desorption

No experimental data are available for choline. Choline is a quaternary ammonium compound (QAC); these compounds are not included in the training set for the K_{oc} estimation of the QSAR model KOCWIN v. 2.00 in EPISUITE™ (EPA, 2016), and therefore outside the program's prediction domain. A K_{oc} value of 2.3 had been estimated using the older QSAR model PCKOCWIN v. 1.66 (OECD, 2004).

Distribution Modeling

Results from Mackay Level I modeling indicate that choline chloride will be distributed completely into water (OECD, 2004).

D. Bioaccumulation

No measured data on bioaccumulation of choline chloride are available. An experimental log K_{ow} is -3.77 (OECD, 2004). Bioaccumulation is not expected in aquatic organisms.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Choline is a vitamin-like essential nutrient. It has low acute toxicity by the oral route, and is slightly irritating to the skin and eyes. Repeated high intake of choline in humans has been reported to cause a slight hypotensive effect. No adverse effects (including tumors) were seen in rats given choline in the diet for 72 weeks. Choline is not genotoxic. High dietary doses of choline to pregnant mice resulted in developmental toxicity (but no teratogenic effects) at levels that were maternally toxic.

B. Metabolism

Choline is a vitamin-like essential nutrient. Although the body can synthesize choline in small amounts, it is insufficient to maintain health and must be consumed in the diet. Choline is required for the synthesis of phospholipids in cell membranes, methyl group metabolism and acetylcholine synthesis (neurotransmitter) (Zeisel and Blusztajn, 1994).

Dietary choline is taken up into the body by transporter proteins present in the cells lining the small intestine (IOM, 2000). In the small intestine, prior to uptake into the small intestinal cells, some choline is metabolized by bacteria to betaine and methylamines (Zeisel et al., 1983). Dietary choline can be present as free choline or in esterified forms (i.e., phosphocholine, glycerophosphocholine, sphingomyelin, and phosphatidylcholine) (Zeisel and Blusztain, 1994). Free choline is formed from these esterified choline compounds by pancreatic enzymes.

Choline is involved in a number of biochemical pathways in eukaryotic and prokaryotic cells. It is a precursor for acetylcholine (a neurotransmitter); phospholipids (structural integrity and signaling roles for cell membranes); and a major source for methyl groups (IOM, 2000).

C. Acute Toxicity

The oral LD_{50} values of choline in rats are approximately 3,500 and 5,500 mg/kg (ECHA). [Kl. scores = 2]

No acute inhalation or dermal toxicity studies are available.

D. Irritation

Application of a 70% aqueous solution to the skin of rabbits for 20 hours under occlusive conditions resulted in ambiguous skin irritation (BASF AG, 1963a; OECD, 2004). [Kl. score = 2].

Slight eye irritation was seen in the eyes of rabbits after instillation of a 70% aqueous solution of choline chloride; no effects were seen 24 hours after exposure (BASF AG, 1963b; OECD, 2004). [Kl. score = 2].

E. Sensitization

No data are available in animals. In a Human Repeated Insult Patch Test (HRIPT), there was no evidence of dermal sensitization in two hundred subjects given 0.5% (w/v) aqueous solution of choline chloride during the induction phase and 0.2% (w/v) aqueous solution during the challenge phase (Colgate-Palmolive, 2003; OECD, 2004).

F. Repeated Dose Toxicity

Oral

A 72-week feeding study was conducted to investigate the impact of choline chloride on the liver tumor promoting activity of phenobarbital and DDT in diethylnitroamine-initiated Fischer 344 rats. Animals received approximately 500 mg/kg-day choline chloride. Following the end of the exposure period, the animals were kept on the same untreated diet as the control group until study termination at week 103. Histopathology was limited to the liver and organs that developed gross abnormalities. There were no significant differences between treated and control animals on survival rates, body weights, and relative liver weights. There were no increased number of neoplastic liver nodules, hepatocellular carcinomas, lung tumors, leukemia or other tumors between treated and control animals. The NOAEL for choline chloride in this study is 500 mg/kg-day (Shivapurkar *et al.*, 1986). [Kl. score = 3]

In humans, oral administration of 10,000 mg/day choline chloride in a pilot study treating a small number of patients with Alzheimer's disease resulted in a slight hypotensive effect (Boyd *et al.*, 1977). This dose was regarded as a LOAEL by the U.S. Institute of Medicine (IOM) Standing Committee on the Scientific Evaluation of Dietary Reference Intake (2000).

Inhalation

No studies are available.

Dermal

No studies are available.

G. Genotoxicity

In Vitro Studies

Choline chloride was not mutagenic to bacteria in reverse mutation assays (Haworth *et al.*, 1984; JETOC, 1997; Litton Bionetics, 1977).

A small, but statistically significant, and dose-related increase in chromosomal aberrations was reported in Chinese Hamster Ovary (CHO) cells at doses of 50 and 500 μg/ml choline chloride in the absence of S9 only (Bloom *et al.*, 1982). No higher concentrations were examined. These results could not be confirmed in two studies using CHO cells at concentrations of choline chloride up to 5,000 μg/ml (Galloway *et al.*,1985).

In sister chromatid exchange (SCE) assays, ambiguous results were obtained in two parallel studies (at two different laboratories) in CHO cells at concentrations up to 50 and 500 μg/ml choline chloride, respectively. Cytotoxicity was observed at 5,000 μg/ml. In laboratory 2, the increase in SCEs, which was sporadic and not dose-related, that was observed with metabolic activation was not reproduced in laboratory 1. Laboratory 1 showed a weak positive at the top dose without metabolic activation, but a comparison with laboratory 2 was not possible due to insufficient number of cells analyzed (Bloom *et al.*, 1982; Galloway *et al.*, 1985).

Choline chloride was negative in a gene conversion assay with *Saccharomyces cerevisiae* strain D4 in the presence or absence of metabolic activation (Litton Bionetics, 1977; OECD, 2004).

In Vivo Studies

No studies are available.

G. Carcinogenicity

No studies are available.

H. Reproductive Toxicity

No reliable studies have been conducted that address female fertility or reproductive toxicity by a relevant route of exposure.

I. Developmental Toxicity

Pregnant female mice were given in their feed 0, 1, 2.5, 5, or 10% choline chloride (0 or approximately 1,250, 4,160, 10,800, or 20,000 mg/kg choline chloride) on gestational days 1 to 18. Maternal body weight gain was reduced in all treated groups except for the 1,250 mg/kg group. Maternal weight gain of dams with embryonic/fetal absorptions showed no net weight gain at ≥4,160 mg/kg, but there was net weight loss in the 20,000 mg/kg group. All fetuses were resorbed in the 20,000 mg/kg group. Embryonic/fetal lethality of 35% and 69% were seen in the 4,160 and 10,800 mg/kg groups, respectively. No resorptions occurred in the 1,250 mg/kg group. Developmental toxicity was seen at ≥4,160 mg/kg group. There were no statistically significant increases in malformations in any dose group. The NOAEL for maternal and developmental toxicity is 1,250 mg/kg-day (BASF AG 1966; OECD 2004). [Kl. score = 2]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

The Standing Committee on the Scientific Evaluation of Dietary Reference Intakes selected hypotension as the critical effect from the study by Boyd *et al.* (1977) when deriving a Tolerable Upper Intake Level. Boyd *et al.* (1977) reported a LOAEL of 10,000 mg/day choline chloride (7,500 mg/day choline). An uncertainty factor of 2 was chosen because of the limited data regarding hypotension and the inter-individual variation in response to cholinergic effects. Thus, the value for the Tolerable Upper Intake Value for repeated exposure of adults to choline is 3,500 mg/day choline.

Note that the Australian National Health and Medical Research Council (2014) concluded that there are no data to suggest that there is increased susceptibility to choline during pregnancy or lactation; thus the upper level of intake choline is the same for women during pregnancy or lactation as it is for adults (3,500 mg/day choline).

Oral Reference Dose (oral RfD)

An oral RfD for choline is derived as follows: the LOAEL of 7,500 mg/day from the Boyd *et al.* (1977) study is divided by an uncertainty factor of 2 to obtain a value of 3,500 mg choline/day or 50 mg choline/kg-day for a 70 kg person.

Oral RfD = 50 mg/kg-day [choline]

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (50 x 70 x 0.1)/2 = 175 mg/L [choline]

The Australian drinking water guideline value for chloride ions is 250 mg/L based on aesthetics (ADWG, 2011).

B. Cancer

There are no carcinogenicity studies on choline chloride. Thus a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Choline chloride does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Choline chloride is of low toxicity concern to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

Table 2 lists the results of acute aquatic toxicity studies conducted on choline chloride.

Table 2: Acute Aquatic Toxicity Studies on Choline Chloride

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Oryzias latipes	96-hr LC_{50}	>100 (nominal and measured)	1	MOE Japan (1999a); OECD (2004)
Leuciscus idus	96-hr LC_{50}	>10,000*	2	OECD (2004); ECHA
Daphnia magna	48-hr EC_{50}	349 (nominal and measured)	2	MOE Japan (1999a); OECD (2004)
Daphnia magna	48-hr EC_{50}	>500*	2	OECD (2004)
Pseudokirchneriella subcapitata	72-hr EC_{50}	>1,000 (nominal and measured)	1	MOE Japan (1999a); OECD (2004)

*78% aqueous solution of choline chloride.

Chronic Studies

In a 21-day *Daphnia magna* reproduction test, the nominal and measured NOEC was reported to be 30.2 mg/L (MOE Japan, 1999d) [Kl. score = 1].

The NOEC from a 72-hr algae *Pseudokirchneriella subcapitata* study is 30.2 mg/L (MOE Japan, 1999c; OECD, 2004) [Kl. score = 1].

C. Terrestrial Toxicity

No data are available.

Choline is present in all plant and animal cells, mostly in the form of phospholipids (phosphotidylcholine or lecithin, lysophosphatidylcholine, choline plasmalogens and sphingomyelin), which are essential components of membranes (IOM, 2000).

D. Calculation of PNEC

The PNEC calculations for choline chloride follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (>100 mg/L), invertebrates (349 mg/L), and algae (>1,000 mg/L). Results from chronic studies are available for invertebrates (21-day NOEC = 30.2 mg/L) and algae (72-hour NOEC = 32 mg/L). On the basis that the data consists of chronic studies on two trophic level (albeit not on the species with the lowest $E(L)C_{50}$), an assessment factor of 100 has been applied to the lowest reported NOEC of 30 mg/L for *Daphnia*. The $PNEC_{aquatic}$ is 0.3 mg/L (0.22 mg/L for choline).

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 0.15 mg/kg sediment wet weight.

The calculations are as follows:

$$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$$
$$= (0.844/1280) \times 1000 \times 0.22$$
$$= 0.15$$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$$K_{sed\text{-}water} = 0.8 + [0.2 \times Kp_{sed}/1000 \times BD_{solid}]$$
$$= 0.8 + [0.2 \times 0.092/1000 \times 2400]$$
$$= 0.844$$

Where:
Kp_{sed} = solid-water partition coefficient (L/kg).
BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$$Kp_{sed} = K_{oc} \times f_{oc}$$

= 2.3 x 0.04
= 0.092

Where:

K_{oc} = organic carbon normalized distribution coefficient (L/kg). The K_{oc} for choline is estimated to be 2.3 L/kg (OECD, 2004).
F_{oc} = fraction of organic carbon in sediment = 0.04 [default].

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ for choline is 0.007 mg/kg soil dry weight (choline).

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
= (0.05/1500) x 1000 x 0.22
= 0.007

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
= 2.3 x 0.02
= 0.05

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for choline is estimated to be 2.3 L/kg (OECD, 2004).
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. LIVESTOCK HAZARD ASSESSMENT

Although choline is present in the diet of livestock (as a component of plant cell membranes), it is also given in significant volumes as an feed additive. Unlike humans, dietary choline in ruminants is rapidly and extensively degraded in the rumen of sheep (Neill et al., 1979) and cattle (Atkins *et al.*, 1988; Sharma and Erdman, 1988). Sharma and Erdman (1988) reported that increasing dietary choline intake in cows from 23.5 g/day in the controls to 326 g/day in the choline-supplemented diet group increased duodenal choline flow from 1.2 to 2.5 g/day, indicating intestinal uptake of only 0.8% to 5%.

No toxicity data are available on livestock.

A livestock oral reference dose (RfD) was derived for choline using the value determined for humans and taking into account the low oral uptake (≤5%) of choline in ruminants.

Oral RfD [livestock] = oral RfD [humans]/oral uptake fraction [livestock]
= 50/0.05
= 1,000 mg/kg-day [choline]

IX. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Choline chloride is readily biodegradable and thus it does not meet the screening criteria for persistence.

Based on a measured log Kow of -3.77, choline chloride does not meet the criteria for bioaccumulation.

The NOEC values from chronic toxicity studies on choline chloride are >0.1 mg/L. Thus, choline chloride does not meet the criteria for toxicity.

The overall conclusion is that choline chloride is not a PBT substance.

X. CLASSIFICATION AND LABELING

A. Classification

Not classified.

B. Labelling

No signal word.

C. Pictogram

None

XI. SAFETY AND HANDLING (Aqueous Solutions of Choline Chloride)

A. FIRST AID

Eye Contact
In case of contact, immediately flush eyes with plenty of water for at least 15 minutes.

Skin Contact
Wash thoroughly with soap and water.

Ingestion
Rinse mouth with water and then drink plenty of water. Never give anything by mouth to an unconscious person.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
Keep product and empty container away from heat and sources of ignition. May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: carbon monoxide, carbon dioxide, nitrogen oxides.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus and protective suit.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Use appropriate protective equipment.

Environmental Precautions
Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled
Soak up with inert absorbent material.

D. STORAGE AND HANDLING

General Handling
Keep product and empty container away from heat and sources of ignition. Ensure adequate ventilation, especially in confined areas.

Storage

Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
Workplace Australia has not established an occupational exposure standard for choline chloride.

Engineering Controls
Good general ventilation should be used.

Personal Protection Equipment

Respiratory Protection:
Respiratory protection is not required.

Hand Protection:
Chemical resistant protective gloves.

Skin *Protection*:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Safety glasses with side-shields.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Wearing of closed work clothing is recommended. Ensure that eyewash stations and safety showers are close to the workstation location.

F. TRANSPORT INFORMATION

Choline chloride is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XII. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XIII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIV. REFERENCES

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CITRIC ACID

This dossier on citric acid does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of citric acid in its use in drilling muds and water treatment. The information presented in this dossier was obtained primarily from the OECD-SIDS documents on citric acid (OECD 2001a,b) and the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch et al., 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC): 2-Hydroxy-1,2,3-propanetricarboxylic acid

CAS RN: 77-92-9

Molecular formula: $C_6H_8O_7$

Molecular weight: 192.122

Synonyms: citric acid; 1,2,3-propanetricarboxylic acid, 2-hydroxy-; 2-hydroxy-1,2,3-propanetricarboxylic acid

SMILES: C(C(=O)O)C(CC(=O)O)(C(=O)O)O

Citric acid is an ubiquitous natural substance that is an intermediate in the basic physiological tricarboxylic acid (TCA) cycle in every eukaryote cell.

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Citric Acid

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	White crystalline solid; odourless.	2	ECHA
Melting Point	153°C	2	ECHA
Boiling Point	Not available; decomposition	-	ECHA
Density	1.67 @ 20°C	2	ECHA
Vapor Pressure	2.21 x 10^{-6} Pa @ 25°C	2	ECHA
Partition Coefficient (log K_{ow})	-1.61 to -1.80	2	ECHA
Water Solubility	Very soluble	4	ECHA
Flash Point	345°C	4	ECHA
Auto flammability	1010°C	4	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Citric acid is readily biodegradable. It is not expected to bioaccumulate. Due to its high water solubility, citric acid is unlikely to adsorb to soil or sediment.

B. Biodegradation

Citric acid can be considered readily biodegradable based on the results of the ready and inherent aerobic biodegradation studies listed in Table 2.

Table 2: Biodegradation Studies on Citric Acid (OECD 2001a,b)

Test System	Results*	Notes	Klimisch Score
Modified Sturm	97% (CO_2 evolution); 100% (DOC removal)	Readily biodegradable; exposure period not stated	2
Closed Bottle Test	BOD_{30}/COD Ratio = 90%	Readily biodegradable	2
BOD_5/COD Ratio	BOD_5 = 526 mg; COD = 728 mg; BOD_5/COD Ratio = 0.72	Readily biodegradable; concentration of test substance and activated sludge not stated	2
BOD_1/ThOD Ratio	BOD_1/ThOD Ratio = 13%	-	2
BOD_{20}/ThOD Ratio	BOD_{20}/COD Ratio = 98%	Readily biodegradable; initial test substance concentration 720 mg/L	2
Zahn-Wallen Test	85%, 1 day (DOC removal)	Inherently biodegradable	2
Zahn-Wallen Test	98%, 7 days (DOC removal)	Inherently biodegradable	
Coupled Units Test	93% (COD removal)	Ultimately biodegradable; exposure period not stated.	2

C. Environmental Distribution

Absorption/desorption

No experimental data are available for citric acid. Using KOCWIN program in EPISuite™ (EPA, 2016), the estimated K_{oc} value from the K_{ow} value of -1.08 is 0.3617 L/kg.

D. Bioaccumulation

The log K_{ow} for citric acid is -1.61 to -1.80. Thus, citric acid is not expected to bioaccumulate.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Citric acid exhibits low toxicity by the oral and dermal routes. It is an eye irritant, but slightly to non-irritating to the skin. No adequate studies were found to evaluate the sensitization potential of citric acid. Minimal toxicity and no carcinogenic effects were observed in rats given oral doses of citric acid for up to two years. Citric acid was not mutagenic to bacteria, but *in vitro* studies using human lymphocytes showed genotoxic effects. *In vivo* genotoxicity studies were negative. There were no reproductive or developmental effects in rats given oral doses of citric acid.

B. Acute Toxicity

The acute oral LD_{50} in male rats was reported to be 11,700 mg/kg (ECHA) [Kl. score = 2]. The acute oral LD_{50} values in mice are 5,400 and 5,790 mg/kg (ECHA) [Kl. score = 2]. The acute dermal LD_{50} value in rats is >2,000 mg/kg (ECHA) [Kl. score = 1].

C. Irritation

Application of 0.5 g citric acid powder to the skin of rabbits for 4 hours under semi-occlusive conditions was slightly irritating. The mean of the 24, 48, and 72-hour scores were: 0.3 for erythema and 0.0 for edema (ECHA) [Kl. score = 1]. Application of a 50% aqueous solution of citric acid to the skin of rabbits for 4 hours under occlusive conditions was non-irritating (ECHA) [Kl. score = 2].

Instillation of a 30% aqueous solution of citric acid into the eyes of rabbits produced well defined to moderate conjunctival irritation that did not fully resolve after the 14-day observation period. A 10% solution was associated with weak to moderate conjunctival effects, which resolved after 7 days (ECHA) [Kl. score = 2].

D. Sensitization

No adequate studies were found to evaluate the sensitization potential of citric acid.

E. Repeated Dose Toxicity

Oral

Male rats were given 0, 1.2, 2.4, or 4.8% citric acid in their feed for 6 weeks. The daily intakes were reported to be 1,150, 2,260, or 4,670 mg/kg-day. The high-dose animals had mild blood and urine parameter changes and slight degeneration of the thymus gland and spleen. The NOAEL is 2.4% in the diet or 2,260 mg/kg-day (OECD, 2001a,b). [Kl. score = 4]

Rats were given 3% or 5% citric acid in their diet for two years. The estimated daily intakes were 1,200 and 2,000 mg/kg-day, respectively. A slight decrease in growth was reported in the 2% group, but no tissue abnormalities in the major organs. The NOAEL is 1,200 mg/kg-day (OECD, 2001a,b). [Kl. score = 4]

Inhalation

No studies are available.

Dermal

No studies are available.

F. Genotoxicity

In Vitro Studies

Citric acid was not mutagenic in bacterial reverse mutation assays with strains of *S. typhimurium* or *E. coli* with and without metabolic activation (OECD, 2001a,b; ECHA). [Kl. score = 2]

Peripheral human lymphocytes were treated with 50 to 3,000 µg/ml citric acid. A statistically significant dose-dependent increase in the micronuclei was observed. In another set of studies by the same laboratory, there was a statistically significant and dose-related increase in the number of cells with aberrations, including sister chromatid unions. The study authors reported that the pH of the medium was unchanged (ECHA). [Kl. score = 2]

In Vivo Studies

Citric acid was not mutagenic in a dominant lethal assay when male rats were given either a single oral dose of citric acid (1.2 to 120 mg/kg) or a single oral dose on five consecutive days (300 to 3,500 mg/kg) (OECD 2001a,b) [Kl. score = 2]. There were no increases in chromosomal aberrations in the bone marrow of rats given either a single oral dose of citric acid (1.2 to 120 mg/kg) or a single oral dose on five consecutive days (300 to 3,500 mg/kg) (ECHA) [Kl. score = 2].

G. Carcinogenicity

Oral

There was no evidence of carcinogenicity in rats given 3% or 5% citric acid in feed (1,200 or 2,000 mg/kg/day, respectively) for two years (OECD, 2001a,b). [Kl. score = 4]

H. Reproductive Toxicity

In a non-standard repeat dose dietary study (duration and frequency not specified), 5% citric acid in feed did not affect either the number of young born to mice or rats or their subsequent survival up to the point of weaning (ECHA). [Kl. score = 4]

I. Developmental Toxicity

Pregnant female rats were dosed by oral gavage with 0, 2.95, 13.7, 63.6, or 295 mg/kg citric acid on GD 6-15. No maternal or developmental effects were noted. The NOAEL for maternal and developmental toxicity is 295 mg/kg-day, the highest dose tested (OECD, 2001a,b; ECHA). [Kl. score = 2]

Pregnant female rats were dosed by oral gavage with 0, 2.41, 11.2, 52, or 241 mg/kg citric acid on GD 6-15. No maternal or developmental effects were noted. The NOAEL for maternal and developmental toxicity is 241 mg/kg-day, the highest dose tested (OECD, 2001a,b; ECHA). [Kl. score = 2]

Pregnant female rabbits were dosed by oral gavage with 0, 4.25, 19.75, 91.70, or 425 mg/kg citric acid on GD 6-18. No maternal or developmental effects were noted. The NOAEL for maternal and developmental toxicity is 425 mg/kg-day, the highest dose tested (OECD, 2001a,b; ECHA). [Kl. score = 2]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for citric acid follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

In a two-year dietary study, the only effect seen in rats fed either 3 or 5% citric acid (approx. 1,200 or 2,000 mg/kg-day) was a slight decrease in growth in the 5% dose group. In the absence of statistical analysis of the body weight gain data, a conservative approach was taken, and the 5% dose group was considered an LOAEL. The NOAEL of 3% citric acid in the diet (1,200 mg/kg-day) will be used for determining the oral reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
- UF_A (interspecies variability) = 10
- UF_H (intraspecies variability) = 10
- UF_L (LOAEL to NOAEL) = 1
- UF_{Sub} (subchronic to chronic) = 1
- UF_D (database uncertainty) = 1

Oral RfD = 1,200/(10 x 10 x 1 x 1 x 1) = 1,200/100 = 12 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,

Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

Where:
- Human weight = 70 kg (ADWG, 2011)
- Proportion of water consumed = 10% (ADWG, 2011)
- Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (12 x 70 x 0.1)/2 = 42 mg/L

B. Cancer

Citric acid was not carcinogenic to rats in a chronic dietary study. Thus, no cancer reference value was derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Citric acid does not exhibit the following physico-chemical properties:
- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Citric acid is of low toxicity concern to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

The 48-hour LC_{50} values in *Leuciscus idus melanotus* (golden orfe) from two separate laboratories were 440 mg/L and 760 mg/L (ECHA) [Kl. scores = 2]. The 96-hour LC_{50} in *Lepomis macrochirus* (fathead minnow) is >100 mg/L (ECHA) [Kl. score = 2).

The 24-hour EC_{50} in *Daphnia* is 85 mg/L in un-neutralized test solution and 1,535 mg/L in a neutralized solution (OECD, 2001a,b; ECHA). [Kl. score = 2]

The 8-day toxicity threshold value (EC_0) in *Scenedesmus quadricauda* is 640 mg/L (ECHA; OECD, 2001a,b). [Kl. score = 2]

Chronic Studies

No studies are available.

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for citric acid follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for only fish (440 mg/L) and *Daphnia* (1,535 mg/L, neutralized). On the basis that the data consist of short-term results from two trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 440 mg/L for fish. The $PNEC_{water}$ is 0.44 mg/L.

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 0.277 mg/kg wet weight.

The calculations are as follows:

$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$
$= (0.807/1280) \times 1000 \times 0.44$
$= 0.277$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$K_{sed\text{-}water} = 0.8 + [0.2 \times Kp_{sed}/1000 \times BD_{soilid}]$
$= 0.8 + [0.2 \times 0.014/1000 \times 2400]$
$= 0.807$

Where:
Kp_{sed} = solid-water partition coefficient (L/kg).

BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$Kp_{sed} = K_{oc} \times f_{oc}$
= 0.3617 x 0.04
= 0.014

Where:

K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for citric acid is estimated to be 0.3617 L/kg.
F_{oc} = fraction of organic carbon suspended sediment = 0.04 [default].

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is 0.002 mg/kg soil dry weight.

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
= (0.007/1500) x 1000 x 0.44
= 0.002

Where:

Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
= 0.3617 x 0.02
= 0.007

Where:

K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for citric acid is estimated to be 0.3617 L/kg.
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT ASSESSMENT

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009, ECHA, 2008).

Citric acid is readily biodegradable; thus, it does not meet the screening criteria for persistence.

The log K_{ow} values for citric acid are -1.61 to -1.80. Thus, citric acid does not meet the screening criteria for bioaccumulation.

There are no adequate chronic aquatic toxicity studies on citric acid. The acute $E(L)C_{50}$ values for citric acid are >1 mg/L in fish and invertebrates. Thus, it does not meet the screening criteria for toxicity.

The overall conclusion is that citric acid is not a PBT substance.

IX. CLASSIFICATION AND LABELING

The information in this section is for a citric acid solution.

A. Classification

Eye Irritant Category 2

B. Labelling

Warning

C. Pictogram



X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact

In the case of contact, immediately flush eyes with plenty of water for at least 15 minutes. If symptoms persist, seek medical advice.

Skin Contact

Wash thoroughly with soap and water.

Inhalation

If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Ingestion

Rinse mouth with water and then drink plenty of water. Never give anything by mouth to an unconscious person. If symptoms develop, seek medical advice.

B. FIRE FIGHTING INFORMATION

Extinguishing Media

Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards

No data are available.

Special Protective Equipment for Firefighters

Wear self-contained breathing apparatus.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions

Use appropriate protective equipment.

Environmental Precautions

Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilt

Pick up with absorbent material. Dispose of contaminated material as prescribed.

D. STORAGE AND HANDLING

General Handling

No special measures necessarily provided product is used correctly.

Other Handling Precautions

Avoid eye and skin contact.

Storage

Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards

Workplace Australia has not established an occupational exposure standard for citric acid.

Engineering Controls

None

Personal Protection Equipment

Respiratory Protection: Respiratory protection is not required.

Hand Protection: Chemical resistant protective gloves.

Skin Protection: Body protection must be chosen depending on activity and possible exposure.

Eye protection: Safety glasses with side-shields.

Other Precautions: Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible.

F. TRANSPORT INFORMATION

Citric acid is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods Code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

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XIV. ACRONYMS AND GLOSSARY

°C	degrees Celsius
ADWG	Australian Drinking Water Guidelines
DEWHA	Department of the Environment, Water, Heritage and the Arts
EC	effective concentration
ECHA	European Chemicals Agency
EU	European Union
GHS	Globally Harmonised System of Classification and Labelling of Chemicals
HHRA	enHealth Human Risk Assessment
HPV	High Production Volume
IUPAC	International Union of Pure and Applied Chemistry
Kl	Klimisch scoring system
LOAEL	lowest observed adverse effect level
mg/kg	milligrams per kilogram
NOAEL	no observed adverse effect level
NOEC	no observed effective concentration
OECD	Organisation for Economic Co-operation and Development
PBT	Persistent, Bioaccumulative and Toxic
PNEC	Predicted No Effect Concentration
ppm	parts per million
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RfD	Reference Dose
SDS	Material Safety Data Sheet
SMILES	simplified molecular-input line-entry system
USEPA	United States Environmental Protection Agency
µm	micrometre

COFFEE EXTRACT

This dossier on coffee extract does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of coffee extract in its use in hydraulic fracturing fluids. The information presented in this dossier was obtained from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name: Coffee, bean, roasted, extract

CAS RN: 68916-18-7

Molecular formula: UVCB substance

Molecular weight: UVCB substance

Synonyms: Coffee extract; coffee, bean, roasted, extract

Table 1 shows all of the constituents found in roasted arabica and robusta coffees.

Table 1: Composition of Medium-Roasted Coffee (Clarke, 1987; IARC, 1991)

Components	**Typical average content (dry basis, %)**		**% extractable with water, 100°C[a]**
	Arabica	**Robusta**	
Alkaloids (caffeine)	1.3	2.4	75 - 100
Trigonelline (including roasted by-products)	1.0	0.7	85 - 100
Minerals (as oxide ash)	4.5	4.7	90
Acids			
Residual chlorogenic	2.5	3.8	100
Aquinic	0.8	1.0	100
Aliphatic	1.6	1.6	100
Sugars			
Sucrose	0.0	0.0	-
Reducing	0.3	0.3	100

Polysaccharides (unchanged from green)	33	37	10
Lignin	2.0	2.0	0
Pectins	3.0	3.0	-
Proteinaceous compounds			
Protein	10	10	15 – 20
Free amino acids	0.0	0.0	-
Lipids (coffee oil)	17	11	1
Caramelized or condensation products (*e.g.*, melanoidins) by difference	23	22.5	20-25
Volatile substances other than acids	0.1	0.1	40-80

[a]Maier (1981), for normal household brewing

II. PHYSICO-CHEMICAL PROPERTIES

Table 2: Overview of the Physico-chemical Properties of Coffee Extract

Property	**Value**	**Klimisch score**	**Reference**
Physical state at 20°C and 101.3 kPa	Viscous liquid	2	ECHA
Melting point	ca. -16.82 to -15.95°C	1	ECHA
Boiling point	>102.21°C	1	ECHA
Density	1.234 g/cm^3 @ 20°C	1	ECHA
Vapor pressure	21.8 Pa @ 20°C	1	ECHA
Partition coefficient (log K_{ow})	<0.36 @ 25°C	1	ECHA
Water solubility	2.85 mg/L @ 25°C	1	ECHA
Flash point	No flash to boiling.	1	ECHA
Auto flammability	>600°C	1	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Coffee extract is inherently biodegradable and is expected to have a low potential for bioaccumulation. The potential for adsorption is unknown; however, the low octanol water partition coefficient for coffee extract suggests that it is low. The acute toxicity by the oral and dermal routes is low.

B. Biodegradation

Coffee extract is inherently biodegradable. In an OECD 301D test, degradation was 50.2% after 28 days (ECHA) [Kl. score = 1].

C. Environmental Distribution

Adsorption/desorption

No experimental data are available for coffee extract. Coffee extract is an UVCB substance containing a wide range of different constituents (see Table 1); thus, a K_{oc} value cannot be calculated.

D. Bioaccumulation

No bioconcentration studies have been conducted on coffee extract. Coffee extract is not expected to bioaccumulate based on the experimental log K_{ow} of <0.36 (ECHA).

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

The information on the human health hazard for coffee extract includes primarily data on caffeine, the pharmacologically active constituent of coffee extract, as well as the extract itself. Coffee extract is not irritating to the skin or eyes. Caffeine consumption up to 400 mg caffeine/day in healthy adults is not associated with overt, adverse cardiovascular effects, behavioral effects, reproductive and developmental effects, acute effects, or bone status. Also, consumption up to 300 mg caffeine/day in healthy pregnant women is generally not associated with adverse reproductive and developmental effects.

B. Pharmacokinetics

Caffeine is rapidly and completely adsorbed in humans, with approximately 99% absorbed within 45 minutes of consumption (Carillo and Benitez, 2000). Plasma caffeine levels may be influenced by the diet or route of exposure, but peak plasma levels occur approximately 15 to 120 minutes after consumption (Mandel, 2002; Beach *et al.*, 1984; Bonati *et al.*, 1984; Collomp *et al.*,

1991). Caffeine is water soluble and is rapidly distributed throughout the body, detected in all bodily fluids, including saliva, breast milk, urine and semen (Beach *et al.*, 1984). Caffeine elimination follows first-order kinetics (Newton *et al.*, 1981), with the plasma half-life of caffeine at approximately 3 to 6 hours in healthy adults and does not accumulate in body fat or other tissues (Kaplan *et al.*, 1997; Nawrot *et al.*, 2003). Caffeine is rapidly metabolized and excreted (1-3 mg/kg/minute) in the urine (Kaplan *et al.*, 1997), and varies between species, with a slightly different metabolic route noted in rats (Nawrot *et al.*, 2003).

C. Acute Toxicity

Animal Studies

The oral LD_{50} value of an aqueous extract of roasted and ground beans of *Coffea canephora robusta* containing 7.5% caffeine was between 2,000 and 5,000 mg/kg (ECHA) [Kl. score = 1].

No acute inhalation studies are available on coffee extract. The 4-hour LC_{50} value of a caffeine aerosol in rats is 4.94 mg/L (ECHA) [Kl. score = 2].

No acute dermal studies are available on coffee extract. The dermal LD_{50} value of an aqueous solution of caffeine in rats is >2,000 mg/kg (ECHA) [Kl. score = 2].

Human Studies

Studies in human have focused on caffeine, the pharmacologically active component in coffee. The fatal acute oral dose is estimated at 10 and 14 g (approximately 160 to 230 mg/kg for a 60 kg person) (Hodgman, 1998). The serum caffeine concentration is the most reliable indicator of potential caffeine toxicity, with a serum caffeine concentration >100 μg/ml considered lethal in humans (Mrvos *et al.*, 1989). Human caffeine consumption at up to 10 g has caused convulsions and vomiting, with recovery in six hours (Dreisbach, 1974). An acute dose of one gram caffeine can cause adverse effects, progressing from restlessness, nervousness, and irritability to delirium, emesis, neuromuscular tremors and convulsions (IOM, 2004). However, caffeine consumption through the day at up to 900 mg has been reported without adverse effects (Nawrot *et al.*, 2003).

D. Irritation

Coffee silverskin extracts was not considered a skin irritant when tested in an *in vitro* reconstructed human epidermis test (ECHA) [Kl. score = 1].

Coffee, bean, roasted, extract was not considered an eye irritant when tested in a bovine corneal opacity and permeability test (ECHA) [Kl. score = 1].

E. Sensitization

No studies are available.

F. Repeated Dose Toxicity

<u>Oral</u>

Male and female rats were given in their drinking water 0, 25, 50, or 100% with either instant or brewed coffee for 91 days. The average daily intakes of caffeine were 0, 20, 40, or 80 mg/kg-day for the brewed coffee and slightly lower intakes for the instant coffee. At study termination, the kidneys of the 100% male coffee groups had enlarged kidneys based on both absolute and relative weights. In the females, liver and kidneys were enlarged in all rats given brewed coffee, although the relative weights were significantly higher only in the 100% group. In the ≥50% instant coffee groups, both absolute and relative liver and kidney weights were increased, although there was no clear dose-response pattern. Histopathologic examination showed no treatment-related effects. In the absence of corresponding histopathologic changes, the liver and kidney weight changes were considered to be adaptive changes and not adverse. The NOAEL for this study is 100% coffee in drinking water, which corresponds to 80 mg/kg-day (Nolen, 1981; ECHA) [Kl. score = 2].

In an NTP study, male and female F344 rats were dosed by oral gavage with 0, 188, 375, 750, 1,500, or 3,000 ppm caffeine for 90 days. The average daily intakes were: 0, 19.7, 42, 85.4, 151, or 272 mg/kg-day for males; and 0, 23, 51, 104, 174, or 287 mg/kg-day for females). Body weight gain was reduced in all treated groups but was only significant in the 3,000 ppm animals (26% and 20% for males and females, respectively). Water consumption was decreased in the 3,000 ppm animals; it was increased in the 375 and 750 ppm groups. The only treatment-related effects observed was cellular enlargement in the salivary gland, which was dose-dependent. This effect in the salivary gland was considered an adaptive response as a result of the pharmacological effect of caffeine (sympathomimetic) and not an adverse effect. The NOAEL for this study is 1,500 ppm, which corresponds to 151 and 174 mg/kg-day for males and females, respectively (ECHA) [Kl. score = 2].

Inhalation

No studies are available.

Dermal

No studies are available.

G. Genotoxicity

In Vitro Studies

Instant and home brew coffees (caffeinated and decaffeinated) were evaluated for genotoxicity in an in vitro chromosomal aberration test using human lymphocytes with or without metabolic activation (S9 mix). Chromosomal aberrations were increased with all coffee samples with or without S9, although there was less of an increase with S9. Pure caffeine tested with or without S9 at doses equivalent to the levels in the caffeine-containing coffees did not induce a statistically significant increase in chromosomal aberrations (Aeschbacher et al., 1985; ECHA) [Kl. score 2].

Instant and home brew coffees (caffeinated and decaffeinated) were evaluated for mutagenicity in an in vitro bacterial reverse mutation assay with or without metabolic activation (S9 mix). The *S. typhimurium* strains were TA 98, TA 100, TA1535, TA 1537, and TA 1538. A mutagenic response was observed with TA 100 in the absence of S9, but not with S9. None of the other

strains showed a mutagenic response with or without S9 (Aeschbacher and Würzner, 1980; ECHA) [Kl. score = 2].

Five Americano coffees from selected coffee chains were evaluated for mutagenicity in an in vitro bacterial reverse mutation assay with or without metabolic activation (S9 mix). The *S. typhimurium* strains were TA 98, TA 100, and TA 1535. There were no mutagenic responses with or without metabolic activation (Liu et al., 2017; ECHA) [Kl. score = 2].

In Vivo Studies

Male Swiss OF-1 mice were dosed by oral gavage with 0, 500, 1,000, 2,000, or 3,000 mg/kg instant coffee for five consecutive days. There was no treatment-related increase in the frequency of micronuclei in bone marrow cells (Aeschbacher et. al., 1984 ECHA) [Kl. score = 2].

H. Carcinogenicity

No carcinogenicity studies are available.

I. Reproductive/Developmental Toxicity

Animal Studies

A one-generation reproductive toxicity study was conducted in rats. Male and female rats were given in their drinking water 0, 25, 50, or 100% with either instant or brewed coffee. The average daily intakes were 0, 20, 40, or 8 mg/kg-day for the brewed coffee and slightly lower intakes for the instant coffee. Exposure of parental animals were for 91 days and during mating. Exposure continued through the first gestation period and through weaning. Ten days later, the females were mated the second time and were sacrificed on GD 13 or 21. There were no indications of reproductive or developmental toxicity (Nolen, 1981; ECHA) [Kl. score = 2].

Human Studies

Studies in human have focused on caffeine, the pharmacologically active component in coffee. Studies that evaluated the potential teratogenicity of caffeine have been discussed in a review (Christian and Brent, 2001). In animal studies, caffeine administration to pregnant animals has been found to induce teratogenicity and toxic effects on the development of the fetuses only at doses that also caused toxic effects in the dams (Christian and Brent, 2001). Christian and Brent (2001) concluded that studies reporting positive teratogenic effects were administering large doses of caffeine that were far greater than human consumption and were providing the caffeine via gavage, which results in much higher peak serum caffeine levels and therefore overstates toxicity potential. Neither rodents nor humans could attain such peak exposures by consuming solutions of caffeine over several hours, the usual mode of human caffeine consumption.

There have been questions raised on whether high intake of coffee or caffeine may increase the risk of miscarriage. Caffeine crosses the placenta and increases maternal catecholamine levels (Goldstein and Warren, 1962). The American College of Obstetricians and Gynecologists (2010) have concluded the following: “Moderate caffeine consumption (less than 200 mg per day) does not appear to be a major contributing factor in miscarriage or preterm birth. The relationship of

caffeine to growth restriction remains undetermined. A final conclusion cannot be made at this time as to whether there is a correlation between high caffeine intake and miscarriage."

The American College of Obstetricians and Gynecologists (2010) have concluded that moderate caffeine consumption (<200 mg/day) does not appear to be a major contributing factor in miscarriage or preterm birth.

A recent systematic review of the potential adverse effects of caffeine consumptions in humans concluded that consumption up to 400 mg caffeine/day in healthy adults is not associated with reproductive and developmental effects. Also, consumption up to 300 mg caffeine/day in healthy pregnant women is generally not associated with adverse reproductive and developmental effects (Wikoff et al., 2017).

J. Human Studies

Caffeine is a stimulant and has been studied for its physiological and behavioral effects. Caffeine increases heart rate and blood pressure, increases diuresis, increases locomotion and alertness, and decreases sleepiness. Clinical studies indicate that doses <450 mg do not increase the risk or severity of cardiac arrhythmia, while acute doses of 150 mg caffeine may decrease heart rate (James, 1991; Green *et al.*, 1996; Myer, 1998). Studies evaluating effects of caffeine on cardiovascular health or serum cholesterol levels have not provided a consistent adverse effect with caffeine consumption (Nawrot *et al.*, 2003).

Nawrot *et al.* (2003) concluded in their review of the effects of caffeine on human health that "for the healthy adult population, moderate daily caffeine intake at a dose level up to 400 mg/day (equivalent to 6 mg/kg body weight/day in a 65-kg person) is not associated with adverse effects such as general toxicity, cardiovascular effects, effects on bone status and calcium balance (with consumption of adequate calcium), changes in adult behavior, increased incidence of cancer and effects on male fertility." It was indicated that habitual daily use of caffeine at greater than 500-600 mg/day (8.3 - 10 mg/kg) (4-7 cups of coffee or 7-9 cups of tea) could be considered a health risk. For women, caffeine intake greater than 400 mg/day (6.7 mg/kg) "may increase the risk of detrusor instability (unstable bladder) development in women" (Nawrot *et al.*, 2003).

A recent systematic review of the potential adverse effects of caffeine consumptions in humans also concluded that consumption up to 400 mg caffeine/day in healthy adults is not associated with overt, adverse cardiovascular effects, behavioral effects, acute effects or bone status (Wikoff et al., 2017).

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for coffee extract follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

<u>Oral</u>

A 90-day drinking water study on brewed and instant coffee reported no adverse effects up to 80 mg/kg-day (Nolen, 1982). A NTP 90-day oral gavage toxicity study in rats showed no adverse effects up to 174 mg/kg-day (NTP).

In two separate reviews (Nawrot et al., 2003; Wikoff et al., 2017) with the most recent one conducted using a systematic review approach (Wikoff et al., 2003), caffeine consumption in healthy adults up to 400 mg/day is not associated with any adverse health effects. Based on the acceptable daily intake of caffeine in coffee extract, the acceptable daily intake of caffeine of 400 mg/day will be used to derive the oral reference dose and drinking water guidance value for coffee extract.

Oral Reference Dose (oral RfD)

For a 70 kg person, the oral reference dose is 400/70 = 6 mg/kg-day.

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (5.7 x 70 x 0.1)/2 = <u>20 mg/L</u>

B. Cancer

No studies are available. Thus, a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Coffee extract does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Coffee extract has a low acute toxicity concern for aquatic life.

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies conducted on coffee extract.

Table 3: Acute Aquatic Toxicity Studies on Coffee Extract

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Oncorhynchus mykiss	96-hr LL_{50}	>100 WAF	1	ECHA
Daphnia magna	48-hr EL_{50}	>100 WAF	1	ECHA
Pseudokirchneriella subcapitata	72-hr EL_{50}	>100 WAF (growth)	1	ECHA

Chronic Studies

No studies are available.

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for coffee extract follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)L_{50}$ values are available for fish (>100 mg/L WAF), invertebrates (>100 mg/L WAF), and algae (>100 mg/L WAF). On the basis that the data consist of short-term results from three trophic levels, an assessment factor of 100 has been applied to the acute $E(L)L_{50}$ value of 100 mg/L WAF from fish, invertebrates, and algae. The $PNEC_{water}$ is 1 mg/L.

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. The $PNEC_{sed}$ was not calculated using the equilibrium partitioning method because the K_{oc} value cannot be determined.

PNEC soil

There are no toxicity data for terrestrial or soil organisms. The $PNEC_{soil}$ was not calculated using the equilibrium partitioning method because the K_{oc} value cannot be determined.

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008). Coffee extract is not readily biodegradable, but it does appear to be inherently biodegradable; thus, it is not expected to meet the screening criteria for persistence.

Based on a measured log K_{ow} of <0.36, coffee extract does not meet the screening criteria for bioaccumulation.

There are no chronic aquatic toxicity studies on coffee extract. The acute $E(L)L_{50}$ values for coffee extract are >1 mg/L for fish, invertebrates, and algae. Thus, coffee extract does not meet the screening criteria for toxicity.

The overall conclusion is that coffee extract is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Not classified.

B. Labelling

No signal word.

C. Pictogram

None.

X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
In case of contact, immediately flush eyes with plenty of water. If easy to do, remove contact lenses.

Skin Contact
Take off contaminated clothing immediately. Wash thoroughly with soap and water. Get medical attention if irritation develops and persists.

Inhalation
If inhaled, remove from area to fresh air. Get medical attention.

Ingestion
Rinse mouth with water and then drink a glass of water. Get medical attention. Do not induce vomiting. Never give anything by mouth to an unconscious person.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: carbon monoxide, carbon oxides, nitrogen oxides.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Use personal protective clothing.

Environmental Precautions
Do not empty into drains.

Steps to be Taken if Material is Released or Spilled
For small amounts: Pick up with absorbent material. Dispose of contaminated material. For large amounts: pump off product.

D. STORAGE AND HANDLING

General Handling
No special measures necessary provided product is used correctly.

Storage
Keep container tightly closed and dry. Store in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards

Workplace Australia has not established an occupational exposure limit for coffee extract.

Engineering Controls
None

Personal Protection Equipment

Respiratory Protection: Respiratory protection not required.

Hand Protection: Wear chemical resistant protective gloves.

Skin Protection: Body protection must be chosen depending on activity and possible exposure.

Eye protection*:* Wear safety goggles with side shields.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Wearing of closed work clothing is recommended. Ensure that eyewash stations and safety showers are close to the workstation location.

F. TRANSPORT INFORMATION

Coffee extract is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

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DIETHANOLAMINE

This dossier on diethanolamine (DEA) does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of diethanolamine in its use in drilling muds and hydraulic fracturing fluids. The majority of information presented in this dossier was obtained from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC): 2,2'-iminodiethanol

CAS RN: 111-42-2

Molecular formula: $C_4H_{11}NO_2$

Molecular weight: 105.14

Synonyms: Diethanolamine; 2,2'-iminodiethanol; 2,2'-dihydroxydiethylamine; 2-[(2-hydroxyethyl)amino]ethanol; bis(2-hydroxyethyl)amine; DEA; di(2-hydroxyethyl)amine; ethanol, 2,2'-iminobis-(9Cl); ethanol, 2,2'iminodi-(8Cl)

SMILES: C(CO)NCCO

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Diethanolamine

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Crystals (prisms) or syrupy liquid (>82°F)	2	ECHA
Melting Point	27°C	1	ECHA
Boiling Point	268.9°C (decomposition occurs ≥200°C)	1	ECHA
Density	1.095.3 kg/m^3	2	ECHA
Vapor Pressure	1 hPa @ 108°C (measured); 0 hPa at 25°C	2	ECHA

Partition Coefficient (log K_{ow})	-2.46 @ 25°C	2	ECHA
Water Solubility	Miscible	2	ECHA
Flash Point	176°C @ 1,013 hPa	2	ECHA
Auto flammability	375°C @ 1,013 hPa	1	ECHA
Flammable	Not flammable	1	ECHA
Viscosity	390.9 mPa s @ 30°C; 102.7 mPa s @ 50°C	2	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Diethanolamine is readily biodegradable. It is not expected to bioaccumulate, and it has low potential to adsorb to soil.

B. Biodegradation

Diethanolamine is readily biodegradable. In an OECD 301F test, there was 50% degradation after 7 days, 80% after 14 days, and 93% after 28 days (OECD 2007; ECHA) [Kl. score = 1]. In a "Ready" Biodegradability – Dissolved Organic Carbon (DOC) Die-Away test, there was 86% degradation after 7 days and 96% degradation after 10 days (ECHA) [Kl. score = 2]. In modified OECD 301E screening tests using river or pond water, there was 93% and 97% degradation (measured as DOC removal) after 28 days (OECD 2007; ECHA) [Kl. score = 2].

C. Environmental Distribution

Distribution Modeling

No experimental data are available for diethanolamine. The K_{oc} for diethanolamine (as the charged molecule) was calculated to be 10 at pH values between 5 and 8 (Franco and Trapp, 2008; Franco et al., 2009; ECHA). [Kl. score = 2]

E. Bioaccumulation

There are no bioaccumulation studies on diethanolamine. The BCF was estimated to be 2.3 based on calculations from OASIS Catalogic v.5.11.15 [BCF base-line model v.0208] (Dimitrov et al., 2005; ECHA).

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Diethanolamine exhibits moderate acute toxicity by the oral route, but low acute toxicity by the inhalation and dermal routes. It is a skin irritant and a severe eye irritant. Diethanolamine is not a skin sensitizer. Repeated oral exposure to rats (in drinking water) resulted in anemia, kidney toxicity, demyelinization of the brain/spinal cord, and damage to the testes in males, which included adverse effects on the sperm. Repeated oral exposure to mice (in drinking water) resulted in adverse effects to the kidney, liver, and heart. Repeated dermal exposure to rats and mice resulted in systemic toxicity, which included kidney toxicity, anemia (rats only), and liver toxicity (mice only). Rats exposed nose-only to an aerosol of diethanolamine developed anemia, adaptive liver and kidney effects, damage to the male reproductive organs, and upper respiratory tract irritation. There was no evidence of neurotoxicity. In short-term oral studies, rats and mice exposed to diethanolamine showed some immune-modulating effects at dose levels that resulted in overt signs of systemic toxicity. Diethanolamine was not genotoxic in a variety of *in vitro* and *in vivo* genotoxicity tests. Diethanolamine was not carcinogenic to rats in a two-year NTP dermal bioassay; but, in mice, there was an increased incidence of liver tumors in males and females and kidney tumors in males. Studies by the oral and dermal routes showed testicular damage in male rats, but no adverse effects in female reproductive organs. Developmental toxicity occurred in rats when exposures by the oral, dermal, or inhalation routes also caused maternal toxicity. There was no developmental toxicity in rabbits even at doses that caused maternal toxicity.

B. Pharmacokinetics/Metabolism

Following oral administration of [^{14}C]-diethanolamine, 57% of the dose was absorbed (Matthews et al., 1997). Absorption was lower through the skin than from oral administration. Diethanolamine may also facilitate its own absorption in rats, as 3% and 16% of the dermally applied doses (in 95% ethanol) of 2 and 27 mg/kg, respectively, were absorbed through the skin in a 48-hour period. Dermal absorption of diethanolamine is higher in the mouse than the rat: absorption was 25 to 60% from dermal doses of 8 to 80 mg/kg (Matthews et al., 1997).

The distribution of diethanolamine is similar across all routes of exposure (Matthews et al., 1997; Mendrala et al., 2001). The highest concentrations were found in the liver and kidney. The half-life of diethanolamine from tissues is about 6-7 days (Mendrala et al., 2001).

Following an oral dose of [^{14}C]diethanolamine to male F344 rats, the livers showed levels of un-metabolized diethanolamine, N-methyl-diethanolamine, N,N-dimethyl-diethanolamine, and phosphates of diethanolamine. In addition, the organic extract of the liver had radioactivity co-eluting with phosphatidyl ethanolamine and phosphatidyl choline. When the organic extract was digested with sphingomyelinase, 30% of the phospholipids were identified as ceramides and the remaining 70% as phosphoglycerides. Incubation of human liver slices with [^{14}C]-diethanolamine showed similar incorporation of diethanolamine into ceramides, followed by methylation (Matthews et al., 1995).

Diethanolamine is excreted primarily in urine as the parent compound (25-36%), with lesser amounts of O-phosphorylated and N-methylated metabolites (Matthews et al., 1997).

C. Acute Toxicity

The oral LD_{50} value for male and female rats combined was determined to be 1,600 mg/kg (ECHA) [Kl. score = 2]. The oral LD_{50} in female Wistar rats is 1,820 mg/kg (ECHA) [Kl. score = 2].

There were no deaths in rats following an 8-hour inhalation exposure to an atmosphere enriched with diethanolamine vapor. The technically highest attainable concentration is 1.9 mg/m^3 or 0.44 ppm (ECHA) [Kl. score = 2]. There were no deaths in rats following an 8-hour exposure to 0.2 mg/L diethanolamine vapor (ECHA) [Kl. score = 2].

There are no reliable acute dermal toxicity studies on diethanolamine.

D. Irritation

Application of 2 mL of diethanolamine to the skin of rabbits for 20 hours was irritating. The mean of the 24, 48, and 72 hours scores were 2.00 for erythema and 1.33 for edema (ECHA) [Kl. score = 2].

Instillation of diethanolamine into the eyes of rabbits was irritating. The mean of the 24, 48, and 72 hour scores were 1.67 for corneal opacity; 0.00 for iridial lesions; 1.50 for conjunctival redness; and 0.83 for chemosis. Corneal lesions still persisted in one of two animals at the end of the 8-day observation period (ECHA) [Kl. score = 2]. Instillation of 100 mg diethanolamine into the eyes of rabbits produced a mean irritation score based on Kay and Calandra of 50.75, indicating severe irritation (ECHA) [Kl. score = 2].

E. Sensitization

Diethanolamine was not considered a skin sensitizer in a mouse local lymph node assay (ECHA). [Kl. score = 1]

F. Repeated Dose Toxicity

Oral

Male and female F344 rats were given diethanolamine in their drinking water for 13 weeks at concentrations of 0, 320, 630, 1,250, 2,500, or 5,000 ppm for males; and 0, 160, 320, 630, 1,250, or 2,500 ppm for females. The average daily intakes were estimated to be: 0, 25, 48, 97, 2,202, or 436 mg/kg-day for males; and 0, 14, 32, 57, 124, or 242 mg/kg-day for females. In the top dose group, 2/10 males died during the study. Weight gain was reduced in the ≥630 ppm males and the ≥320 ppm females. Decreased water consumption among the higher dose groups may have contributed in part to the decreased body weight gain. Clinical signs of toxicity included tremors, emaciation, abnormal posture, and rough hair coat in the two highest dose groups. A dose-dependent microcytic, normochromic anemia was seen in all dose groups for both sexes. Hematologic effects included decreases in erythrocyte and reticulocyte counts, hemoglobin concentration, hematocrit, MCV, and MCH. MCV was reduced in rats at all dose levels. Hematologic effects were not associated with microscopic changes in the femoral bone marrow. Relative kidney weights were increased in a dose-dependent manner in the ≥320 ppm males and ≥160 ppm females, accompanied by increases in the incidence and/or severity of nephropathy, renal tubular cell necrosis, or tubular mineralization. Nephropathy consisted of tubules lined by epithelial cells with more basophilic staining of the cytoplasm and a higher nuclear/cytoplasmic ratio; occasionally, thickened basement membranes were seen around these tubules. This lesion was present to a minimal degree in controls, particularly in male rats, but was increased in incidence and severity in the 5,000 ppm males and in most of the groups of treated females. Increased nephropathy was considered a regenerative change and was supported by the observation of tubular necrosis at the higher dose groups. Relative liver weights were increased in the ≥630 ppm males and ≥320 ppm females, with no corresponding histopathological changes in the liver. There was, however, mild to moderate increases in serum levels of total bile acids in the ≥160 ppm females and in the ≥630 ppm males. Decreases in testis and epididymis weights (≥1,250 ppm) were associated microscopically with degeneration of seminiferous epithelium and with hypospermia (≥2,500 ppm). Testicular degeneration was diagnosed in all high-dose males and in 3/10 of the 2,500 ppm males. Intraluminal cellular debris and reduced numbers of sperm cells were present in the epididymis. These findings correlated with decreases in sperm motility and sperm count per gram caudal tissue. There was also atrophy of the seminal vesicle and prostate glands in the higher dose group males. In females, the estrous cycle length was similar across all groups. Minimal to mild demyelination of the brain and spinal cord was noted in the ≥2,500 ppm males and the ≥1,250 ppm females; there were no neurological clinical signs that could be attributed to these lesions. Cytoplasmic vacuolization of the zona glomerulosa of the adrenal cortex was seen in the 5,000 ppm males and in the ≥1,250 ppm females. This was a minimal change consisting of small clear vacuoles in the cytoplasm of these cells and may have been related to increased mineralocorticoid production secondary to kidney damage and/or dehydration. The most

sensitive endpoints were the microcytic anemia in both sexes and kidney effects in females (weight, nephrotoxicity) and males (weights). The LOAELs are 320 ppm (25 mg/kg-day) for males and 160 ppm (14 mg/kg-day) for females (NTP 1992; Melnick et al., 1994a). [Kl. score = 1]

Male and female B6C3F1 mice were given diethanolamine in their drinking water at concentrations of 0, 630, 1,250, 2,500, 5,000 or 10,000 ppm for 13 weeks. The average daily intakes were estimated to be: 0, 104, 178, 442, 807, or 1,674 mg/kg-day for males; and 0, 142, 347, 884, 1,154, or 1,128 mg/kg-day for females. All of the ≥5,000 ppm animals and 3/10 of the 2,500 ppm females died during the study. Body weight gains were lower in the 2,500 ppm males and in the 1,250 and 2,500 ppm females. Animals that survived to the end of the study had similar water consumption compared to the controls. Clinical signs in the animals that died early in the 2,500 ppm group were tremors, ruffled fur, emaciated appearance, abnormal posture, and hypoactivity. There was no significant gross findings at necropsy in the mice that died early or survived to study termination. Absolute and relative liver weights were increased in a dose-dependent manner in male and female mice and was associated with increases in serum alanine aminotransferase and sorbital hydrogenase activities and, in addition, microscopic changes diagnosed as hepatocellular cytologic alteration and necrosis. Cytologic alteration consisted of multiple hepatocyte changes including hypertrophy with increased eosinophilia and disruption of hepatic cords. These lesions were observed in mice that died early and those that survived to the end of the study. There was also increased nuclear pleomorphism and the frequent presence of large, multinucleated hepatocytes. These giant cells often contained 10 or more nuclei. Hepatocyte necrosis was randomly distributed and involved single cells or small foci. Absolute and relative kidney weights were increased in males and were associated with a dose-dependent increase in the incidence of nephropathy among those mice that survived to the end of the study. Nephropathy was minimal; there were renal tubules lined by basophilic cells with high nuclear/cytoplasmic ratio. This was considered to be a regenerative response, although active tubular necrosis was observed only in a few early-death mice at ≥5,000 ppm. Increased heart weight was seen in the 2,500 ppm females, and relative heart weight was seen in the 2,500 ppm males and the 1,250 and 2,500 ppm females. There was also minimal-to-marked degeneration and necrosis of cardiac myocytes in both sexes exposed to ≥2,500 ppm. Myocardial degeneration was generally more severe in mice that died early than in those that survived to study termination. The most sensitive endpoint was the increase in liver weights with corresponding histopathological changes. The LOAEL was 630 ppm (104 and 142 mg/kg-day in males and females, respectively) (NTP, 1992; Melnick *et al.*, 1992b). [Kl. score = 1]

Inhalation

Male and female Wistar rats were exposed nose-only to 0, 15, 150, or 450 mg/m^3 diethanolamine aerosol, 6 hours/day, 5 days/week for 90 days. The MMAD values were 1.1 – 1.9 μm, 1.0 μm, and 0.6 – 0.9 μm for the 15, 150, and 450 mg/m^3 exposure groups, respectively. The percent aerosol ranged among the exposure groups,, from 92 to 95%.

There were no deaths during the study. The 400 mg/m^3 males had slightly decreased body weights. The neurotoxicity endpoints (functional observation battery, sensorimotor test/reflexes, and motor activity) and ophthalmoscopy examination showed no treatment-related effects. At 400 mg/m^3, there was a significant decrease in red blood cells, hemoglobin, hematocrit, and mean corpuscular volume in both sexes. A marginal increase in anisocytosis was seen in the 400 mg/m^3 males; and no treatment-related effects were seen in white or differential blood counts. ALP serum activity was increase in the $\geq$150 mg/m^3 animals, and reduced ALT in the $\geq$150 mg/m^3 males. Blood chemistry changes included increased calcium, total protein, albumin, globulin in the $\geq$150 mg/m^3 females; and increased total protein and albumin in the $\geq$150 mg/m^3 males as a trend. Absolute and relative liver and kidney weights were increased in the $\geq$150 mg/m^3 animals. Histopathologic examination showed diffuse testicular atrophy accompanied by oligozoospermia in the epididymides, and slight prostate atrophy in the some of the 400 mg/m^3 males. There was also minimal or slight tubular hyperplasia of the kidney in some females as well as intratubular lithiasis in increased number (also in the 400 mg/m^3 males). There was also indications of local irritation of the respiratory tract. The larynx appeared to be the most sensitive area where some epithelia damage was observed at all concentrations. Focal inflammation at the tracheal bifurcation occurred in the $\geq$150 mg/m^3 animals. No treatment-related effects were seen in the neuropathologic examination. The NOAEC for systemic toxicity is 15 mg/m^3. The LOAEC for localized effects (irritation) is 15 mg/m^3; a NOAEC was not established (Garner et al., 2008). [Kl. score = 1]

Male and female Wistar rats were exposed nose-only to 0, 1.5, 3, or 8 mg/m^3 diethanolamine aerosol, 6 hours/day, 5 days/week for 90 days. Additional group of female rats were exposed for 90 days followed by a 3-month recovery period. The MMAD values were 0.6 μm, 0.6 μm, and 0.7 μm for the 1.5, 3, and 8 mg/m^3 exposure groups, respectively. At 8 mg/m^3, the animals showed upper respiratory tract irritation in the form of squamous metaplasia of the laryngeal epithelium at the base of the epiglottis; this was accompanied by some inflammatory cell infiltration. These effects were reversible following the 3-month recovery period. The NOAEC for localized effects (irritation) is 3 mg/m^3 (ECHA). [Kl. score = 1]

Dermal

Male and female F344 rats were given daily dermal applications of 0, 32, 63, 125, 250, or 500 mg/kg diethanolamine, 5 days/week for 13 weeks. The animals that died during the study are as follows: one 500 mg/kg male during week 9 and 2 500 mg/kg females that were killed in a moribund condition during week 10. Final mean body weights were lower in the $\geq$250 mg/kg male and the $\geq$125 mg/kg females. The primary clinical signs of toxicity in the $\geq$125 mg/kg animals were irritation and crusting of the skin at the application site. In all dosed groups, there was a moderate, poorly regenerative, microcytic, normochromic anemia in both sexes. Red blood cell variables were decreased in the $\geq$32 mg/kg dose groups. There were no histologic changes in the femoral bone marrow in any dose group. Serum biochemical changes in males were

increased UN and albumin in the 63 and 250 mg/kg groups, respectively, and mild increases in ALT in the ≥125 mg/kg animals. In females, UN, albumin, and total protein increased in the ≥32 mg/kg groups (≥63 mg/kg for total protein), and total bile acids increased in the ≥250 mg/kg groups. A mild increase was seen in ALT in the 500 mg/kg females. The kidney was a target organ. Absolute and relative kidney weights in male and female rats; these were associated with increased severity or increased incidences of nephropathy, renal tubular cell necrosis, or tubular mineralization. The incidence and severity of nephropathy was increased in a dose-dependent manner at the lower dose levels in females, but there was no clear treatment effect on this lesion in males. Tubular necrosis was observed in the ≥250 mg/kg females, but no active necrosis was found in the corresponding male groups. Tubular mineralization, consistent with previous necrosis, was present in the 500 mg/kg males, as well as being increased in incidence and severity in most treated female groups. The absolute and relative liver weights were increased in a dose-dependent manner in both sexes; there were no corresponding histopathologic changes even though there were some mild serum biochemical changes. There were no adverse effects on the testes or epididymides; sperm morphology and vaginal cytology was unaffected by treatment. The skin lesions were dose-related in incidence and severity, and consisted of ulcers, chronic active inflammation, acanthosis, and hyperkeratosis. Demyelination in the medulla oblongata was observed in the 500 mg/kg animals, and in seven 250 mg/kg females; the lesions were characterized by intramyelinic vacuoles arranged symmetrically around the medial medulla oblongata in the region of the tectospinal tract. The lesions were minimal in severity and there was no spinal cord involvement. The LOAEL for this study is 32 mg/kg-day; a NOAEL was not established (NTP, 1992; Melnick et al., 1994a). [Kl. score = 1]

Male and female $B6C3F_1$ mice were given daily dermal applications of 0, 80, 160, 320, 630, and 1,250 mg/kg diethanolamine, 5 days/week for 13 weeks. At 1,250 mg/kg, there were early deaths and reduced body weight gain. Skin lesions were seen in the ≥80 mg/kg groups, there was acanthosis at 80 mg/kg and with a dose-dependent increased incidence up to ulcerations, inflammation, and hyperkeratosis at the higher levels. Liver weights were increased in a dose-dependent manner in the ≥32 mg/kg groups and were associated with morphological alterations in the liver in the ≥32 mg/kg groups. Kidney weights were increased in a dose-dependent manner in the ≥32 mg/kg groups with an increased incidence of tubular necrosis only in the 1,250 mg/kg group. There was also degeneration in the heart and cytologic alterations in the salivary gland in the 1,250 mg/kg group only. The LOAEL for this study is 80 mg/kg-day; a NOAEL was not established (NTP, 1992;Melnick et al., 1994b) [Kl. score = 1]

G. Genotoxicity

In Vitro Studies

Table 2 presents the results of the *in vitro* genotoxicity studies on diethanolamine.

Table 2: *In vitro* Genotoxicity Studies on Diethanolamine

Test System	Results*	Klimisch	Reference

	-S9	+S9	Score	
Bacterial reverse mutation (*S. typhimurium* and *E. coli* strains)	-	-	2	Dean et al. (1985)
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	Haworth et al. (1983)
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	-	-	2	Myhr et al. (1986)
Chromosomal aberration (rat liver cells RL1 and RL4)	-	NA	2	Dean et al. (1985)
Chromosomal aberrations (CHO cells)	-	-	2	Loveday et al. (1989)
Sister chromatid exchange (CHO cells)	-	-	2	Loveday et al. (1989)

*+, positive; -, negative; NA, not applicable

In vivo Studies

Male and female B6C3F$_1$ mice were given daily dermal applications of 0, 80, 160, 320, 630, or 1,250 mg/kg diethanolamine for 13 weeks. There was no induction of micronuclei in the peripheral blood erythrocytes at any dose level (NTP, 1992; Witt et al., 2000) [Kl. score = 1].

H. Carcinogenicity

Oral

No studies are available.

Inhalation

No studies are available.

Dermal

Male and female F344/N rats were given dermal application of diethanolamine for 104 weeks. For males, the doses were 0, 16, 32 or 64 mg/kg-day; and for females, the doses were 0, 8, 16 or 32 mg/kg-day. There was no difference in survival rates between treated and control animals. Mean body weights were lower in the 64 mg/kg-day males from

week 8 to 89 and in the 32 mg/kg-day females from week 97 compared to the control animals. The incidences of tumors was not increased in the treated groups compared to the controls. (NTP, 1999). [Kl. score = 1]

Male and female B6C3F$_1$ mice were given dermal applications of 0, 40, 80 or 160 mg/kg-day diethanolamine by dermal application for 104 weeks. There was reduced survival in the treated female mice (88, 66, 66, and 46% for the 0, 40, 80 and 160 mg/kg-day groups, respectively). This was attributed to liver tumors. No differences were seen in survival rates in the treated male mice compared to the controls. Mean body weights in the 80 and 160 mg/kg-day males were lower than those in the control animals after week 88. Mean body weights in the treated female mice were lower than those of the controls from week 73 (40 and 80 mg/kg-day) and week 53 (160 mg/kg-day).

The incidence of hepatocellular adenomas and of hepatocellular adenomas and carcinomas (combined) were significantly increased in all male and female dose groups, while the incidences of hepatoblastoma was increased in the mid- and high-dose groups. In the female mice, the incidences of hepatocellular neoplasms were significantly higher in all dosed groups compared to the control. Non-neoplastic lesions were seen only in the liver of all male and female dose groups and consisted of cytoplasmic alteration, characterized by mild to moderate enlargement of centrilobular hepatocytes, and syncytial alteration, characterized by scattered hepatocytes with three or more small nuclei.

The incidence of renal tubule adenomas was also increased in males with a positive trend, but the incidences of carcinoma and hyperplasia did not follow this pattern. A step section evaluation found additional adenomas and hyperplasias in all treated male groups. The combined analysis of single and step sections indicated a dose-related increase in the incidence of renal hyperplasia and renal tubule adenoma or carcinoma (combined), and increase in the incidences of renal tubule adenoma in male mice (NTP, 1999). [Kl. score = 1]

<u>Mode-of-Action for Mouse Liver Tumors in DEA-exposed Mice</u>

Effects of DEA on choline homeostasis

Dietary choline deficiency or deprivation induces liver tumors in rodents (Newberne *et al.*, 1982). In contrast, dietary supplementation of choline with or without methionine reduces the incidence of liver tumors in carcinogen-treated mice (Fullerton *et al.* 1990; Newberne *et al.*, 1990). DEA is structurally similar to ethanolamine and choline, important endogenous precursors for normal membrane structure and function. Choline is also oxidized to betaine, an essential methyl group donor in 1-carbon metabolism. The mechanisms by which choline deficiency is thought to be carcinogenic include enhanced cell proliferation, altered methylation status, and altered signal transduction (Rogers, 1995; Zeisel, 1996; Zeisel and Blustjazn, 1994). The development of intracellular

choline deficiency as the mode of action by which DEA cause the mouse liver tumors observed in the NTP bioassay is supported by the following experimental evidence:

1. $B6C3F_1$ mice dosed dermally with 160 mg/kg DEA, 5 days/week for 2 weeks showed a marked decrease in choline metabolites and S-adenosylmethionine (SAM) levels in their livers similar to animals kept on a choline-devoid diet, indicating the development of choline deficiency. These effects were reversed following a 2-week recovery period (Lehman-MeKeeman *et al.*, 2002). A significant reduction in the hepatic levels of choline metabolites, including choline, phosphocholine, and glycerophospho-choline, and SAM levels was also reported by Stott *et al.* (2000) with $B6C3F_1$ mice dosed in a similar regimen with DEA via dermal and/or oral routes.

2. $B6C3F_1$ mice have a much lower ability than C57Bl/6 mice to maintain nascent methylation capacity, a characteristic that is believed to contribute to a higher spontaneous liver tumor incidence in $B6C3F_1$ mice (Counts *et al.*, 1996). In a study by Lehman-McKeeman *et al.*, (2002), choline deficiency, as evidenced by changes in phosphocholine concentrations, was produced in both strains of mice. However, unlike the $B6C3F_1$ mouse, DEA did not alter SAM concentrations in the C57Bl/6 strain.

3. DEA is incorporated into rat liver phospholipids (Barbee and Hartung, 1979; Mathews *et al.*, 1995) and can alter the biosynthesis of hepatic phosphatidylethanolamine and phosphatidylcholine (PC). In cultured cells, DEA inhibited cellular uptake of choline, decreased PC synthesis, and became incorporated into phospholipid fractions. These *in vitro* effects were prevented by culturing cells in the presence of excess choline (Lehman-McKeeman and Gamsky, 1999).

4. DEA caused morphological transformation in Syrian hamster embryo (SHE) cell transformation assay. However, this response was prevented when SHE cells were cultured in a medium containing excess choline (Lehman-McKeeman and Gamsky, 2000).

5. DNA synthesis was increased in mouse and rat, but not human, hepatocytes incubated with DEA. Incubation of mouse and rat, but not human, hepatocytes in medium containing reduced choline increased DNA synthesis. Mouse and rat hepatocytes incubated in medium with excess choline reduced DEA-induced DNA synthesis to control levels or below (Kamendulis and Klaunig, 2005).

6. DNA hypomethylation in GC-rich promotor regions observed in primary mouse hepatocytes which have been treated with DEA are similar to those caused by choline-deficient medium (Bachman *et al.*, 2005).

In situ formation of N-nitrosodiethanolamine

DEA is a secondary amine and may react with a nitrosating agent under certain conditions to form N-nitrosodiethanolamine. This nitrosoamine has been shown to be mutagenic *in vitro* and cause liver tumors in rats and doses of 2 mg/kg-day and higher (ECETOC, 1990). Rats given high, often toxic, oral bolus doses of DEA and nitrite have

shown or inferred to produce N-nitrosodiethanolamine (Preussman *et al.*, 1981; Yamamoto *et al.*, 1995). Studies by Stott *et al.* (2000) showed, however, that mimicking the dosing conditions in the NTP study (160 mg/kg DEA dermally) and drinking water supplemented with 170 ppm sodium nitrite to favor nitrosation did not result in N-nitrosodiethanolamine formation in the gastric contents, blood or urine of mice. The findings of Stott *et al.* (2000) suggest that the mouse liver tumors observed in the NTP bioassay were unlikely due to *in situ* nitrosamine formation.

Relevance to Humans

There are marked species differences in susceptibility to choline deficiency, with rats and mice being far more susceptible than other species including humans (Zeisel and Blusztajn, 1994). Rats and mice have a higher dietary choline requirement than humans in large part because rodents oxidize choline more rapidly than humans (Sidransky and Farber 1960). DEA was carcinogenic in mice, but not in rats, in the NTP dermal carcinogenicity studies. The fact that DEA was not carcinogenic to rats, a species highly susceptible to choline deficiency, should be an important consideration in the overall evaluation of human cancer risk. DEA is less readily absorbed across rat skin than mouse skin, and the resulting blood and tissue concentrations of DEA are at least three-times lower in rats than in mice at similar dosages (Mathews *et al.*, 1997). Lehman-McKeeman *et al.*, (2002) determined the NOAEL for DEA-induced choline deficiency in mice (based on phosphocholine concentrations) to be 10 mg/kg-day. Thus, there is a critical concentration of DEA that must be reached in order to affect choline homeostatis. In the rats, the lack of a carcinogenic response suggests that it is unlikely that exposure to DEA reached this concentration or that rats are not as susceptible as mice to the effects of DEA on hepatic choline metabolism. Overall, the results suggest that the hepatocarcinogenic effects of DEA in mice are not predictive of similar susceptibility in other laboratory animals or humans.

I. Reproductive Toxicity

No specific reproductive toxicity studies have been conducted on diethanolamine by any route of exposure.

In the NTP 13-week drinking water study, F344 rats were given 0, 160 (females only), 320, 630, 1,250, 2,500 or 5,000 ppm (males only) diethanolamine. All high-dose males and 3/10 of the 2,500 ppm males showed testicular degeneration; male rats in the higher dose groups also had atrophy of the seminal vesicles and prostate glands. Testis and epididymal weights in the $\geq$1,250 ppm males were decreased and were associated microscopically with degeneration of seminiferous epithelium, as well as hypospermia and reduced sperm motility in the $\geq$2,500 ppm males. The NOAEL for reproductive effects in males was 630 ppm (corresponding to 48 mg/kg-day). There were no effects noted in the female reproductive organs (NTP 1992; Melnick *et al.* 1994b).

In a 90-day inhalation study, some of the male Wistar rats exposed whole-body to 400 mg/m^3 showed diffuse testicular atrophy accompanied by oligozoospermia in the epididymides, and slight prostate atrophy (ECHA).

J. Developmental Toxicity

Oral

A Chernoff-Kavlok screen was conducted on diethanolamine. Initially, four female CD-1 mice were given by oral gavage 0, 200, 380, 720, 1,370, 2,605, and 2,605 mg/kg diethanolamine during GD 6-15; a subsequent study was conducted which consisted of dosing 50 female CD-1 mice with 450 mg/kg during GD 6-15. Mortality was seen at ≥720 mg/kg, with 100% mortality in the ≥1,370 mg/kg groups. Dams dosed with ≥200 mg/kg showed clinical signs of intoxication. There was no mortality in the 450 mg/kg dams; nor was there any effect on litter size and pup birth weight, but the number of viable litters, the percent of pup survival, and pup weight gain were reduced (York *et al.* 1988). Kl. score = 2]

Female SD rats were dosed by oral gavage with 0, 50, 125, 200, 250, or 300 mg/kg diethanolamine from GD 6-19. All dams in the 300 mg/kg group had to be killed early due to excessive toxicity. At 200 and 250 mg/kg, the dams exhibited either morbidity or died. Water intake was affected early in the gestation period in the 125 and 250 mg/kg dams; it was comparable to controls after GD 12. Reduced maternal body weight and weight change, as well as food intake, were seen in the ≥200 mg/kg dose groups. The ≥125 mg/kg dams had increased absolute kidney weights on postnatal day (PND) 21. There were no maternal effects in the 50 mg/kg dams. There was postimplantation deaths at ≥200 mg/kg on PND 0 and increased early postnatal mortality (PND 0-4) in the ≥125 mg/kg dose groups. Pup body weight was reduced at ≥200 mg/kg, with females affected more than males. Pup body weight gain was predominantly reduced during the early postnatal period. There were statistically significant differences at the end of the lactational period, which were flawed by the low number of animals. The NOAEL for maternal and postnatal developmental (screening) toxicity was 50 mg/kg-day (Price *et al.* 2005). [Kl. score = 2]

Inhalation

Pregnant female Wistar rats were exposed by inhalation to 0, 10, 50, or 200 mg/m^3 diethanolamine 6 hours/day on GD 6 to 15. Maternal toxicity was seen at 200 mg/m^3; there were vaginal hemorrhages in 8/21 pregnant rats on GD 14. There was also a markedly increased number of fetuses with skeletal variations (mainly cervical ribs) in the 200 mg/m^3 exposed group. The NOAEC for maternal and developmental toxicity is 200 mg/m^3 (ECHA). [Kl. score = 1]

Dermal

Pregnant female SD rats were given dermal applications of 0, 150, 500, or 1,500 mg/kg diethanolamine from GD 6 to 15. There was a dosing discrepancy and mid-dose was adjusted from 500 to 380 mg/kg. There was moderate skin irritation in the 380 mg/kg group, and severe skin irritation in the 1,500 mg/kg group. Body weight gain was lower in the 1,500 mg/kg group, and absolute and relative kidney weights were increased in the $\geq$380 mg/kg group All treated groups exhibited hematological effects that included anemia, abnormal red cell morphology (poikilocytosis, anisocytosis, polychromasia), and decreased platelet count. The 1,500 mg/kg group also had increased lymphocytes and total leukocytes. There were no treatment-related effects on body weight or incidences of malformations/abnormalities. In the 1,500 mg/kg litters, there were increased incidences of six skeletal variations involving the axial skeleton and distal appendages. The skeletal variations included poor ossification in the parietal bones; cervical centrum #5 and thoracic centrum #10; lack of ossification in all proximal hindlimb phalanges and some forelimb metacarpals; and callused ribs. The NOAELs for maternal and developmental toxicity are 150 and 380 mg/kg-day (Marty et al., 1999). [Kl. score = 2]

Pregnant female New Zealand rabbits were given dermal applications of 0, 35, 100, or 350 mg/kg diethanolamine on GD 6 to 18. At 350 mg/kg, maternal toxicity consisted of marked skin irritation, reduced feed consumption, and color changes in the kidneys. There were no hematologic changes. Body weight gain was reduced in the 100 mg/kg group. There was no evidence of developmental toxicity at any dose level. The NOAELs for maternal and developmental toxicity are 35 and 350 mg/kg-day (Marty et al., 1999). [Kl. score = 2]

K. Immunotoxicity

Female F344 rats were given oral gavage doses of 0, 50, 100, or 200 mg/kg diethanolamine for 14 days. Body weights and/or body weight changes were significantly decreased in the $\geq$100 mg/kg dose groups; liver and kidney weights were increased in a dose-dependent manner. A dose-dependent increase in urea nitrogen was seen in all dose groups. Erythrocytes, hematocrit, hemoglobin and reticulocytes were dose-dependently decreased. The reticulocytes were the most sensitive erythroid parameter, which was decreased at all dose levels. Besides an increase in the proliferative response to allogenic cells (MLR), several immune functional assays were decreased including the natural killer cell response and the cytotoxicity of resident macrophages. Conversely, the cytotoxicity of peptone-elicited macrophages was increased. The LOAEL was 50 mg/kg-day based on a significant decrease in reticulocyte number and increase in urea nitrogen (Munson *et al.* 1992a). [Kl. score = 2]

Female B6C3F$_1$ mice were given oral gavage doses of 0, 100, 300, or 600 mg/kg diethanolamine for 14 days. There was no effect of body weights. The liver weights were increased and red blood cell count parameter were dose-dependently decreased at all dose levels. Diethanolamine treatment increased the number of B-cells, decreased the number of CD4+CD8- (18%) T-cell subsets. A dose-dependent decrease in the antibody-

forming cell response to sheep erythrocytes at the high-dose was seen, as well as a decreae in the cytotoxic T-cell response at the highest effector/target ratio. The cytotoxicity of resident macrophages was decreased, but the cytotoxicity of resident macrophages stimulated with gamma interferon was not affected nor the cytotoxicity of peptone-elicited macrophages with or without stimulation. Among the three host resistance studies, a decrease in host resistance was observed to *Streptococcus pneumonia* and in the B16F10 melanoma tumor model. The LOAEL for this study was considered to be 100 mg/kg-day based on significantly reduced cytotoxic T lymphocytes (CTL) activity, an increase in tumor burden following challenge with the B16F10 melanoma tumor and a clear decrease in red blood cell parameter at the lowest dose (Munson *et al.* 1992b). [Kl. score = 2]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for diethanolamine follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

In a 13-week study conducted by the National Toxicology Program, F344 rats were given diethanolamine in their drinking water for 13 weeks. The doses were 0, 25, 48, 97, 2,202, or 436 mg/kg-day for males; and 0, 14, 32, 57, 124, or 242 mg/kg-day for females. The most sensitive endpoints were the microcytic anemia in both sexes and kidney effects in females (weight, nephrotoxicity) and males (weight). The LOAELs were 25 and 14 mg/kg-day) for males and females, respectively (NTP 1992; Melnick et al., 1994a).

In a 13-week study conducted by the National Toxicology Program, $B6C3F_1$ mice were given diethanolamine in their drinking water for 13 weeks. The doses were 0, 104, 178, 442, 807, or 1,674 mg/kg-day for males; and 0, 142, 347, 884, 1,154, or 1,128 mg/kg-day for females. The most sensitive endpoint was the increase in liver weights with the corresponding histopathological changes. The LOAELs were 104 and 142 mg/kg-day in males and females, respectively (NTP, 1992; Melnick *et al.*, 1992b).

The lowest NOAEL of 14 mg/kg-day from the rat 13-week drinking water study will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 10
UF_{Sub} (subchronic to chronic) = 10
UF_D (database uncertainty) = 1

[maximum UF = 3,000]

Oral RfD = 14/3,000 = <u>0.005 mg/kg-day</u>

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (0.005 x 70 x 0.1)/2 = <u>0.02 mg/L</u>

B. Cancer

Diethanolamine was not carcinogenic to rats in the two-year NTP dermal bioassay; but, in the mice, there was an increased incidence of liver tumors in males and females and kidney tumors in males (NTP, 1999). As discussed above, the mouse liver tumors from DEA exposure are unlikely to be predictive of the carcinogenic risk to humans based on choline deficiency as a mechanism of carcinogenesis. No mode-of-action has been proposed for the kidney tumors in male mice.

NICNAS conducted a human health tier III assessment on diethanolamine (NICNAS). Regarding the classification for carcinogenicity, NICNAS concluded that "[t]he data on the mode of action are insufficient to conclude that diethanolamine-induced tumours in mice are relevant for humans and, therefore, based on the available information, diethanolamine is not classified for carcinogenicity."

Thus, a cancer reference value for diethanolamine was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Diethanolamine does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Diethanolamine exhibits moderate acute toxicity to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies on diethanolamine.

Table 3: Acute Aquatic Toxicity Studies on Diethanolamine

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Oncorhynchus mykiss	96-h LC_{50}	460	2	ECHA
Pimephales promelas	96-h LC_{50}	1,460*	2	Mayes et al. (1983)
Pimephales promelas	96-h LC_{50}	1,664	2	ECHA
Lepomis macrochirus	48-h LC_{50}	1,850	2	Turnbull et al. (1954)
Carassius auratus	24-h LC_{50}	>5,000 (neutralised) 800 (non-neutralised)	2	Bridlé et al. (1979)

Ceriodaphnia dubia	48-h EC_{50}	30.1 (24°C) 89.9 (20°C)	2	Cowgill et al. (1985)
Daphnia magna	48-h EC_{50}	55	2	LeBlanc (1980)
Daphnia magna	48-h EC_{50}	171	2	Zurita et al. (2005)
Pseudokirchneriella subcapitata	72-h EC_{50} (growth rate)	9.5 (Test 1) 19 (Test 2)	2	ECHA
Desmodesmus subspicatus	72-h EC_{50}	14.9 (growth rate) 6.2 (biomass)	2	ECHA
Desmodesmus subspicatus	72-h EC_{50}	107.3 (growth rate) 74.5 (biomass)	2	ECHA
Chorella vulgaris	72-h EC_{50}	778 (growth rate)	2	ECHA

*Geometric mean of 96-h LC_{50} values of fry, juvenile, and subadult fish. Not neutralized.

Chronic Studies

Table 4 lists the results of chronic aquatic toxicity studies on diethanolamine.

Table 4: Chronic Aquatic Toxicity Studies on Diethanolamine

Test Species	**Endpoint**	**Results (mg/L)**	**Klimisch score**	**Reference**
Daphnia magna	EC_{10} NOEC	1.05 0.76	1	ECHA
Pseudokirchneriella subcapitata	EC_{10} (growth rate)	1.4 (Test 1) 1.1 (Test 2)	2	ECHA
Desmodesmus subspicatus	EC_{10} (neutralized)	2.4 (growth rate) 2.0 (biomass)	2	ECHA
Desmodesmus subspicatus	EC_{10} (non-	85.7 (growth rate)	2	ECHA

	neutralized)	41.3 (biomass)		
Pseudokirchneriella subcapitata	7-d NOEC	10	2	ECHA

C. Terrestrial Toxicity

In an earthworm (*Eisenia Andrei, Eisenia fetida*, or *Lumbricus terrestris*) study, the 35-day LC_{50} was 4,141 mg/kg soil dry weight (mortality); the 63-day EC_{50} was 776 mg/kg soil dry weight (reproduction); and the 63-day EC_{25} was 171 mg/kg soil dry weight (reproduction) (ECHA). [Kl. score = 2]

In a springtails (*Folsomia candida*) study, the 28-day LC_{50} was 8,301 mg/kg soil dry weight (mortality); the 28-day EC_{50} was 4,205 mg/kg soil dry weight (reproduction); and the 28-day EC_{25} was 2,102 mg/kg soil dry weight (reproduction) (ECHA). [Kl. score = 2]

D. Calculation of PNEC

The PNEC calculations for diethanolamine follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (460 mg/L), *Daphnia* (30.1 mg/L), and algae (9.5 mg/L). Results from chronic studies are also available for two trophic levels, with the lowest EC_{10} value being 1.1 mg/L for *Daphnia* and algae. On the basis that the data consists of short-term results from three trophic levels and long-term results from three trophic levels, an assessment factor of 50 has been applied to the lowest reported EC_{10} of 1.1 mg/L for algae. The $PNEC_{water}$ is 0.02 mg/L.

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 0.016 mg/kg sediment wet weight.

The calculations are as follows:

$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$
$= (0.99/1280) \times 1000 \times 0.02$
$= 0.016$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$K_{sed\text{-}water} = 0.8 + [(0.2 \times Kp_{sed})/1000 \times BD_{solid}]$
$= 0.8 + [(0.2 \times 0.4/1000 \times 2400]$
$= 0.99$

Where:
Kp_{sed} = solid-water partition coefficient (L/kg).
BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$Kp_{sed} = K_{oc} \times f_{oc}$
$= 10 \times 0.04$
$= 0.4$

Where:
K_{oc} = organic carbon normalized distribution coefficient (L/kg). The K_{oc} for diethanolamine (as the charged molecule) was calculated to be 10 L/kg.
F_{oc} = fraction of organic carbon in sediment = 0.04 [default].

PNEC soil

Experimental results are available for chronic toxicity on two trophic levels. Although $E(L)C_{50}$ values are available from these studies, there are no EC_{10} or NOEC values. Therefore, the PNECsoil was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is 0.027 mg/kg soil dry weight.

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
$= (0.2/1500) \times 1000 \times 0.02$
$= 0.027$

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
$= 10 \times 0.02$
$= 0.2$

Where:

K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for diethanolamine (as the charged molecule) was calculated to be 10 L/kg.
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Diethanolamine is readily biodegradable; thus, it does not meet the screening criteria for persistence.

The estimated BCF value for diethanolamine calculated from a QSAR model is 2.3; thus, it does not meet the criteria for bioaccumulation.

The EC_{10} or NOEC values from the chronic aquatic toxicity studies on diethanolamine are >0.1 mg/L. Thus, diethanolamine does not meet the screening criteria for toxicity. In a mouse dermal carcinogenicity study, there was an increased incidence of liver tumors in males and females and kidney tumors in males. NICNAS has concluded that "[t]he data on the mode of action are insufficient to conclude that diethanolamine-induced tumours in mice are relevant for humans and, therefore, based on the available information, diethanolamine is not classified for carcinogenicity." Thus, diethanolamine does not meet the criteria for toxicity.

The overall conclusion is that diethanolamine is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Acute Toxicity Category 4 [Oral]
Skin Irritant Category 2
Eye Damage Category 1
STOT RE Category 2 [Target organs: liver, blood, kidney]

[Aquatic Acute Category 2]

B. Labelling

Danger

C. Pictogram



X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
Immediately flush open eyes with plenty of water for at least 15 minutes. Remove contacts, if present and easy to do. Get medical attention immediately, preferably a physician for an ophthalmologic examination.

Skin Contact
Remove contaminated clothing. Wash thoroughly with soap and water.

Inhalation
If inhaled, remove from area to fresh air. Give artificial respiration if victim is not breathing. Get medical attention.

Ingestion
Rinse mouth with water and then drink plenty of water. Get medical attention. Never give anything by mouth to an unconscious person.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
Keep product and empty container away from heat and sources of ignition. May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: nitrogen oxides, carbon monoxide, carbon dioxide.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus and chemical-protective clothing.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Use appropriate protective equipment. Handle in accordance with good industrial hygiene and safety practice. Avoid contact with skin, eyes, and clothing.

Environmental Precautions
Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled
For large amounts: dike spillage and pump off product. For residues: pick up with suitable absorbent material. Dispose of contaminated material as prescribed.

D. STORAGE AND HANDLING

General Handling
Keep product and empty container away from heat and sources of ignition. Ensure adequate ventilation, especially in confined areas.

Storage
Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
Workplace Australia has not established an occupational exposure standard for diethanolamine.

Engineering Controls
Good general ventilation should be used.

Personal Protection Equipment

Respiratory Protection:
Use respiratory protection in case of vapor or aerosol release.

Hand Protection:
Chemical resistant protective gloves.

Skin *Protection*:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Safety glasses with side-shields.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Wearing of closed work clothing is recommended. Ensure that eyewash stations and safety showers are close to the workstation location.

F. TRANSPORT INFORMATION

Diethanolamine is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

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DISODIUM OCTABORATE TETRAHYDRATE

This dossier on disodium octaborate tetrahydrate does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of disodium octaborate tetrahydrate in its use in drilling muds and hydraulic fracturing fluids. Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC) [Disodium octaborate]: disodium;(9,11-dioxido-5-oxoboranyloxy-2,4,6,8,10,12,13-heptaoxa-1,3,5,7,9,11-hexaborabicyclo[5.5.1]tridecan-3-yl)oxy-oxovorane

CAS RN: 12280-03-4

Molecular formula: $Na_2B_8O_{13}\bullet 4H_2O$

Molecular weight: 412.4

Synonyms: Disodium octaborate tetrahydrate; disodium octaborate

SMILES (disodium octaborate): B(=O)OB1OB2OB(OB(OB(O2)OB(O1)OB=O)[O-])[O-].[Na+].[Na+]

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Disodium Octaborate Tetrahydrate

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	White, odorless, crystalline powder	1	ECHA
Melting Point	>1,000°C	1	ECHA
Density	1.874 g/cm^3	1	ECHA
Vapor Pressure	9.9 x 10^{-17} Pa @ 25°C	1	ECHA
Water Solubility	223.65 g/L @ 20°C	1	ECHA
Auto flammability	Not a self-heating substance	1	ECHA

Exposure to borates are often expressed in terms of boron (B) equivalents based on the fraction of boron in the source substance on a molecular weight basis. The B equivalents used are a generic designation rather than a designation of the element boron. The factor for converting disodium octaborate tetrahydrate to B-equivalents is 0.2096.

III. ENVIRONMENTAL FATE PROPERTIES

Many minerals contain boron, which is present as the sodium or calcium borate salt. Thus, boron is ubiquitous and widely distributed in the environment. It is present in rocks, soil and water and is released into the environment primarily from the weathering of rock and soil, volatilization of sea water, and anthropogenic activity.

Disodium octaborate tetrahydrate ($Na_2B_8O_{13} \bullet 4H_2O$) is very soluble in water, with the main species in freshwater being the borate ion $[B(OH)_4]^-$ and boric acid $B(OH)_3$, depending on the pH. The relative proportion of boric acid and borate ions is controlled by pH: $B(OH)_3 + 2H_2O \Leftrightarrow [B(OH)_4]^- + H_3O^-$. In dilute aqueous solutions, boric acid does not dissociate at pH <7; at pH values between 7 and 11, both boric acid and borate ions are present. In dilute aqueous solutions and physiological conditions, the predominant species present is un-dissociated boric acid. So, the consideration of boric acid addresses the relevant environmental stability properties for borates.

In natural waters, boron forms stable species and exists primarily as un-dissociated boric acid [$B(OH)_3$] and complex polyanions (*e.g.*, $[B(OH)_4]^-$). These forms of boron are highly soluble and not easily removed from solution by natural mechanisms. Borate and boric acid are in equilibrium depending on the pH of the water. At an acidic pH, boron exists in solution mainly as un-dissociated boric acid, whereas at alkaline pH it is present as borate ions.

Degradation is not applicable to inorganic borates, such as disodium octaborate tetrahydrate. It is not subject to hydrolysis, photodegradation, or biodegradation (ECHA). Inorganic borates are subject to chemical transformation processes (adsorption, complexation, precipitation, fixation) once released into the environment (ECHA).

The WHO review of boron (WHO, 1998) noted that “highly water soluble materials are unlikely to bioaccumulate to any significant degree and that borate species are all present essentially as un-dissociated and highly soluble boric acid at neutral pH”. A BCF of <0.1 was reported in Chinook salmon fed boron-supplemented diets for 60 to 90 days (Hamilton and Wiedmeyer, 1990).

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Disodium octaborate tetrahydrate exhibits low acute toxicity by the oral and dermal routes. It is not a skin or eye irritant, or a skin sensitizer. Toxicity studies on boric acid, borax (disodium tetraborate decahydrate), and boron oxide have been used to read-across to disodium octaborate tetrahydrate. This is justified because, in aqueous media at physiological pH, all of these inorganic borate compounds will predominantly exist as un-dissociated boric acid. The developing fetus and the testes are the two most sensitive targets of boron toxicity in multiple species. The testicular effects include reduced organ weight and organ to body weight ratio, atrophy, degeneration of the spermatogenic epithelium, impaired spermatogenesis, reduced fertility, and sterility. The developmental effects from boron exposure include high prenatal mortality; reduced fetal body weight; and malformations and variations. Repeated inhalation exposure to boron oxide resulted in slight irritation to the respiratory tract, but no systemic toxicity. Boric acid was not genotoxic; and boric acid and borax was not carcinogenic to rodents.

B. Acute Toxicity

The oral LD_{50} of disodium octaborate tetrahydrate in rats is 2,550 mg/kg (ECHA) [Kl. score = 1]. The oral LD_{50} of boric acid in rats is 3,450 mg/kg (ECHA) [Kl. score = 1]. The oral LD_{50} of anhydrous boric acid in rats is >2,500 mg/kg. [Kl. score = 1].

There are no acute inhalation studies on disodium octaborate tetrahydrate. The 4-hour inhalation LC_{50} value for boric acid in rats is >2.01 mg/L. The mass median aerodynamic diameter (MMAD) was 2.8 μm (ECHA) [Kl. score = 1]. In another study, the 4-hour inhalation LC_{50} value for boric acid in rats was >2.03 mg/L (ECHA) [Kl. score = 1]. The 4-hour inhalation LC_{50} value for disodium tetraborate pentahydrate in rats is >2.04 mg/L (ECHA) [Kl. score = 1].

The dermal LD_{50} of disodium octaborate tetrahydrate in rabbits is >2,000 mg/kg (ECHA) [Kl. score = 1]. The dermal LD_{50} of boric acid in rabbits is >2,000 mg/kg (ECHA) [Kl. score = 1]. The dermal LD_{50} of sodium tetraborate pentahydrate in rabbits is >2,000 mg/kg (ECHA) [Kl. score = 1].

C. Irritation

Application of 0.5 g. of disodium octaborate tetrahydrate to the skin of rabbits for 4 hours under occlusive conditions was not irritating. The mean of the 24, 48, and 72 hour scores were: 0.22 for erythema and 0.00 for edema (ECHA) [Kl. scores = 1].

Application of 0.5 g. of boric acid to the skin of rabbits for 24 hours under occlusive conditions was not irritating. The mean of the 24 and 72 hour scores were: 0.13 for erythema and 0.00 for edema (ECHA) [Kl. scores = 1]. Application of 0.5 g. of sodium tetraborate pentahydrate to the skin of rabbits for 4 hours under occlusive conditions was not irritating. The mean erythema and edema scores were 0.00 (ECHA) [Kl. scores = 2].

Disodium octaborate tetrahydrate was not considered to be an eye irritant when 0.053 or 0.049 g. was instilled into the eyes of rabbits (ECHA) [Kl. scores = 1]. Instillation of 0.08 mL boric acid into the eyes of rabbits was slightly irritating. The mean of 24, 48, and 72 hours scores were: 0.22 for corneal opacity; 0.22 for iridial lesions; 2.8 for conjunctival redness; and 1.89 for chemosis (ECHA) [Kl. score = 1].

D. Sensitization

Disodium octaborate tetrahydrate was not a skin sensitizer to guinea pigs in a Buehler test (ECHA) [Kl. score = 1].

Boric acid was not a skin sensitizer to guinea pigs in a Buehler test (ECHA) [Kl. score = 1]. Sodium tetraborate pentahydrate was not a skin sensitizer to guinea pigs in a Buehler test (ECHA) [Kl. score = 1]. Sodium tetraborate decahydrate was not a skin sensitizer to guinea pigs in a Buehler test (ECHA) [Kl. score = 1].

E. Repeated Dose Toxicity

Oral

Male and female SD rats were given in their feed boric acid at doses of 0, 52.5, 175, 525, 1,750 or 5,250 ppm B equivalents for 90 days. The average intake has been estimated to be approximately 0, 2.6, 8.8, 26, 87.5 or 262.5 mg B/kg-day, respectively (EPA, 2004). By week 6, all of the animals in the highest dose died. Clinical signs in the top two dose levels were rapid respiration, inflamed eyes, swollen paws, and desquamated skin on the paws and tails. There was also reduced food consumption and body weight gain. The 1,750 ppm females showed reduced liver, spleen ovary, and adrenal weights; the 1,750 ppm males showed reduced liver, spleen, kidney, testes, and adrenal weights. The adrenals of 4 of the 1,750 ppm males showed minor increases in lipid content and size of the cells in the zona reticularis. Atropied testis (complete atrophy of the spermatogenic epithelium and decreased in the size of the seminiferous tubules) was seen in all of the 1,750 ppm males. One 525 ppm male had partial testicular atrophy. The NOAEL for this study is 175 ppm boron or 8.8 mg B/kg-day (Weir and Fisher, 1972). [Kl. score = 2]

Male and female SD rats were given in their diet borax at doses of 0, 52.5, 175, 525, 1,750 or 5,250 ppm B equivalents for 90 days. The average intake has been estimated to be approximately 0, 2.6, 8.8, 26, 87.5 or 262.5 mg B/kg-day, respectively (EPA, 2004). By week 6, all of the animals in the highest dose died. Clinical signs in the top two dose levels were rapid respiration, inflamed eyes, swollen paws, and desquamated skin on the paws and tails. There was also reduced food consumption and body weight gain. The 1,750 ppm females showed reduced liver, spleen and ovary weights; the 1,750 ppm males showed reduced liver, spleen, kidney, testes, and brain weights. The adrenals of the majority of the 1,750 ppm males and females showed slight to moderate increases in lipid content and size of the cells in the zona reticularis. Atropied testis (complete atrophy of the spermatogenic epithelium and decreased in the size of the seminiferous tubules) was

seen in all of the 1,750 ppm males. Four 525 ppm males had partial testicular atrophy. Spermatogenic arrest was found in one 525 ppm male. The NOAEL for this study is 175 ppm boron or 8.8 mg B/kg-day (Weir and Fisher, 1972). [Kl. score = 2]

Male and female B6CF1$_1$ mice were given in the diet 0, 1,200, 2,500, 5,000, 10,000 or 20,000 ppm boric acid for 13 weeks (control and highest dose group) or 16 weeks (remaining dose groups). These dietary levels correspond to approximately 0, 34, 70, 141, 281 and 563 mg B/kg-day for males, respectively; and 0, 47, 97, 194, 388 and 776 mg B/kg-day for females, respectively (EPA, 2004). There was mortality (8/10 males; 6/10, females) in the 20,000 ppm, as well as hyperkeratosis and acanthosis. One male also died in 10,000 ppm group. Degeneration or atrophy of the seminiferous tubules occurred in the $\geq$5,000 ppm males. Minimal to mild extramedullary hematopoiesis of the spleen was observed in all dose groups. The LOAEL for this study is 1,200 ppm, corresponding to 34 and 47 mg B/kg-day for males and females, respectively (NTP 1987). [Kl. score = 2]

Male and female SD rats were given in their diet 0, 117, 350 or 1,170 ppm boric acid for two years. The average intake has been estimated to be approximately 0, 5.9, 17.5 or 58.5 mg B/kg-day, respectively (EPA, 2004). The 1,170 ppm rats had decreased food consumption during the first 13 weeks of the study and suppressed growth throughout the study. Signs of toxicity in the 1,170 ppm animals included swelling and desquamation of the paws, scaly tails, inflammation of the eyelids, and bloody discharge from the eyes. All of the 1,170 ppm males had testicular atrophy at the 6, 12 and 24 month time points. The seminiferous epithelium was atrophied, and the tubular size in the testes was decreased. There were significant decreases in the absolute and relative testes weights. Brain and relative thyroid weights were increased. The NOAEL for this study is 350 ppm B equivalents or 17.5 mg B/kg-day (Weir and Fisher, 1972). [Kl. score = 2]

Male and female B6C3F$_1$ mice were given 0, 2,500 or 5,000 ppm boric acid in their feed for 103 weeks (NTP, 1987). These dose levels were equivalent to 0, 275 or 550 mg/kg-day boric acid or 0, 48 or 96 mg B/kg-day (EPA, 2004). There was reduced survival in the male mice, which was significantly different from the controls in the 2,500 ppm mice after week 63 and in the 5,000 ppm mice after week 84. The survival rates by the end of the study were 82, 60 and 44% in the 0, 2,500, and 5,000 ppm males, respectively; and 66, 66 and 74% in the 0, 2,500, and 5,000 ppm females, respectively. Mean body weights were 10-17% lower in the 5,000 ppm animals after 32 (males) or 52 (females) weeks compared to the controls There was testicular atrophy and interstitial cell hyperplasia in the testes of the 5,000 ppm males. A dose-related increase in the incidences of splenic lymphoid depletion in male mice was also observed. NTP considered this lesion to be associated with stress and debilitation, and it is reflected in the increased mortality in these groups of male mice. The NOAEL for this study is (NTP, 1987). [Kl. score = 2]

Inhalation

Male and female rats were exposed by inhalation to 0, 77, 175, or 470 mg/m^3 boron oxide. The exposures were 6 hours/day, 5 days/week for 24, 12, and 10 weeks for the 77, 175, and 470 mg/m^3 concentrations groups, respectively. The MMAD were 2.5, 1.9, and 2.4 μm for the 77, 175, and 479 mg/m^3 concentrations groups, respectively. There was no evidence of systemic toxicity. Some of the 470 mg/m^3 had reddish exudate from the nose. As these animals were covered with dust, this effect may have been local irritation of the nose and from the animals scratching the nose. The NOAEL for systemic toxicity is 470 mg/m^3, the highest exposure concentration tested. The NOAEL for localized effects (irritation) is 175 mg/m^3 (ECHA). [Kl. score = 2]

Dermal

No studies are available.

F. Genotoxicity

In Vitro Studies

There are no *in vitro* genotoxicity studies on disodium octaborate tetrahydrate. Table 2 presents the results of the *in vitro* genotoxicity studies on boric acid.

Table 2: *In vitro* Genotoxicity Studies on Boric Acid

Test System	**Results***		**Klimisch Score**	**Reference**
	-S9	**+S9**		
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	1	ECHA
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	ECHA
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	-	-	1	ECHA
Chromosomal aberrations (Chinese Hamster Ovary cells)	-	-	1	ECHA
Chromosomal aberrations (Chinese Hamster Ovary cells)	-	-	1	ECHA
Chromosomal aberrations (Human peripheral lymphocytes)	NS	+	2	ECHA

Unscheduled DNA synthesis (rat liver cells)	NA	-	1	ECHA

*+, positive; -, negative; NA, not applicable; NS, not specified.

In Vivo Studies

No studies are available on disodium octaborate tetrahydrate.

Male and female Swiss Webster mice were given two daily doses of 0, 225, 450, 900, 1,800, or 3,500 mg/kg boric acid. The frequency of micronucleated polychromatic erythrocytes were not increased at any dose level (ECHA) [Kl. score = 1].

G. Carcinogenicity

Oral

No studies have been conducted on disodium octaborate tetrahydrate.

Male and female SD rats were given in their diet disodium tetraborate decahydrate (Borax) or boric acid at doses of 0, 117, 350, or 1,170 ppm as B equivalents (approximately 0, 5.9, 17.5, or 58.5 mg B/kg-day) for two years. There was no mention of tumors in the report. Nevertheless, NTP (1987) concluded that this study provided adequate data on the lack of carcinogenic effects of boric acid in rats (Weir and Fisher, 1972; EPA, 2004).

Male and female $B6C3F_1$ mice were given in their diet 0, 2,500, or 5,000 ppm boric acid for 103 weeks. The dietary levels are equivalent to 0, 446, or 1,150 mg/kg-day boric acid or 0, 78.1, or 201.3 mg B/kg-day. There was no evidence of carcinogenicity (NTP, 1987). [Kl. score = 2]

H. Reproductive Toxicity

A three-generation reproductive toxicity study was conducted in albino rats (strain not specified) with boric acid. Male and female rats were fed a diet containing 0, 117, 350 or 1,170 ppm boron (approximately 0, 5.9, 17.5 or 58.5 mg B/kg-day, respectively). In the lower two dose groups, there were no treatment-related effects on reproduction. Litter size, progeny weights, fertility, live birth indices, lactation, appearance were similar to the controls. No gross abnormalities were noted in these two dose groups. The 1,170 ppm dose group were found to be sterile, and there were no litters from mating the treated females with control males. Lack of viable sperm was found in the atrophied testes of all 1,170 ppm males. Decreased ovulation was also seen in the majority of the ovaries of the 1,170 ppm females. The NOAEL for this study is 350 ppm boron or approximately 17.5 mg B/kg-day (Weir and Fisher, 1972). [Kl. score = 2]

A three-generation reproductive toxicity study was conducted in albino rats (strain not specified) with disodium tetraborate decahydrate. Male and female rats were fed a diet containing 0, 117, 350 or 1,170 ppm boron (approximately 0, 5.9, 17.5 or 58.5 mg B/kg-day, respectively). In the lower two dose groups, there were no treatment-related effects on reproduction. Litter size, progeny weights, fertility, live birth indices, lactation, appearance were similar to the controls. No gross abnormalities were noted in these two dose groups. The 1,170 ppm dose group were found to be sterile, and there were no litters from mating the treated females with control males. Lack of viable sperm was found in the atrophied testes of all 1,170 ppm males. Decreased ovulation was also seen in the majority of the ovaries of the 1,170 ppm females. The NOAEL for this study is 350 ppm boron or approximately 17.5 mg B/kg-day (Weir and Fisher, 1972). [Kl. score = 2]

In a continuous breeding protocol, male and female CD-1 mice were given in their diet 0, 1,000, 4,500 or 9,000 ppm boric acid in their feed. The authors estimated that the average daily intakes were: 0, 26.6, 111, and 220 mg B/kg-day to males; and 0, 31.8, 152, 257 mg B/kg-day to females. Boric acid consumption did not differ among the groups. There were no litters in the 9,000 ppm breeding pairs. At 4,500 ppm, there was a successful first litter, after which there was a progressive decrease in fertility; only one pair produced a fourth and fifth litter. All fertility indices were affected in the 4,500 ppm group. A complete crossover mating trial was conducted using control mice and the 4,500 ppm mice. The results showed that the probable cause of the reduced fertility was a decrement in male fertility. A dose-related decrease in body, testicular and epididymal weights was observed in the 4,500 and 9,000 ppm F_0 males. Sperm count was significantly decreased in these two dose groups, and percent motile sperm was decreased in all dose groups. Testicular histopathology showed seminiferous tubular atrophy in the 9,000 ppm males and partial atrophy of the seminiferous tubules in the 4,500 ppm males. There were no histopathologic changes in the 4,500 ppm females. No statistically significant decreases in mating index, fertility index, or live pups/litter in the 4,500 ppm females, but the number of days to litter in this dose group was increased. Estrous cyclicity was unaffected. Reproductive organ weights were unaffected, but relative maternal liver and kidney/adrenal weights were reduced. An F_1 fertility trial was performed using offspring from the 1,000 ppm groups. There was no decreases in mating, fertility or reproductive performance. The F_2 adjusted live pup weight was slightly, but significantly, reduced from controls. A clear NOAEL for reproductive toxicity in males was not seen in this study. The 1,000 ppm males had decreased sperm motility in the F_0 generation and decreased sperm concentration in the F_1 generation. Decreased F_2 pup relative body weight was statistically significant from controls. The NOAEL in this study for females is 1,000 ppm boric acid or 32 mg B/kg-day). The LOAEL in this study for males is 1,000 ppm or 27 mg B/kg-day; a NOAEL was not established (Fail *et al.* 1991). [Kl. score = 2]

I. Developmental Toxicity

Pregnant female SD rats were given 0, 0.1, 0.2 or 0.4% boric acid in their feed on gestational days (GD) 0 to 20 or 0.8% boric acid on GD 6 to 15. The average amounts of boric acid ingested were estimated to be 0, 78, 163, 330 or 539 mg/kg-day (0, 13.6, 28.5 or 57.7 mg B/kg-day), respectively. Effects on the pregnant rats were altered food and/or water intake at ≥0.2% boric acid, increased liver and kidney weights relative to body weights at ≥0.2%, reduced weight gain at ≥0.4%, and increased corrected weight gain at 0.4% boric acid. There was a reduction in fetal body weights in all treated groups (94, 87, 63, and 47% of control weight, respectively). Increased malformations occurred at ≥0.2%, and prenatal mortality was increased at 0.8%. There was a dose-response for altered skeletal morphology in rats (≥0.1%), and specific findings were significantly elevated above controls at ≥0.2%. Specifically, there was an increased incidence of short rib XIII (a malformation) and a decreased incidence or rudimentary or full rib(s) at lumbar I (an anatomical variation) (Heindel *et al.* 1992). [Kl. score = 2]

Pregnant female SD rats were given in their feed 0, 0.025, 0.005, 0.075, 0.1 or 0.2% boric acid on GD 0 to 20. Approximately half of the dams were terminated on GD 20, and the remaining dams delivered their litters. Pup growth and viability were monitored until postnatal day (PND) 21. The average amounts of boron ingested on GD 20 were: 0, 3.3, 6.3, 9.6, 13.3, and 25 mg B/kg-day], respectively. The average amounts of boron ingested on PND 21 were : 0, 3.2, 6.5, 9.7, 12.9, and 25.3 mg B/kg-day, respectively. There were no maternal deaths and no treatment-related clinical signs. Maternal body weights were similar across all groups during gestation. However, decreased maternal body weights (GD 19 and 20 at sacrifice) and decreased maternal body weight gain (GD 15-18 and GD 0-20) were statistically significant in trend tests. There was a 10% reduction in gravid uterine weight (statistically significant) in the 0.2% group. Corrected maternal weight (maternal gestational weight minus reduced gravid uterine weight) was unaffected by treatment. Feed intake in the 1,000 ppm dams was minimally affected and only during the first three days of dosing. Water consumption was higher in the treated groups after GD 15. The number of corpora lutea and uterine implantation sites, and the percentage of preimplantation loss were similar across all groups. Increased relative kidney weights were increased in the 0.2% group. There were no differences in the viability of the offspring between treated and controls. On GD 20, fetal body weight was 94% and 88% of controls in the 0.1% and 0.2% groups, respectively; recovery was complete at birth (~GD 22). The incidence of short rib XIII was increased on GD 20 in the ≥0.1% groups, but only in the 0.2% group at PND 21. The incidence of wavy rib was increased on GD 20 in the ≥0.1% group; the reversibility of this effect was confirmed on PND 21. There was a slight decrease in extra lumbar ribs in the 0.2% group on GD 20, and extra lumbar ribs were seen in the 0.2% group on PND 21. The developmental NOAEL was considered to be 0.075% boric acid or 9.6 mg B/kg-day on GD 20; and 0.1% boric acid or 12.9 mg B/kg-day on PND 21 (Price *et al.* 1996a). [Kl. score = 1]

Pregnant Swiss mice were given in their diet 0, 0.1, 0.2 or 0.4% boric acid on gestational days (GD) 0 to 17. The average amounts of boric acid ingested were estimated to be 248, 452 or 1,003 mg/kg-day (0, 43.4, 79.0 or 175.3 mg/B/kg-day), respectively. Maternal toxicity consisted of mild kidney lesions (≥0.1%), increased water intake and relative kidney weights (0.4%), and decreased water intake during treatment. Fetal body weights

were reduced in the ≥0.2% groups, and there were increased incidences of resorptions and malformed fetuses per litter in the 0.4% group. The LOAEL for maternal toxicity is 248 mg/kg-day boric acid or 43.4 mg B/kg-day; a NOAEL was not established. The NOAEL for developmental toxicity is 248 mg/kg-day boric acid or 43.4 mg B/kg-day (Heindel *et al.* 1992). [Kl. score = 2]

Pregnant female New Zealand rabbits were dosed by oral gavage with 0, 62.5, 125 or 250 mg/kg boric acid (0, 10.9, 21.9 or 43.7 mg B/kg) during GD 6-19. Feed intake was in the 250 mg/kg maternal animals during the exposure period, but it was increased in the ≥125 mg/kg dose groups. In the 250 mg/kg group, maternal body weights during GD 9-30, weight gain during GD 6-19, gravid uterine weight, and number of corpora lutea per dam were significantly reduced. In the ≥125 mg/kg groups, maternal corrected gestational weight gain was increased compared to controls. Maternal liver weights were unaffected by treatment. In the 250 mg/kg group, relative, but not absolute, kidney weights were increased, although no effects in the kidney were noted in the histopathological examination. Prenatal mortality was increased in the 250 mg/kg group (90% resorptions/litter versus 6% for controls); the proportion of pregnant females with no live fetuses was increased (73% versus 0%), and live litter size was reduced (2.3 fetuses versus 8.8). Thus, there were only 14 live fetuses (6 live litters) available for evaluation in the 250 mg/kg group. The percentage malformed fetuses/litter was increased in the 250 mg/kg group, primarily due to cardiovascular defects (72% versus 3% of controls). There was no definitive maternal or developmental toxicity in the 62.5 or 125 mg/kg dose groups. The NOAEL for maternal and developmental toxicity is 125 mg/kg-day boric acid or 21.9 mg B/kg-day (Price *et al.* 1996b). [Kl. score = 1]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for disodium octaborate tetrahydrate follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

The developing fetus and the testes are the two most sensitive targets of boron toxicity in multiple species (EPA, 2004; ECHA, 2010). The testicular effects include reduced organ weight and organ to body weight ratio, atrophy, degeneration of the spermatogenic epithelium, impaired spermatogenesis, reduced fertility, and sterility (EPA, 2004). The developmental effects from boron exposure include high prenatal mortality; reduced fetal body weight; and malformations and variations (EPA, 2004).

The U.S. Environmental Protection Agency (U.S. EPA) derived an Oral Reference Dose

(RfD) for boron of 0.2 mg B/kg-day (U.S. EPA 2004) based on developmental effects in rats from two studies (Price *et al.* 1996a; Heindel *et al.* 1992).

The RfD was derived using the benchmark dose (BMD) method ($BMDL_{05}$ from Allen *et al.* 1996) using a data derived uncertainty factor of 66. Decreased fetal body weight ($BMDL_{50}$ = 59 mg boric acid/kg-day or 10.3 mg B/kg-day) was considered by Allen *et al.* (1996) as the most suitable endpoint for developing a point of departure, because the benchmark doses calculated for the other endpoints (incidence of total malformations, enlarged lateral ventricles in the brain, shortening of rib XIII, and variations of the first lumbar rib) were higher.

Derivation of an Oral Reference Dose

Oral RfD = $BMDL_{05}$ / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 7.9 [3.16, toxicodynamics; 3.3, toxicokinetics]
UF_H (intraspecies variability) = 6.2 [3.16, toxicodynamics; 2.0, toxicokinetics]
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 10.3/(7.9 x 6.3 x 1 x 1 x 1) = 10.3/66 = <u>0.2 mg B/kg-day</u>

Derivation of a drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (0.2 x 70 x 0.1)/2 = <u>0.7 mg/L</u>

Australian drinking water guideline

The Australian drinking water guideline for boron is 4 mg/L (ADWG, 2011).

B. Cancer

There was no evidence of carcinogenicity in rat and mouse chronic studies conducted on disodium tetraborate decahydrate and/or boric acid. Thus, a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Disodium octaborate tetrahydrate does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Aquatic Toxicity

The summary of the data used by ANZECC to develop a water quality guideline for boron is as follows:

Freshwater Fish
The chronic values for four species ranged from 40 μg/L (32-day LOEC in *O. mykiss*) to 27,600 μg/L (32-day LOEC in *O. mykiss*). Other *O. mykiss* data were order of magnitude higher than 40 μg/L, including those from the same paper (2,100 μg/L for a 87-day NOEC and 27,600 μg/L for a 32-day LC_{50}). All other geometric means were >4,000 μg/L.

Freshwater Crustaceans
The chronic data ranged from a 21-day MATC value of 4,665 μg/L for *Daphnia magna* based on growth to an LC_{50} value of 54,200 μg/L from a 21-day *Daphnia* study. A measured NOEC of 6,000 μg/L based on reproduction was also reported.

Freshwater Algae
The data ranged from a 14-day NOEC of 400 μg/L for *Chlorella pyrenoidosa* to a NOEC of 5,200 μg/L for *Chlorella vulgaris*. Both values are based on population growth.

C. Terrestrial Toxicity

There are considerable number of terrestrial toxicity studies on borates. See the ECHA REACH database (ECHA) for summaries of the relevant studies.

D. Calculation of PNEC

PNEC water

The ANZECC water quality guideline (2000) used a "freshwater high reliability trigger value for boron of 370 μg/L was calculated using the statistical distribution method at 95% protection."

"Although the 95% protection level is higher than the 32-day LOEC of 100 μg/L for O. mykiss, this figure appeared anomalous and other data on this species showed much less toxicity. The low figure may need to be checked. The 95% figure is considered sufficiently protective for slightly-moderate disturbed ecosystems" (ANZECC, 2000).

PNEC sediment

No experimental toxicity data on sediment organisms are available. Disodium octaborate tetrahydrate dissociates completely in water and its environmental distribution is dominated by its high water solubility. K_{ow} and K_{oc} parameters do not readily apply to inorganics, such as disodium octaborate tetrahydrate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sed}$. Based on the its properties, no adsorption of disodium octaborate tetrahydrate to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

PNEC Soil

In the ECHA REACH database (ECHA), a $PNEC_{soil}$ was derived for boron using the species sensitivity distribution method and an assessment factor of 2. The $PNEC_{soil}$ was determined to be 5.7 mg/kg soil dry weight.

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Disodium octaborate tetrahydrate is an inorganic compound that dissociates completely to boric acid and the borate anion in aqueous media. Biodegradation is not applicable to these inorganic compounds; both boric acid and borate are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria are not considered applicable to disodium octaborate tetrahydrate.

Disodium octaborate tetrahydrate is a water-soluble substance that is not expected to bioaccumulate. Limited data indicate that bioaccumulation (BCF values are low) is not significant in aquatic and terrestrial food chains. Thus, it does not meet the criteria for bioaccumulation.

Boric acid and inorganic borates are reproductive toxicants and have been classified under GHS as known or presumed human reproductive toxicants (Category 1B). Thus, disodium octaborate tetrahydrate meets the PBT criteria of toxicity.

The overall conclusion is that disodium octaborate tetrahydrate is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Reproductive Toxicant Category 1B

B. Labelling

Danger

C. Pictogram



X. SAFETY AND HANDLING

A. First Aid

Eye Contact
Immediately flush open eyes with plenty of water for at least 15 minutes. Remove contacts, if present and easy to do. Get medical attention.

Skin Contact
Wash thoroughly with soap and water.

Inhalation
If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Ingestion
Swallowing small quantities (one teaspoon) will not cause any harm to adults. If larger amounts are swallowed, give two glasses of water to drink and seek medical attention. Never give anything by mouth to an unconscious person.

Notes to Physician
Observation only is required for adult ingestion of <5 grams. For ingestion of >5 grams, maintain adequate kidney function and force fluids.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
Disodium octaborate tetrahydrate is a flame retardant. It is not flammable, combustible, or explosive.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus and chemical-protective clothing.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Use personal protective clothing. Avoid dust formation. Ensure adequate ventilation. Do not breathe dust. Wear respiratory protection if ventilation is inadequate. Avoid contact with skin, eye, and clothing.

Environmental Precautions
Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled
Scoop up and remove.

D. STORAGE AND HANDLING

General Handling
No special measures necessary provided product is used correctly.

Other Handling Precautions
Avoid eye and skin contact. Avoid creating or inhaling dust.

Storage

Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
Workplace Australia has not established an occupational exposure standard for disodium octaborate tetrahydrate.

[The workplace exposure standard for disodium tetraborate decahydrate (borax) in Australia is 5 mg/m^3 as an 8-hour TWA. The workplace exposure standard for disodium tetraborate pentahydrate in Australia is 1 mg/m^3 as an 8-hour TWA.]

Engineering Controls
Ensure adequate ventilation. Localized ventilation should be used to control dust levels below permissible exposure limits.

Personal Protection Equipment

Respiratory Protection:
Use respiratory protection when airborne concentrations are expected to exceed exposure limits.

Hand Protection:
Chemical resistant protective gloves.

Skin *Protection*:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Safety glasses with side-shields.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible.

F. TRANSPORT INFORMATION

Disodium octaborate tetrahydrate is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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ETHANOL

This dossier on ethanol does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of ethanol in its use in drilling muds and hydraulic fracturing fluids. Ethanol consumption in alcoholic beverages is out of the scope of this dossier. The information presented in this dossier was obtained from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC): Ethanol

CAS RN: 64-17-5

Molecular formula: C_2H_6O

Molecular weight: 46.069

Synonyms: Ethyl alcohol, grain alcohol, alcohol, methylcarbinol, ethyl hydroxide, ethyl hydrate, algrain, alkohol, anhydrol, tecsol

SMILES: CCO

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Ethanol

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Colorless liquid with a mild odor.	2	ECHA
Melting point	-114°C	2	ECHA
Boiling point	78.2°C	2	ECHA
Density	0.789 g/cm^3 @ 20°C	2	ECHA
Vapor pressure	57.26 hPA @ 19.6°C	2	ECHA
Partition coefficient (log K_{ow})	-0.35 @ 24°C	2	ECHA
Water solubility	789 g/L @ 20°C	2	ECHA
Flash point	13°C	2	ECHA

Property	Value	Klimisch score	Reference
Auto flammability	>363 and <425ºC	2	ECHA
Viscosity	1.17 mPa s @ 20ºC	2	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Ethanol is readily biodegradable and not expected to bioaccumulate.

B. Biodegradation

Ethanol is readily biodegradable. The degradation of ethanol was approximately 74% and 84% (O_2 consumption) within 10 and 20 days, respectively, in a biodegradation test using a non-adapted domestic inoculum in a freshwater medium (ECHA) [Kl. score = 2].

C. Environmental Distribution

Adsorption/desorption

No experimental data are available for ethanol. Using KOCWIN in EPISUITE™ (EPA, 2019), the estimated K_{oc} value from log K_{ow} is 2.199 L/kg. The estimated K_{oc} value from the molecular connectivity index (MCI) is 1.045 L/kg.

D. Bioaccumulation

There are no bioaccumulation studies on ethanol. Ethanol is not expected to bioaccumulate based on a log K_{ow} of -0.35 (ECHA).

IV. HUMAN HEALTH HAZARD ASSESSMENT

Human health toxicological information was obtained from Inventory Multi-Tiered Assessment and Prioritisation (IMAP), which is an assessment framework conducted via Australia's National Industrial Chemicals Notification and Assessment Scheme (NICNAS), unless otherwise cited. Statements regarding toxicity are based solely on the determination of applicable regulatory agency.

A. Summary

Ethanol has a low acute toxicity by the oral, dermal, and inhalation routes of exposure, as measured by lethality. Sublethal doses, however, have been shown to produce central nervous system depression, respiratory depression, and coma. Deaths were reported in rodent studies due to cardiorespiratory failure. Ethanol is not irritating to the skin, but it is slightly irritating to the eyes. Repeated exposures by the oral route have not resulted in any systemic toxicity to rodents, except from exposure to high doses. Evidence of the carcinogenicity of ethanol is confined to epidemiological studies assessing the impact of alcoholic beverage consumption. These do not indicate any such hazard exists from potential exposure to ethanol in the workplace or from the use of ethanol in consumer products (OECD, 2004). Ethanol is not genotoxic or mutagenic. Ethanol does not show specific reproductive or developmental toxicity. Any reproductive and developmental effects were only observed secondary to maternal toxicity.

B. Acute Toxicity

Oral

The chemical has low acute toxicity by oral exposure in animal tests. The median lethal dose (LD50) in rats is >2000 mg/kg bw. Observed sub-lethal effects included central nervous system depression, e.g. inebriation, disturbances of gait, dose-related decreases in responses to painful stimuli, respiratory depression, and coma. Deaths were reported due to cardiorespiratory failure (OECD, 2005; HSDB; REACH).

Dermal

Few studies are available on the dermal toxicity of the chemical. A poorly documented rabbit study reported death in one of four animals following a dose of 20000 mg/kg bw. Although limited data are available, the apparent low dermal toxicity from this study is regarded as consistent with low uptake of ethanol through intact skin. The median lethal dose (LD50) in rats is greater than 2000 mg/kg bw. Observed sub-lethal effects were not reported for the study (OECD, 2005; REACH).

Inhalation

The chemical has low acute toxicity by inhalation exposure in animal tests. The lowest reported median lethal concentration (LC50) is 124.7 mg/L/four hours in rats. Observed sub-lethal effects included attempts to escape, reddish-watery eyes, nasal secretions, closing of eyelids, snout wiping, intermittent respiration, loss of pain reflex, abdominal position, and apathy (OECD, 2005; REACH).

C. Irritation

The chemical is not regarded as irritating to skin. The chemical is frequently applied to skin as a biocidal surgical wipe (70–80 % concentration) and as a component of cosmetics, personal care, and household cleaning products. There appear to be few documented concerns regarding skin irritation arising from these uses. Direct contact of the eye with the liquid chemical causes immediate discomfort accompanied by reflexive closure of the eye. Even though the acute effect subsides rapidly and the recovery is complete, foreign body type discomfort may persist for a day or two. Although inhaling the chemical at 5000 ppm (9600 mg/m^3) has been reported as irritating in humans;

lacrimation and coughing are only induced at a much higher concentrations (OECD, 2005).

Concentrations of the chemical attained in humans in the upper gastrointestinal tract after consumption of alcoholic beverages can cause local irritation.

The chemical produced irritant effects in several eye irritation studies in rabbits. While the severity of these effects was not consistent across all the studies, these were sufficiently severe in some studies to support classification, particularly under the Globally Harmonised System of Classification and Labelling of Chemicals.

D. Sensitization

The available data indicate that the chemical does not induce skin sensitisation in animals. An ear swelling study was used to examine the skin sensitising potential of ethanol. Ethanol was applied twice on the right ear after an induction procedure involving two scapular subcutaneous injection of adjuvant and multiple topical ethanol applications to the abdomen over a period of 14 days. The degree of contact hypersensitivity is deduced from ear swelling measured 24 and 48 hours after application. Ethanol was found not to cause any statistical increase in ear swelling, in contrast to 3 positive controls which all caused a statistically significant increase.

Data is also available from studies using ethanol as a vehicle. In a guinea pig maximisation study that used ethanol as a carrier solvent for the substance being tested (polyakylene glycol block copolymers) no positive reactions were obtained. It can be concluded that ethanol cannot have any significant skin sensitising properties since it was used as a solvent in this study at levels of up to 75%. A study was carried out to evaluate the effect of vehicles (e.g. ethanol) for use in the mouse local lymph node assay (LLNA), and their influence on the skin sensitization potential of fragrance materials. Groups of mice were treated with each test fragrance in ethanol (1:3 or 3:1 mixtures of the two), or with ethanol alone. Although there were no true control data for comparison with the ethanol-alone treated animals, the level of induced T-lymphocyte proliferation was low for ethanol when compared with that for fragrance materials known to be mild to moderate skin sensitizers, and comparable to other inert vehicles tested.

E. Repeated Dose Toxicity

<u>Oral</u>

Many repeated dose studies of chemical have been conducted in many species, predominantly with the aim of assessing adverse effects associated with the consumption of alcoholic beverages. Consequently, these are mostly conducted through oral exposure and with doses well in excess of those that might be encountered in occupational exposure or consumer products (OECD, 2005), or unintentional public exposures from environmental contamination.

In a 90-day study, SD rats were fed a mixture containing 16.25% USP ethanol at 3 dose levels (Kl =2). A single dose of 4 ml/kg of pure ethanol and water were used as controls. No significant differences were noted in body weight, haematology, opthamology, clinical chemistry or urine chemistry. Dose-related increases in liver to body weight ratios of female rats were seen at final sacrifice although the absolute liver weights of the high dose ethanol treated group, while significantly increased relative to the 100% ethanol treated group, was not different from the water control group. In addition, increased liver weights were observed in the male rats. Significant increases in kidney weights were observed in the mid and high dose groups. No histopathologic findings were attributed to ethanol treatment with exception of increased minimal focal to multifocal renal tubular epithelial hyperplasia in the high dose 20 ml/kg mixture containing 16.25% ethanol and the 100% USP ethanol control treated rats versus the water treated controls. It should be noted however that renal tubular epithelial hyperplasia is a common incidental finding in laboratory rats and it is uncertain whether the higher incidence of this lesion in the ethanol dosed rats compared with water controls is due to a random variation or to ethanol. Gonadal tissues were examined for both gross pathology and histopathology and no treatment-related effects were detected. The NOAEL for the study was determined at 10 ml/Kg for a mixture containing 16.25% ethanol for increased kidney weight and renal tubular epithelial hyperplasia in males (equivalent to 1.73g/kg). The LOAEL for this study was determined at 4 ml/kg for 100% USP ethanol (3.16g/kg) for increased kidney weight and renal tubular epithelial hyperplasia in males.

Inhalation

As properly conducted studies in animals are not available, there are no valid data on the effects of repeated inhalation exposure to the chemical. However, limited information is presented below to indicate that the chemical is likely to be of low toxicity following repeated inhalation exposure.

Dermal

No data are available.

F. Genotoxicity

Overall, ethanol is not considered to be mutagenic or genotoxic (OECD, 2005; REACH).

In Vitro Studies

Table 2: *In vitro* Genotoxicity Studies on Ethanol

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* and *E. coli* strains)	-	-	1	Zeiger et al., 1992
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	-	-	2	Wangenheim and Bolcsfoldi, 1988

*+, positive; -, negative;

In Vivo Studies

Several in vivo micronucleus assays have assessed the potential for the chemical to induce damage to chromosomes of erythroblasts. No effect was reported in rats when administered 5 % of the chemical (approximately 4 g/kg bw/day) in drinking water, or in mice at up to 40 % (approximately 31 g/kg bw/day). Chemical-related mortality was observed in the latter study. Marginally statistically significant increases in the incidence of micronucleated bone marrow erythrocytes were reported in rats fed for six weeks with a diet containing ethanol at 12–16 g/kg/day. Although there is very limited evidence that the chemical induces micronuclei in the bone marrow of rodents, the chemical has the potential to induce micronuclei in bone marrow erythrocytes at very high doses. KI scores were not listed for these studies (IMAP, 2014).

G. Carcinogenicity

Oral

A significant number of carcinogenicity studies have been identified, but the majority of these are only partial studies designed to look at aspects of the carcinogenic hazard resulting from drinking ethanol containing beverages and are judged unreliable for assessing the cancer hazard of ethanol as a chemical substance. Only two studies were identified as reliable.

In a study to assess the carcinogenic potential of ethanol, groups of rats were exposed to ethanol at concentrations of 1% and 3% in a liquid semi-synthetic diet for a period of 2 years, approximately equivalent to 1 and 3g/kg respectively. Each dose group used a control matched for caloric content using glucose. From the data it was possible to conclude that ethanol did not cause any treatment related increase in tumours and the no effect level was identified as > 3g/kg.

In a study designed and conducted to determine the long-term toxicity and carcinogenicity of urethane in ethanol, groups of mice were exposed to ethanol at concentrations up to 5% in drinking water for a period of 2 years, with control groups consuming drinking water alone. The only significant cancer finding was a dose related increase in the rate of hepatocellular adenomas for male mice in comparison with the concurrent controls. The species of mouse used in this study is known to have a high spontaneous incidence of these tumours. In comparison to historic controls, the incidence rate in the ethanol dosed animals was not high and the controls were significantly lower (although it should be noted that no historic control information was available for animals on the study diet used.) Analysis of the data using the Benchmark dose approach showed a BMDL10 of 1400mg/kg for liver adenomas in males. There was no significant increase in tumour rates (including mammary tumours) in females.

The International Agency for Research on Cancer (IARC) has concluded that there is sufficient evidence in humans and experimental animals to establish carcinogenicity of alcohol consumption and ethanol, respectively. It was also concluded that there is sufficient evidence in experimental animals to establish carcinogenicity of acetaldehyde (major metabolite of ethanol). Consequently, IARC has classified that ‘alcohol

consumption is carcinogenic to humans (Group 1)' and that 'ethanol in alcoholic beverages is carcinogenic to humans (Group 1)'. This conclusion was supported by an analysis of the expanded human dataset that carcinogenic effects appeared independent of the type of alcoholic beverage (IARC, 2010; IARC, 2012). As the use of the chemical in alcoholic beverages is not considered in this report, the above assessment of carcinogenicity of alcohol beverages may not be relevant to occupational exposure to the chemical or from using the chemical in consumer products (OECD, 2005). Furthermore, studies in animals conducted mostly through oral exposure at very high doses, exceeding the 'maximum tolerated dose', may be of little relevance when assessing risks associated with occupational exposure or using consumer products containing the chemical (OECD, 2005). Thus, classification is not considered appropriate (IMAP).

Inhalation
No information available (IMAP, REACH).

H. Reproductive and Developmental Toxicity

The chemical does not show specific reproductive or developmental toxicity. Any reproductive and developmental effects were only observed secondary to maternal toxicity. As results of inhalation studies showed no developmental toxicity from chemical exposures even at maternally toxic doses, it can be concluded that deliberate oral consumption of alcoholic beverages is required for any reproductive or developmental toxicity (OECD, 2005).

The most reliable study (Kl = 1) performed to the most appropriate protocol and the one given the greatest weight as well as the key study is a two-generation study investigated the effects of 5%, 10% and 15% ethanol in drinking water in reproduction and fertility. Male and female CD-1 mice were continuously treated for 1 week prior to mating and for a 14-week breeding period followed by a 21-day holding period when they were separated and housed individually. The F1 offspring of the 15% ethanol pairs had fewer live pups per litter but ethanol treatment had no effect on the proportion of breeding pairs producing at least 1 litter during the continuous breeding phase or the number of litters per pair. The F1 offspring from the 15% group had decreased bodyweight at weaning and mating, and a decreased weight of testis, epididymides and seminal vesicles which was no longer evident when these were adjusted for body weight. There was also a significantly decreased percentage motile sperm but no changes in sperm concentration, and percentage of abnormal sperm or tailless sperm. When reproductive performance of F1 control and 15% ethanol-treated breeding pairs was assessed at 74 days of age, there was no significant difference in mating and fertility between the groups. However, adjusted live pup weight for the ethanol group was significantly reduced compared to controls which was likely due to generalized maternal toxicity.

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for ethanol follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

The lowest NOAEL from these studies is 1,730 mg/kg-day based on increased relative and absolute liver weight and absolute heart, liver, kidney and lung weight in male mice from a 90-day dietary study (1996). The NOAEL of 1,730 mg/kg-day will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD):

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 3
UF_D (database uncertainty) = 1

Oral RfD = 1730/(10 x 10 x 1 x 3 x 1) = 1730/300 = 6 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:

Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (6 x 70 x 0.1)/2 = 21 mg/L

B. Cancer

Evidence of the carcinogenicity of ethanol is confined to epidemiological studies assessing the impact of alcoholic beverage consumption. These do not indicate any such hazard exists from potential exposure to ethanol in the workplace or from the use of

ethanol in consumer products (OECD, 2004). Therefore, no cancer reference value was derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Ethanol is a flammable liquid.

Ethanol does not exhibit the following physico-chemical properties:
- Explosivity
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies conducted on ethanol.

Table 3: Acute Aquatic Toxicity Studies on Ethanol

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Pimephales promelas	96-hr LC_{50}	15,300	2	ECHA
Pimephales promelas	96-hr LC_{50}	14,200	2	ECHA
Ceriodaphnia dubai	48-hr EC_{50}	5012	2	ECHA
Chlorella vulgaris	72-hr EC_{50}	275	2	ECHA

Chronic Studies

The 5-d NOEC to *Brachydanio rerio* in an OECD 212 embryo and sac-fry stage test is 250 mg/L (ECHA) [Kl. score = 2].

The 10-d NOEC to *Ceriodaphnia dubia* in a *Daphnia* reproduction test is 9.6 mg/L (ECHA) [Kl. score = 2].

The 72-hr EC_{10} to algae *Chlorella vulgaris* is 11.5 mg/L (ECHA) [Kl. score = 2].

C. Terrestrial Toxicity

No data are available.

D. Calculation of PNEC

The PNEC calculations for ethanol follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (14,200 mg/L), invertebrates (5,012 mg/L), and algae (275 mg/L). Results from chronic studies are available for fish (250 mg/L), invertebrates (9.6 mg/L), and algae (11.5 mg/L). On the basis that the data consists of short- and long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported NOEC or EC_{10} value of 9.6 mg/L for invertebrates. The $PNEC_{aquatic}$ is 0.96 mg/L.

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the PNECsoil was calculated using the equilibrium partitioning method. The PNECsoil is 0.013 mg/kg soil dry weight.

The calculations are as follows:

$$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$$
$$= (0.02/1500) \times 1000 \times 0.96$$
$$= 0.013$$

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$$Kp_{soil} = K_{oc} \times f_{oc}$$
$$= 1.05 \times 0.02$$
$$= 0.02$$

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for ethanol based on the molecular connectivity index (MCI) is 1.05 L/kg (EPA, 2019).
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Ethanol is readily biodegradable; thus, it does not meet the screening criteria for persistence.

Based on a measured log K_{ow} of -0.35, ethanol does not meet the screening criteria for bioaccumulation.

No chronic aquatic toxicity studies are available on ethanol. The acute $E(L)C_{50}$ values for ethanol are >1 mg/L. Thus, ethanol does not meet the criteria for toxicity.

The overall conclusion is that ethanol is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Flammable liquid, Category 2
Eye irritation, Category 2B
Acute Toxicity, Category 3
Reproductive toxicity, Category 2
Specific target organ toxicity – Repeated exposure, Category 2
Specific target organ toxicity – Single exposure, Category 3

B. Labelling

Danger

C. Pictogram



X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact

Protect unexposed eye. Rinse/ flush exposed eye(s)s gently using water for 15-20 minutes. Remove contact lens(es) if able to do so during rinsing. Seek medical attention if irritation persists or if concerned.

Skin Contact
Wash affected area with soap and water. Rinse thoroughly. Seek medical attention if irritation, discomfort, or vomiting persists.

Inhalation
Move exposed individual to fresh air. Loosen clothing as necessary and position individual in a comfortable position. Seek medical advice if irritation persists.

Ingestion
Rinse mouth thoroughly. Do not induce vomiting. Have exposed individual drink sips of water. Seek medical attention if irritation, discomfort, or vomiting persists.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
For small fires, use dry chemicals, CO_2, water spray or alcohol-resistant foam. For large fire, use water fog or alcohol-resistant foam. Use appropriate fire suppression agents for adjacent combustible materials or sources of ignition.

Specific Exposure Hazards
Combustion products may include carbon oxides or other toxic vapors. Dangerous fire hazard when exposed to hear, sparks, and open flames.

Special Protective Equipment for Firefighters
Wear protective equipment. Use NIOSH-approved respiratory protection/ breathing apparatus. Use spark-proof tools and explosion-proof equipment. Move product containers away from fire or keep cool with water spray as a protective measure, where feasible.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Beware of vapors accumulating to form explosive concentrations. Vapors can accumulate in low areas. Keep unprotected persons away.
Wear protective equipment. Use respiratory protective device against the effects of fumes/ dust/ aerosol. Ensure adequate ventilation. Keep away from ignition sources. Protect from heat.
For large spills, wear splash goggles, full suit, respirator, boots and gloves and use self-contained breathing apparatus.

Environmental Precautions

Prevent from reaching drains, sewer, or waterway. Collect contaminated soil for characterisation. Collect spilled liquid for recovery, treatment, or disposal.

Steps to be Taken if Material is Released or Spilled
Eliminate sources of ignition. Stop the spill, if possible. Contain spill material by diking or using inert absorbent. Spill may also be contained by using electrically protected vacuum cleaner or by wet-brushing. Transfer to a disposal or recovery container.

D. STORAGE AND HANDLING

General Handling
Prevent formation of aerosols. Use only in well ventilated areas. Avoid splashes or spray in enclosed areas. Prevent exposure to ignition sources; use non-sparking tools and explosion-proof equipment.

Other Handling Precautions
Avoid contact with eyes, skin, and clothing. Avoid breathing vapor. Follow good hygiene procedures when handling chemical materials. Do not eat, drink, smoke, or use personal products when handling substances. Wash hands before breaks and at the end of work.

Storage
Store in a cool location. Provide ventilation for containers. Avoid storage near extreme heat, ignition sources, or open flame. Store away from foodstuffs. Store away from oxidizing agents. Store in cool, dry conditions in well-sealed containers. Keep containers tightly sealed. Store in secure flammable storage area away from sources of ignition. Protect from freezing and physical damage.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
The workplace exposure standard for ethanol in Australia is 1000 ppm (1880 mg/m^3) as an 8-hr TWA. No STEL is listed.

Engineering Controls
Good general ventilation should be used. If applicable, use process enclosures, local exhaust ventilation, or other engineering controls to maintain airborne levels below recommended exposure limits. Avoid storage near extreme heat, ignition sources, or open flame. Use non-sparking tools and explosion-proof equipment.

Personal Protection Equipment

Respiratory Protection: Not required under normal conditions of use. Use suitable respiratory protective device when high concentrations are present. Use suitable respiratory protective devise when aerosol mist is formed. For spills, respiratory protection may be advisable.

Hand Protection: Gloves that are impermeable and resistant to the substance

Skin Protection: Wear chemical resistant gloves (rubber, neoprene or vinyl). Use personal protection equipment that is chemical resistant and prevents skin contact.

Eye protection: Goggles or safety glasses with side shields

Other Precautions:

- Use other PPE as required by the situation.
- Ethanol is a flammable liquid; keep away from ignition sources. Wash hands, forearms, and face thoroughly after handling chemical products, before eating, smoking, and using the lavatory and at the end of the working period.
- Appropriate techniques should be used to remove potentially contaminated clothing. Wash contaminated clothing before reusing.
- Ensure that eyewash stations and safety showers are close to the workstation location.

F. TRANSPORT INFORMATION

UN Number: 1170
UN proper shipping name: Ethanol (mixture)

Transport hazard class: 3 Flammable liquids
Packing group: II

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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ETHYLENE GLYCOL

This dossier on ethylene glycol does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of ethylene glycol in its use in drilling muds and hydraulic fracturing fluids. Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC): Ethane-1,2-diol

CAS RN: 107-21-1

Molecular formula: $C_2H_6O_2$ ($HOCH_2CH_2OH$)

Molecular weight: 62.07

Synonyms: Ethylene glycol; ethane-1,2-diol; 1,2-ethanediol, 2-hydroxyethanol; monoethylene glycol; MEG; glycol alcohol; EG

SMILES: C(CO)O

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Ethylene Glycol

Property	**Value**	**Klimisch score**	**Reference**
Physical state at 20°C and 101.3 kPa	Colourless and odourless syrupy liquid	2	ECHA
Melting Point	-13°C	2	ECHA
Boiling Point	197.4°C	2	ECHA
Density	1.11 g/cm^3	2	ECHA
Vapor Pressure	0.123 hPa	2	ECHA
Partition Coefficient (log K_{ow})	-1.36 (calculated)	2	ECHA
Water Solubility	1,000 g/L @ 20°C	2	ECHA

Flash Point	111°C	2	ECHA
Auto flammability	398°C	2	ECHA
Viscosity	16.1 mPa s @ 25°C	2	ECHA
Henry's Law Constant	0.133 @ 25°C (QSAR)	2	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Ethylene glycol is readily biodegradable, and it is not expected to bioaccumulate. Ethylene glycol has low potential to adsorb to soil and sediment.

B. Biodegradation

Ethylene glycol was readily biodegradable in an OECD 301A test. After 10 days, degradation was 90-100% (ECHA) [Kl. score = 1]. There was 97% degradation after 20 days in a BOD test; and 96% degradation after 28 days in an OECD 301D test (Waggy et al., 1994; OECD, 2004a,b) [Kl. score = 2].

The aerobic degradation of ethylene glycol was measured from grab river water samples at 4, 8, and 20°C. At 20°C, ethylene glycol was completely degraded in three days in all river waters tested; at 8°C, degradation was complete within 14 days. Degradation at 4°C was substantially slower, with degradation of <20% after 14 days in river samples with limited suspended matter and a starting concentration of 10 mg/L (Evans and David, 1974).

C. Environmental Distribution

<u>Adsorption/desorption</u>

No experimental data are available for ethylene glycol. Using KOCWIN in EPISUITE™ (EPA, 2017), the estimated K_{oc} values from the molecular connectivity index (MCI) and from the log K_{ow} are 1 and 0.2239 L/kg, respectively.

D. Bioaccumulation

The calculated log K_{ow} for ethylene glycol is -1.36 (ECHA). The BCF for ethylene glycol in golden ide (*Leuciscus idus melanotus*) after three days of exposure was determined to be 10 (Freitag *et al.*, 1985).

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Following acute ingestion of ethylene glycol, the critical effects in humans in three subsequent stages are central nervous system toxicity, metabolic acidosis, and kidney toxicity. The lethal effects of ethylene glycol in human adults occur at oral doses of ≥1,600 mg/kg. Ethylene glycol is not a skin irritant or a skin sensitizer in laboratory animals. In humans, ethylene glycol may cause skin irritation; there is also a low potential for skin sensitization. It is not an eye irritant. The kidney is the primary target organ from repeated exposures. The proposed mode-of-action (MOA) for the kidney damage involves the formation of a precipitate or crystals from the ethylene glycol metabolite oxalic acid with calcium in the urine. Ethylene glycol is not genotoxic or carcinogenic to rodents. Ethylene glycol did not affect fertility in animal studies, but it did cause developmental effects. In rodents, the developmental effects caused by oral doses of ethylene glycol include teratogenic effects (craniofacial and axial-skeletal malformations and variations). In contrast, no developmental toxicity was seen in rabbit studies. The relevant metabolite for the developmental toxicity seen in rodent, but not rabbit, studies appears to be glycolic acid. This metabolite can be reached at higher concentrations in rats than in rabbits. Based on a physiologically-based pharmacokinetic (PBPK) model for ethylene glycol, humans are unlikely to achieve blood levels of glycolic acid necessary for developmental toxicity.

B. Metabolism

Ethylene glycol is almost completely absorbed in laboratory animals by the oral route (OECD, 2004; Frantz et al., 1996a). A range of 1-51% of ethylene glycol is absorbed by the dermal route based on *in vivo* studies in rodents (Frantz *et al.*, 1996a,b).

The main metabolic pathway for metabolism of ethylene glycol is oxidation via alcohol dehydrogenases and aldehyde dehydrogenases. The main metabolites of ethylene glycol are carbon dioxide, oxalic acid and glycolic acid (OECD, 2004a).

The relevant metabolite for the repeated dose toxicity studies is oxalic acid, which is slowly transported from the liver to the kidneys, where is forms calcium-oxalate crystals (Corley *et al.*, 2005a).

The relevant metabolite for the developmental toxicity seen in rodent, but not rabbit, studies appears to be glycolic acid. This metabolite can be reached at higher concentrations in rats than in rabbits (Carney *et al.*, 1998).

A physiologically-based pharmacokinetic (PBPK) model has been developed for ethylene glycol. When internal dose surrogates were compared in rats and humans over a wide range of exposures, it has been concluded that humans are unlikely to achieve blood levels of glycolic acid necessary for developmental toxicity (Corley *et al.*, 2005b).

C. Acute Toxicity

The oral LD_{50} in rats was reported to be 7,712 mg/kg (ECHA) [Kl. score = 2]. The 6-hour inhalation LC_{50} value for male and female rats was >2.5 mg/L (Tyl *et al.*, 1995a) [Kl. score = 2]. The dermal LD_{50} for male and female mice is >3,500 mg/kg (Tyl *et al.*, 1995b) [Kl. score = 2].

Following acute ingestion of ethylene glycol, the critical effects in humans in three subsequent stages are central nervous system toxicity, metabolic acidosis, and kidney toxicity (ECHA). The lethal effects of ethylene glycol in human adults occur at oral doses of $\geq$1,600 mg/kg (Hess et al., 2004).

D. Irritation

Application of 0.5 mL of ethylene glycol to the skin of rabbits for 23 hours under occlusive conditions was not irritating (Guillot *et al.*, 1982). [Kl. score = 2].

In a Human Repeated Insult Patch Test (HRIPT), ethylene glycol was applied to the skin for 24 hours under occlusive or semi-occlusive conditions for nine times during the induction phase. The induction phase was followed by a rest period of two weeks, followed by a 24-hour challenge on the sixth week of the study. Erythema was seen in a small proportion of the 401 subjects that completed the study. Under the conditions of the study, three subjects had reactions on challenge that were indicative of possible irritation and/or low-level sensitization. These three subjects were re-challenged under occlusive or semi-occlusive conditions one or two weeks later. Re-challenge testing was negative for one subject, but the other two subjects were judged to have irritant reactions to ethylene glycol since their reactions were similar or lesser compared to the skin responses observed during the induction period, and the skin reactions were not greater over time after the challenge or re-challenge (ECHA).

Instillation of 0.05 mL of ethylene glycol into the eyes of rabbits was not irritating (ECHA). [Kl. score = 2]

E. Sensitization

Ethylene glycol was not a skin sensitizer to guinea pigs in a Magnusson and Kligman test (Kurihara *et al.*, 1996) [Kl. score = 2]. In a HRIPT, ethylene glycol was considered to have a low potential for dermal sensitization in humans (ECHA).

F. Repeated Dose Toxicity

<u>Oral</u>

Male and female Fischer 344 rats were given in their feed 0, 0.32, 0.63, 1.25, 2.5, or 5% ethylene glycol for 13 weeks. Mortality was seen in the 5% males, but not in females. Mean weight gain was significantly decreased in the 2.5 and 5% males; there was no significant differences in female rats. Feed consumption was similar across all groups. A significant increase was seen in the left kidney weight in the 2.5 and 5% dose groups (both sexes); this was not seen in the right kidneys. Mean thymus ratio to terminal body weight was significantly decreased in the 5% males. Serum urea nitrogen levels were significantly increased in the 2.5 and 5% males, and significantly increased in the $\geq$0.32% females. Creatinine levels were decreased in the 0.32% groups and significantly increased in the 2.5 and 5% groups. The 2.5% and 5% male rats had kidneys that were rough, granular and/or pitted appearances. The 5% females showed nephrosis, and the 5% males had clusters of crystals in the brain. The NOAEL for this study is 1.25%, which was estimated to be 600 to 1,000 mg/kg-day (Melnick, 1984). [Kl. score = 2]

Male and female Sprague Dawley rats were given in their drinking water ethylene glycol for 90 days. The concentrations for females were 0, 0.5, 1.0, 2.0 or 4.0% (0, 597, 1,145, 3,087 or 5,744 mg/kg-day). The concentrations for males were 0, 0.25, 0.5, 1.0 or 2.0% (0, 205, 407, 947 or 3,134 mg/kg-day). In the 4% groups, there was mortality and decreased body weights (males only). Significant organ weights were noted only in males. Kidney weights were significantly increased in the 1% and 2% males; heart, liver, and lung were significantly decreased in the 2% males. The 4% males also had a significant increase in the brain and gonads relative to body weights. Leukocyte levels were significantly decreased in the 0.5, 2 and 4% females, but not in males. Significant differences were noted in LDH, creatinine, ALT, calcium and glucose in the 1% males; and phosphorus, BUN, and creatinine in the 2% males. There were significant increases in phosphorus in the 1% females and glucose in the 0.5 and 4% females. Kidney lesions were seen in the $\geq$2% females and in the $\geq$1% males, with the lesions more prominent in males than in females. The kidney changes consisted of tubular dilation, tubular degeneration, acute inflammation, birefringent crystals in tubules and pelvic epithelium. The NOAEL for this study is 407 mg/kg-day for males. The LOAEL for females is 597 mg/kg-day; a NOAEL was not established (Robinson *et al.*, 1990). [Kl. score = 2]

Male and female B6C3F$_1$ mice were given in their feed 0, 0.32, 0.63, 1.25, 2.5, or 5.0% ethylene glycol for 13 weeks. There was no mortality and no treatment-related effect on mean weight gain and feed consumption. Organ/body weight ratios were similar across all groups. Serum urea nitrogen and creatinine levels were unaffected. Kidney effects were seen in the male, but not female, mice. Kidney lesions were observed in half of the 5% male mice and one mouse in the 2.5% dose level. Lesions were tubular dilation, cytoplasmic vacuolization, and regenerative hyperplasia of tubular cells. There was no evidence of crystal formation in the tubules. These changes were focal, randomly distributed, and of minimal to mild severity. Hyaline degenerative of the liver was present in the centrilobular hepatocytes in all of the 2.5% and 5% males. These cells showed cytoplasmic accumulations of non bifringent, eosinophilic (hyaline), globular, or crystalline material which resembled erythrocytes in size, shape, and tinctorial properties.

The NOAEL for this study is 1.25%, which was estimated to be 600 to 1,000 mg/kg-day (Melnick, 1984). [Kl. score = 2]

Male Fischer 344 and Wistar rats were given in their feed 0, 150, 500 or 1,000 mg/kg ethylene glycol for 16 weeks. At 1000 mg/kg, the following effects were seen: mortality in Wistar strain (2/10) with prior clinical observations of emaciation and dermal atonia and macroscopic findings of changes in kidneys (pale, calculi) and small seminal vesicles in these animals; mean body weight losses, lower mean body weights and mean cumulative body weight changes in Wistar strain (weeks 2 – 16); lower mean food consumption in Wistar strain; higher mean water consumption in both F344 and Wistar strains; lower mean specific gravity and higher mean total urine volume in both F344 and Wistar strains; macroscopic findings of pale kidneys, presence of calculi, rough surface and dilated pelvis; higher mean absolute and relative kidney weights in both F344 and Wistar strains; renal macroscopic findings of crystal nephropathy in Wistar and F-344 rats, with more severe nephropathy in Wistar strain than in the F344 strain. At 500 mg/kg, the following effects were seen: lower mean body weights (study weeks 3, 6-8, and 10-12) and mean cumulative body weight changes in the Wistar strain throughout the study with slightly lower mean food consumption throughout the study; higher mean water consumption in the Wistar strain; lower mean urine specific gravity and higher mean total urine volume in the Wistar strain; macroscopic findings in the Wistar strain consisting of predominantly pale kidneys, presence of calculi, rough surface, and dilated pelvis; higher mean absolute and relative kidney weight in the Wistar strain; renal macroscopic findings of crystal nephropathy in Wistar and F-344 strains, with more severe nephropathy in the Wistar strain than in the F344 strain. The NOAEL in both the F344 and Wistar rats is 150 mg/kg-day (Cruzan *et al.*, 2004). [Kl. score = 2]

Male Wistar rats were given in their feed 0, 50, 150, 300 or 400 mg/kg ethylene glycol for 12 months. There was mortality in the 300 and 400 mg/kg dose groups (5/20 and 4/20, respectively); the remaining 400 mg/kg animals were euthanized early (day 203) due to excessive weight loss. The 300 mg/kg animals had increased water consumption and urine volume with decreased specific gravity, most likely due to osmotic diuresis. Calculi (calcium oxalate crystals) were found in the bladder and kidney pelvis in the $\geq$300 mg/kg animals. The $\geq$300 mg/kg rats that died prematurely had transitional cell hyperplasia with inflammation and hemorrhage of the bladder wall. Crystal nephropathy (basophilic foci, tubule or pelvic dilatation, birefringent crystals in the pelvic fornix, or transitional cell hyperplasia) was seen in all of the 400 mg/kg and most of the 300 mg/kg rats. These effects were not seen in the 50 or 150 mg/kg rats. Kidney oxalate levels, the metabolite responsible for the kidney toxicity, was not increased in the 50 and 150 mg/kg animals compared to the controls. The NOAEL for this study is 150 mg/kg/day (Corley *et al.*, 2005). [Kl. score = 1]

Male and female Sprague-Dawley rats were given in their feed 0, 0.1, 0.2, 0.5, 1.0 or 4.0% ethylene glycol for two years. There was significant reduction in growth in the 4% males after week 16, and in the 1% males after week 70. The 4% females did not gain any weight past the first year of the study. Water consumption was double that of the controls in the 4% males that initiated soon after the start of the study. The 1% males had

significant increases in water consumption after 6 months and some increase was observed in the 0.5% males. Females only showed increased water consumption in the 4% group. There was 100% mortality in the 1 and 4% males, while mortality of additional dose levels were below that of the controls. There was 100% mortality in the 4% females, while the 1% females were similar to the controls; the 0.1, 0.2 and 0.5% females were increased compared to the controls. Since the 1 and 4% males and the 4% females all died before the study termination date, there are no data for these groups on terminal organ weight. For males, the terminal organ weights were decreased in all dose levels compared to the controls. For females, the organ weights were similar to the controls. The 1 and 4% males and females had kidneys with stones and crystals. The NOAEL for this study is 0.2% (data was insufficient to calculate the dose) (Blood, 1965). [Kl. score = 2]

Male and female Fischer 344 rats were given in their feed 0, 40, 200 or 1,000 mg/kg ethylene glycol for 24 months. There were numerous adverse effects in the 1,000 mg/kg males and, to a lesser degree, in the 1,000 mg/kg females. The most remarkable effect was the production of urinary calculi in the kidneys, ureters, and urinary bladders of the 1,000 mg/kg males, along with the presence of high levels of calcium oxalate in the urine. Increased incidences of tubular cell hyperplasia, tubular dilation, peritubular nephritis, and focal granulomatous nephritis occurred in the 1,000 mg/kg males. Other significant findings in these males were markedly lower body weight gain, increased absolute and relative kidney weights, decreased absolute and relative liver weights, various hematopoietic changes, and increased water consumption (likely a result of impaired kidney function). Histopathological changes in the 1,000 mg/kg males were mineralization of the heart, lungs, stomach, and vas deferens being the most noteworthy. The various adverse effects in these males resulted in reduced survival; there was increased mortality which became apparent by 8 months, with all males in this group died by month 16. Although calcium oxalate crystals were found in the urine of the 1,000 mg/kg females, no urinary calculi were seen. Absolute and relative kidney weights were increased in these rats. The most significant histopathologic finding in the 1,000 mg/kg females was fatty metamorphosis of the liver. There were transient changes in organ weights, erythroid parameters, water consumption rates, and urine specific gravity in the 200 and 40 mg/kg rats; these effects were considered to be statistical artifacts attributable to chance. Focal soft mineralization was observed in certain organs of the 200 and 40 mg/kg rats, which were considered to be the result of altered calcium metabolism associated with ingestion of ethylene glycol. The NOAEL for this study is considered to be 200 mg/kg-day (DePass *et al.*, 1986a; ECHA). [Kl. score = 2]

Male and female B6C3F$_1$ mice were given in their feed 0, 6,250 ppm (males only), 12,500 and 25,000 ppm (males and females) or 50,000 ppm (females only) for 103 weeks. These concentrations are approximately equivalent to 0, 1,500, 3,000, 6,000 or 12,000 mg/kg-day. Survival, mean body weights, and feed consumption was similar across all groups. There were no treatment-related clinical signs of toxicity. Liver lesions (males only) and arterial hyperplasia (females only) were observed at 12,500 ppm, but no adverse effects were observed at 6,250 ppm. The NOAEL for this study is 6,250 ppm in males, which corresponds to 1,500 mg/kg-day (NTP, 1993). [Kl. score = 2]

Inhalation

No studies are available.

Dermal

No studies in rodents or rabbits are available.

G. Genotoxicity

In Vitro Studies

The *in vitro* genotoxicity studies on ethylene glycol are presented in Table 2.

Table 2: *In vitro* Genotoxicity Studies on Ethylene Glycol

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* and *E. coli* strains)	-	-	1	ECHA
Bacterial reverse mutation (*S. typhimurium* and *E. coli* strains)	-	-	2	ECHA
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	+/-	-	2	McGregor et al. (1991)
Chromosomal aberration (CHO cells)	-	-	2	ECHA

*+, positive; -, negative

In Vivo Studies

A dominant lethal study was conducted in F344 rats given 0, 40, 200, or 1,000 mg/kg-day ethylene glycol in feed. There were slight increases in the dominant lethal mutation index in the high-dose and low-dose groups; these appear to be random occurrences and were not considered to be treatment-related. It was concluded that ethylene glycol was not genotoxic in this study (DePass et al., 1986b). [Kl. score = 2]

H. Carcinogenicity

Oral

Male and female Fischer 344 rats were given in their feed 0, 40, 200 or 1,000 mg/kg ethylene glycol for 24 months. There was increased mortality in the 1,000 mg/kg males, starting at 8 months and resulting in all males in this group dead by 16 months. Survival for the 1,000 mg/kg females and the 200 and 40 mg/kg males and females were similar to the controls. The incidence of mononuclear cell leukemia was statistically significantly higher in the 200 mg/kg males compared to the male controls, but not when compared to the pooled controls (males and females). Evaluation of the data by the method of Thomas et al. (2007), however, showed no treatment-related effect. It was concluded that ethylene glycol was not carcinogenic to rats in this study (DePass et al., 1986). [Kl. score = 2]

Male and female B6C3F_1 mice were given in their feed 0, 6,250 ppm (males only), 12,500 and 25,000 ppm (males and females) or 50,000 ppm (females only) ethylene glycol. These concentrations were approximately equivalent to 0, 1,500, 3,000, 6,000 or 12,000 mg/kg-day. Body weights, survival, and incidence of tumors were similar between treated and control mice (NTP, 1993). [Kl. score = 2]

Inhalation

No studies are available.

Dermal

No studies are available.

I. Reproductive Toxicity

Ethylene glycol was assessed in a Reproductive Assessment by Continuous Breeding (RACB) protocol. The parental mice were administered ethylene glycol via drinking water during pre-mating exposure, cohabitation, pregnancy, and lactation. The F_1 generation received prenatal exposure via maternal exposure during gestation, with the exposure continuing during lactation, weaning, and mating of F_1 animals and production of an F_2 litter. The doses were 0, 0.25, 0.5 or 1% ethylene glycol, which corresponded to approximately 0, 410, 840 or 1,640 mg/kg-day. No adverse effects were noted in the parental animals at doses up to 1%. There was a small, but statistically significant, effects on the numbers of litters per fertile pair, the number of live pups per litter, and live pup weight in the 1% dose group. Neither the 0.25 nor 0.5% dose groups were significantly affected. The number of live pups per litter was lower in the treated groups, but differences were not statistically significant. Unusual facial features (*i.e.*, shorter snout and wide-set eye) and skeletal defects (shortened frontal, nasal, and parietal bones; fused ribs abnormally shaped or missing sternebrae, abnormally shaped vertebrae; and

twisting of the spine) were noted on some of the offspring of the treated mice in the 1% group, but not in the controls. The parental NOAEL is 1% (approximately 1,640 mg/kg-day), and the NOAEL for reproductive toxicity is 0.5% (approximately 840 mg/kg-day (Lamb *et al*., 1985). [Kl. score = 2]

In a three-generation reproductive toxicity study, Fischer 344 rats were given in their diet 0, 40, 200 or 1,000 mg/kg-day ethylene glycol. There were no treatment-related effects on clinical signs of toxicity or survival in the parental animals. There were no significant effects on fertility index, gestation index, gestation survival for all three generations. Mean pup weights in the all three generations were similar between treated and control animals. The NOAEL for parental and reproductive toxicity is 1,000 mg/kg/day (DePass *et al.*, 1986b). [Kl. score = 2]

J. Developmental Toxicity

Pregnant Sprague-Dawley rats were dosed by oral gavage with 0, 50, 150, 500, 1,000 or 2,500 mg/kg ethylene glycol during gestational days (GD) 6-15. Maternal toxicity was observed in the 2,500 mg/kg group and consisted of significantly decreased body weights, increased water consumption, decreased uterine weights, increased kidney weights, and increased relative liver weights. At 500 mg/kg, there were developmental effects, which included reduced fetal body weights, extra or missing ribs, missing arches, and poor ossification in thoracic and lumbar centra. In the 2500 mg/kg group, in addition to skeletal malformations, there was gastroschisis, hydrocephaly, lateral ventricle dilated (tissue depressed), umbilical hernia, and atelectasis. The NOAELs for maternal and developmental toxicity are 1,000 and 500 mg/kg-day, respectively (Neeper-Bradley *et al.*, 1995). [Kl. score = 2]

Pregnant CD rats were dosed by oral gavage with 0, 1,250 2,500 or 5,000 mg/kg ethylene glycol during GD 6-15. In the $\geq$2,500 mg/kg groups, the dams had increased relative kidney weights, decreased gravid uterine weight, and increased water consumption. Maternal body weight gain was significantly decreased in the 1,250 mg/kg group. Live litter size was significantly decreased in the 5,000 mg/kg group, and fetal body weights were decreased in the 1,250 and 5,000 mg/kg groups. Litters with malformed fetuses were observed in the $\geq$1,250 mg/kg groups. The LOAELs for maternal and developmental toxicity are 1,250 mg/kg/day; NOAELs were not established (Price *et al.*, 1985). [Kl. score = 2]

Pregnant Fischer 344 rats were given by oral gavage 0, 40, 200 or 1,000 mg/kg ethylene glycol during GD 6-15. No maternal toxicity was observed at any dose level. There were no significant effects on preimplantation loss, fetal length, fetal weight, total implantations or litter size. There was an increased incidence of skeletal alterations in the 1,000 mg/kg group, which consisted of poorly ossified and unossified vertebral centra. No significant increases in the incidence of major malformations were observed. The NOAELs for maternal and developmental toxicity are 1,000 and 400 mg/kg/day (Maronpot *et al.*, 1983). [Kl. score = 2]

Pregnant CD-1 mice were dosed by oral gavage with 0, 50, 150, 500 or 1,500 mg/kg ethylene glycol during gestational days (GD) 6 to 15. There was no maternal toxicity. At 1,500 mg/kg, there were reduced fetal body weights, fused ribs and arches, poor ossification in thoracic and lumbar centra, and increased occurrence of an extra 14^{th} rib. At 500 mg/kg, there was slight reductions in fetal body weight and increased incidences of extra ribs. The NOAELs for maternal and developmental toxicity were 1,500 and 150 mg/kg/day, respectively (Neeper-Bradley et al., 1995). [Kl. score = 2]

Pregnant CD-1 mice were dosed by oral gavage with 0, 750, 1,500 or 3,000 mg/kg ethylene glycol during GD 6 to 15. There was a significant decrease in maternal gain, gravid uterine weights, and liver weights in the 1,500 mg/kg group. A decreased number of implantation sites per litter was observed in the 1,500 mg/kg group. Significant decrease in liver litter size was observed in the 3,000 mg/kg group and decreased fetal body weights were seen at $\geq$750 mg/kg. Litters with a significant increase in malformed fetuses were observed in the $\geq$750 mg/kg groups. There was a significant dose-related increase in postimplantation loss per litter, though there were no significant pairwise comparisons. The NOAEL for maternal toxicity is 750 mg/kg-day. The LOAEL for developmental toxicity is 750 mg/kg-day; the NOAEL was not established (Price *et al.*, 1985). [Kl. score = 2]

In a short-term reproductive and developmental toxicity screen test, male and female Swiss Crl:CD-1 mice were allowed to mate over a three-day period. The males were dosed by oral gavage from study day 3 to study day 20. The Group A females were exposed throughout the 21-day test period; the Group B females were exposed during GD 8-14. The doses were 0, 250, 700 or 2,500 mg/kg ethylene glycol. The Group A females were sacrificed after 19 days of treatment, and the Group B females were allowed to litter and rear to postnatal day (PND) 4. There was no maternal or paternal toxicity. The 2,500 mg/kg females in Group A had significantly fewer liver implants and more dead implants. The 2,500 mg/kg in Group B had significantly lower total litter weights on PND 1 and 4. The NOAELs for parental and developmental toxicity are 2,500 and 700 mg/kg/day (Harris *et al.*, 1992). [Kl. score = 2]

In a Chernoff/Kavlock assay, pregnant CD-1 mice were dosed by oral gavage with 0 or 11,090 mg/kg ethylene glycol during GD 7-14. The females were allowed to litter and rear to PND 3. Ten percent of the maternal animals died. The number of surviving pups per litter (40% survived), birth weight and pup weight gain were reduced. The LOAELs for maternal and developmental toxicity are 11,090 mg/kg; NOAELs were not established (Schuler *et al.*, 1984; Hardin *et al.*, 1987). [Kl. score = 2]

Pregnant female New Zealand White rabbits were dosed by oral gavage with 0, 100, 500, 1,000, or 2,000 mg/kg ethylene glycol on GD 6 to 19. At 2,000 mg/kg, eight of the 17 does (42.1%) died. Maternal body weights and body weight gain were similar across all groups. There was no developmental toxicity. The NOAEL for maternal toxicity is 1,000 mg/kg-day. The NOAEL for developmental toxicity is 2,000 mg/kg-day, the highest dose tested (ECHA). [Kl. score = 2]

Pregnant female CD rats were dosed by oral gavage with 0, 250, 1,250, or 2,250 mg/kg ethylene glycol on GD 6 to 20. At 2,250 mg/kg, maternal body weight, body weight gain, kidney weight, and postpartum uterine weight were significantly reduced. At 1,250 mg/kg, the gestational period was lengthened and maternal kidney histopathological effects were noted. Developmental toxicity was noted in the 2,250 mg/kg group and included reduced pup weight, reduced viability, and increased malformations (primarily hydrocephaly and abnormalities of the axial skeleton). No developmental toxicity was seen in the 1,250 mg/kg group. The NOAEL for maternal and developmental toxicity is 250 mg/kg-day (ECHA). [Kl. score = 2]

Inhalation

Pregnant female CD rats were exposed by inhalation (whole-body) to 0, 150, 1,000, or 2,500 mg/m^3 ethylene glycol aerosol 6 hours/day on gestational days 6 to 15. There was no treatment-related mortality; a dose-related increased in clinical signs (red fur discoloration on the head and neck) was noted, which was considered to be a non-specific indication of stress. Body weights and body weight gain were unaffected by treatment. There was some evidence of treatment-related reductions in ossification of the fetal skeleton at 1,000 and 2,500 mg/m^3 (considered as fetotoxicity). The NOAECs from inhalation exposure cannot be determined due to confounding oral exposure during whole-body exposure. However, there was no maternal or embryotoxicity at 150 mg/m^3 and no teratogenicity at any aerosol concentration tested (Tyl et al., 1995a). [Kl. score = 2]

Pregnant female CD-1 mice were exposed by inhalation (whole-body) to 0, 150, 1,000, or 2,500 mg/m^3 ethylene glycol aerosol 6 hours/day on gestational days 6 to 15. Reduced maternal body weight was observed in the 2,500 mg/m^3 group on GD 12,15, and 18 and in the 1,000 mg/m^3 group on GD 18. Reduced maternal weight gain was also seen during GD 6-12, 6-15, and GD 6-18 for the $\geq$1000 mg/m^3 groups, and for GD 5-18 for the 2,500 mg/m^3 group. Terminal body weights were reduced in the $\geq$1,000 mg/m^3 groups. Gravid uterine weight was also reduced in the $\geq$1,000 mg/m^3 groups, so that body weight corrected for gravid uterine weight was unaffected. The number of viable implantations per litter was reduced at 2,500 mg/m^3. The number of non-viable implantations per litter was elevated at $\geq$1,000 mg/m^3 because of a significant increase in late resorptions at 1,000 mg/m^3, and a significant increase in late resorptions and in dead fetuses at 2,500 mg/m^3. The number of early resorptions at 2,500 mg/m^3 was also elevated but not statistically. Fetal body weights per litter (male, female, and total) were reduced at $\geq$1,000 mg/m^3. There was a significant increase in the incidence of a number of external, visceral, and skeletal malformation, as well as skeletal variations, at $\geq$1,000 mg/m^3. There was no observable maternal or developmental toxicity at 150 mg/m^3. However, a NOAEC cannot be determined because of the amount of ethylene glycol that may have been ingested from the presence of ethylene glycol on the fur (Tyl et al., 1995a). [Kl. score = 2]

Pregnant female CD-1 mice were exposed by inhalation (nose-only) to 0, 500, 1,000, or 2,500 mg/m^3. The study also included a group exposed to 2,100 mg/m^3 (not discussed

here). Reduced maternal body weight gain were seen in the 2,500 mg/m^3 for GD 9-12, 12-15, 6-15, and 0-18. Absolute kidney weights were increased in the ≥1,000 mg/m^3 groups. Fetal body weights per litter were significantly reduced for the 2,500 mg/m^3. In the 2,500 mg/m^3, there was a significant increase in one skeletal malformation (fusion of the ribs) and an increased incidence of skeletal variations. No other teratogenic effects were observed. The NOECs for maternal and developmental toxicity are 500 and 1,000 mg/m^3, respectively (Tyl et al., 1995c). [Kl. score = 2]

Dermal

Pregnant CD-1 mice were administered by dermal applications of 0, 400, 1,677 or 3,549 mg/kg ethylene glycol 6 hours/day on GD 6-15. There was minimal, if any, treatment-related maternal toxicity. Copora lutea, total implants, percentage of live fetuses per litter, fetal body weights, and incidence of external or visceral malformations were unaffected by treatment. There was, however, a significant increase in two skeletal variations in the 3,549 mg/kg group. The NOAELs for maternal and developmental toxicity were considered to be 3,549 mg/kg-day (Tyl *et al.*, 1995b). [Kl. score = 2]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for ethylene glycol follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

The NOAEL from a 24-month rat dietary study was reported to be 200 mg/kg-day based on kidney lesions in male F344 rats at 1,000 mg/kg-day (Depass et al., 1986b). A subsequent 12-month rat dietary study using male Wistar rats reported a NOAEL of 150 mg/kg-day also based on kidney toxicity at 300 mg/kg-day and higher (Corley et al., 2008). The Wistar rat strain was shown to be more sensitive (approximately three-fold) to the kidney toxicity of ethylene glycol than F344 rats (Cruzan et al., 2004). The NOAEL of 150 mg/kg-day will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Snellings et al. (2013) derived an oral reference dose for ethylene glycol using benchmark dose modeling, with toxicokinetic (PBPK modeling) and toxicodynamic data. The human equivalent dose ($[BMDL_{05}]_{HED}$) was calculated to be 150 mg/kg-day.

Oral RfD = $[BMDL_{05}]_{HED}$ / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 1
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 150/(1 x 10 x 1 x 1 x 1) = 150/10 = 15 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (15 x 70 x 0.1)/2 = 53 mg/L

B. Cancer

Ethylene glycol was not carcinogenic to rats and mice in two-year dietary studies. Thus, a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Ethylene glycol does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Ethylene glycol is of low toxicity concern to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies conducted on ethylene glycol.

Table 3: Acute Aquatic Toxicity Studies on Ethylene Glycol

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Pimephales promelas	96-h LC_{50}	>72,860	1	Pillard (1995)
Oncorhynchus mykiss	96-h LC_{50}	22,810 24,591	2	OECD (2004a,b)
Daphnia magna	48-h EC_{50}	>100	1	ECHA
Daphnia magna	48-h EC_{50}	46,300	2	Gersich et al. (1986)
Ceriodaphnia dubia-affinis	48-h EC_{50}	25,800 (20^oC) 10,000 (24^oC)	2	Cowgill et al. (1985)
Daphnia magna	48-h EC_{50}	46,300 (20^oC) 51,000 (24^oC)	2	Cowgill et al. (1985)
Selenastrum capricornutum	96-h IC_{50} NOEC	10,940 10,000	2	Pillard and DuFrescne (1999)

Chronic Studies

Table 4 lists the results of chronic aquatic toxicity studies conducted on ethylene glycol.

Table 4: Chronic Aquatic Toxicity Studies on Ethylene Glycol

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Pimephales promelas	7-day NOEC	15,380	2	Pillard (1985)
Ceriodaphnia dubia	7-day NOEC (reproduction)	8,590	2	Pillard (1985)

C. Terrestrial Toxicity

No guideline studies have been conducted on ethylene glycol.

D. Calculation of PNEC

The PNEC calculations for ethylene glycol follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute E(L)C_{50} values are available for fish (22,810 mg/L), *Daphnia* (>100 mg/L), and algae (10,940 mg/L). NOEC values from long-term studies are available for fish (15,380 mg/L), invertebrates (8,590 mg/L), and algae (10,000 mg/L). On the basis that the data consists of short-term and long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported E(L)C_{50} value of 100 mg/L for fish. The E(L)C_{50} value is used because the value for fish is lower than the NOEC values for all three trophic levels. The $PNEC_{aquatic}$ is 10 mg/L.

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 6.4 mg/kg sediment wet weight.

The calculations are as follows:

$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$
$= (0.82/1280) \times 1000 \times 10$
$= 6.4$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$K_{sed\text{-}water}$ = 0.8 + [(0.2 x Kp_{sed})/1000 x BD_{solid}]
= 0.8 + [(0.2 x 0.04/1000 x 2400]
= 0.82

Where:
Kp_{sed} = solid-water partition coefficient (L/kg).
BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

Kp_{sed} = K_{oc} x f_{oc}
= 1 x 0.04
= 0.04

Where:
K_{oc} = organic carbon normalized distribution coefficient (L/kg). The K_{oc} for ethylene glycol calculated from EPISUITE™ using the MCI is 1 L/kg.
F_{oc} = fraction of organic carbon in sediment = 0.04 [default].

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is 0.13 mg/kg soil dry weight.

The calculations are as follows:

$PNEC_{soil}$ = (Kp_{soil}/BD_{soil}) x 1000 x $PNEC_{water}$
= (0.02/1500) x 1000 x 10
= 0.13

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

Kp_{soil} = K_{oc} x f_{oc}
= 1 x 0.02
= 0.02

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for ethylene glycol calculated from EPISUITE™ using the MCI is 1 L/kg.
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Ethylene glycol is readily biodegradable and thus does not meet the screening criteria for persistence.

The measured BCF in fish is 10. Thus, ethylene glycol does not meet the criteria for bioaccumulation.

The NOECs from the chronic aquatic toxicity studies on ethylene glycol are >0.1 mg/L. The acute E(L)C_{50} values from the acute aquatic toxicity studies on ethylene glycol are >1 mg/L. Thus, ethylene glycol does not meet the criteria for toxicity.

The overall conclusion is that ethylene glycol is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

STOT RE Category 2 (target organ: kidney)

B. Labelling

Warning

C. Pictogram



X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
In case of contact, immediately flush eyes with plenty of water for at least 15 minutes.

Skin Contact
Wash thoroughly with soap and water.

Inhalation
If inhaled, remove from area to fresh air. Get medical attention.

Ingestion
Rinse mouth with water and then drink a glass of water. Get medical attention. Never give anything by mouth to an unconscious person.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
Keep product and empty container away from heat and sources of ignition. May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: carbon monoxide, carbon dioxide.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Use appropriate protective equipment. Handle in accordance with good industrial hygiene and safety practice.

Environmental Precautions
Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled
For large amounts: dike spillage and pump off product. For residues: pick up with suitable absorbent material. Dispose of contaminated material as prescribed.

D. STORAGE AND HANDLING

General Handling
Keep product and empty container away from heat and sources of ignition. Ensure adequate ventilation, especially in confined areas.

Storage
Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards

The workplace exposure standards for ethylene glycol in Australia is as follows: 10 mg/m^3 as an 8-hour TWA for ethylene glycol (particulate); 20 ppm (52 mg/m^3) as an 8-hour TWA for ethylene glycol (vapour). There is also a skin notation indicating that absorption through the skin may be significant source of exposure.

Engineering Controls
Good general ventilation should be used.

Personal Protection Equipment

Respiratory Protection:
Respiratory protection is not required.

Hand Protection:
Chemical resistant protective gloves.

Skin *Protection*:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Safety glasses with side-shields.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Wearing of closed work clothing is recommended. Ensure that eyewash stations and safety showers are close to the workstation location.

F. TRANSPORT INFORMATION

Ethylene glycol is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

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FATTY ACIDS, TALL OIL, ETHOXYLATED

This dossier on fatty acids, tall oil, ethoxylated does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of fatty acids, tall oil, ethoxylated in its use in drilling muds and hydraulic fracturing fluids. The information presented in this dossier was obtained from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name: Fatty acids, tall oil, ethoxylated

CAS RN: 61791-00-2

Molecular formula: UVCB

Molecular weight: UVCB

SMILES: UVCB

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Fatty Acids, Tall Oil, Ethoxylated (1 – 2.5 Moles Ethoxylated)

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Liquid	1	ECHA
Melting point	-85 to -5°C	1	ECHA
Boiling point	ca. 172°C	1	ECHA
Density	0.958 g/cm^3 @ 20°C	1	ECHA
Vapor pressure	Could not be determined experimentally.	1	ECHA
Partition coefficient (log K_{ow})	Could not be determined experimentally. 5.94 (QSAR)	1 2	ECHA
Water solubility	Could not be determined experimentally.	1	ECHA
Flash point	138°C	1	ECHA

Auto flammability	377°C	1	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Fatty acids, tall oil, ethoxylated is readily biodegradable; will adsorb to soil and sediment; but is not expected to bioaccumulate.

B. Biodegradation

Fatty acids, tall oil, ethoxylated is readily biodegradable. In an OECD 301 B test, degradation was 90 – 100% after 28 days (ECHA) [Kl. score = 1].

C. Environmental Distribution

Adsorption/desorption

Experimental data are available for fatty acids, tall oil, ethoxylated. The test material had different components which differed considerably in adsorption potential. The log K_{oc} values were: <1.8, 2.02, 2.9, 4.39, 5.24, and >5.63. The main constituents peak 4 (log K_{oc} = 4.39) and peak after determination of dead time (DDT) were 49.4% and 43.6% of the test substance.

The log K_{oc} values used to calculate the $PNEC_{soil}$ values are 4.39 and >5.63 (K_{oc} values of 24,547 to 426,580 L/kg, respectively).

D. Bioaccumulation

There are no bioaccumulation studies on fatty acids, tall oil, ethoxylated. Fatty acid, tall oil, ethoxylated contains constituents with log K_{ow} values in the range of 5 to >10 based on QSAR modeling using KOWWIN v1.68 (ECHA), suggesting a potential for bioaccumulation. Bioaccumulation is not expected because the constituents of fatty acids, tall oil, ethoxylated are rapidly biodegraded, metabolized enzymatically, and are sterically hindered from crossing biological membrane (at least for the diester constituents). QSAR modeling using BCFBAF (v. 3.01, Arnot-Gobas, including biotransformation, upper trophic) estimated low BCF values of <100 L/kg for different constituents and including mono- and diester EO1 to EO5 (ECHA).

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

The acute toxicity of fatty acids, tall oil, ethoxylated is low by the oral and inhalation routes. It is not an irritant to the skin and eyes; but it is a skin sensitizer. In a combined repeated dose toxicity study with a reproductive/developmental screening toxicity (OECD 422) test, there was no evidence of systemic, reproductive or developmental toxicity in rats at doses up to 1,000 mg/kg-day of fatty acids, tall oil, ethoxylated. In vitro genotoxicity studies on this substance were negative.

B. Acute Toxicity

The oral LD_{50} in rats is >10,000 mg/kg (ECHA) [Kl. score = 2].

The inhalation 8-hour LC_{50} in rats was greater than the saturated vapor concentration at 20°C (approximately 0.28 mg/L) (ECHA) [Kl. score = 2].

There are no acute dermal toxicity studies on fatty acids, tall oil, ethoxylated.

C. Irritation

Fatty acids, tall oil, ethoxylated was not considered an irritant in an in vitro reconstructed human epidermis test (ECHA) [Kl. score = 1].

Fatty acids, tall oil, ethoxylated was not considered an irritant in an in vitro reconstructed human cornea-like epithelium test (ECHA) [Kl. score = 1].

D. Sensitization

Fatty acids, tall oil, ethoxylated was not considered to be a skin sensitizer in a mouse local lymph node assay (ECHA) [Kl. score = 1].

In a guinea pig Buehler test, fatty acids, tall oil, induced a skin sensitizing response (ECHA) [Kl. score = 1].

E. Repeated Dose Toxicity

Oral

Fatty acids, tall oil, ethoxylated was tested in a combined repeated dose toxicity study with a reproductive/developmental screening toxicity (OECD 422) test. Male and female Wistar rats were dosed daily by oral gavage with 0, 100, 300, or 1,000 mg/kg fatty acids, tall oil, ethoxylated for at least 28 days, including 14 days of pre-mating. There was no indication of toxicity at any dose level. The NOAEL for systemic toxicity is 1,000 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 1].

Inhalation

No studies are available.

Dermal

No studies are available.

F. Genotoxicity

In Vitro Studies

The in vitro studies on fatty acids, tall oil, ethoxylated are presented below in Table 2.

Table 2: *In vitro* Genotoxicity Studies on Fatty Acids, Tall Oil, Ethoxylated

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* and *E. coli* strains)	-	-	1	ECHA
Mammalian cell gene mutation (Chinese hamster fibroblast cells)	-	-	1	ECHA
Chromosomal aberration (human lymphocytes)	-	-	1	ECHA

*+, positive; -, negative

In Vivo Studies

No studies are available.

G. Carcinogenicity

No studies are available.

H. Reproductive/Developmental Toxicity

Fatty acids, tall oil, ethoxylated was tested in a combined repeated dose toxicity study with a reproductive/developmental screening toxicity (OECD 422) test. Male and female Wistar rats were dosed daily by oral gavage with 0, 100, 300, or 1,000 mg/kg fatty acids, tall oil, ethoxylated for at least 28 days, including 14 days of pre-mating. There was no indication of parental toxicity, reproductive, or developmental toxicity at any dose level. The NOAEL for reproductive and developmental toxicity is 1,000 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 1].

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for fatty acids, tall oil, ethoxylated follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

The NOAEL for systemic, reproductive, and developmental toxicity from an OECD 422 study on fatty acids, tall oil, ethoxylated is 1,000 mg/kg-day, the highest dose tested (ECHA). The NOAEL of 1,000 mg/kg-day will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 10
UF_D (database uncertainty) = 1

Oral RfD = 1,000/(10 x 10 x 1 x 10 x 1) = 1,000/1,000 = 1.0 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (1 x 70 x 0.1)/2 = 3.5 mg/L

B. Cancer

There are no carcinogenicity studies on fatty acids, tall oil, ethoxylated. Thus, a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Fatty acids, tall oil, ethoxylated does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Fatty acids, tall oil, ethoxylated has a moderate concern for acute toxicity to aquatic life.

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies conducted on fatty acids, tall oil, ethoxylated.

Table 3: Acute Aquatic Toxicity Studies on Fatty Acids, Tall Oil, Ethoxylated

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Brachydanio rerio	96-hr LL_{50}	>100 [WAF]	1	ECHA
Daphnia magna	48-hr EL_{50}	12.41 [WAF]	1	ECHA
Pseudokirchneriella subcapitata	72-hr EL_{50} 72-hr EL_{10}	39.7 [WAF] 7.08 [WAF]	1	ECHA

Chronic Studies

No studies are available.

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for fatty acids, tall oil, ethoxylated follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)L_{50}$ values are available for fish (>100 mg/L WAF), invertebrates (12.41 mg/L WAF), and algae (39.7 mg/L). On the basis that the data consists of short-term studies for three trophic levels, an assessment factor of 100 has been applied to the lowest reported $E(L)L_{50}$ value of 12.41 mg/L [WAF] for *Daphnia*. The $PNEC_{water}$ is 0.12 mg/L.

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ values range from 39 to >683 mg/kg soil dry weight.

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
$= (491/1500) \times 1000 \times 0.12$
$= 39$

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
$= (8532/1500) \times 1000 \times 0.12$
$= 683$

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
$= 24{,}547 \times 0.02$
$= 491$

$Kp_{soil} = K_{oc} \times f_{oc}$
$= 426{,}580 \times 0.02$
$= 8{,}532$

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for fatty acids, tall oil, ethoxylated were experimentally determined to range from 24,547 to >426,580 (see Section IIIC).
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Fatty acids, tall oil, ethoxylated is readily biodegradable; thus, it does not meet the screening criteria for persistence.

Based on predicted BCF values of <100 L/kg for constituents, fatty acids, tall oil, ethoxylated does not meet the criteria for bioaccumulation.

There are no chronic aquatic toxicity data on fatty acids, tall oil, ethoxylated. The acute $E(L)L_{50}$ values are >1 mg/L. Thus, fatty acids, tall oil, ethoxylated does not meet the screening criteria for toxicity.

The overall conclusion is that fatty acids, tall oil, ethoxylated is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Skin Sensitizer Category 1
Aquatic Acute Toxicity Category 3

B. Labelling

Warning

C. Pictogram



X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
Rinse immediately with plenty of running water. If easy to do, remove contact lenses. Get medical attention if symptoms occur.

Skin Contact
Wash with soap and water. Get medical attention if symptoms persist.

Inhalation
Treat symptomatically. Move to fresh air. Get medical attention if symptoms occur.

Ingestion
Rinse mouth with water and then drink plenty of water. Never give anything by mouth to an unconscious person. Seek medical attention if symptoms occur.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, dry chemical, foam. Do not use water jet.

Specific Exposure Hazards
May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: carbon monoxide, carbon oxides.

Special Protective Equipment for Firefighters

Self-contained breathing apparatus and full protective clothing must be worn in case of fire.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Wear appropriate personal protective equipment. Do not breath mist or aerosol.

Environmental Precautions
Prevent from entering sewers, waterways, or low area

Steps to be Taken if Material is Released or Spilled
Absorb spill with inert absorbent material, then place in a container for chemical waste.

D. STORAGE AND HANDLING

General Handling
Provide adequate ventilation. Wear appropriate personal protective equipment. Observe good hygiene practices.

Other Handling Precautions
Wash hands thoroughly after handling. Avoid breathing mists or aerosols.

Storage
Keep container closed.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards

Workplace Australia has not established an occupational exposure standard for fatty acids, tall oil, ethoxylated.

Engineering Controls
Good general ventilation should be used.

Personal Protection Equipment

Respiratory Protection:
Wear respiratory protection if ventilation is inadequate.

Hand Protection:
Chemical resistant protective gloves.

Skin Protection:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*

Chemical safety goggles.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible.

F. TRANSPORT INFORMATION

Fatty acids, tall oil, ethoxylated is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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GLUTARALDEHYDE

This dossier on glutaraldehyde does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of glutaraldehyde in its use in drilling muds and hydraulic fracturing fluids. The majority of information presented in this dossier was obtained from NICNAS (1994) and the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch et al., 1997).

I. SUBSTANCE IDENTIFICATION

Chemical Name (IUPAC): Glutaraldehyde

CAS RN: 111-30-8

Molecular formula: $C_7H_8O_2$

Molecular weight: 100.12

Synonyms: Pentanedial; glutaral; glutaric dialdehyde; 1,3-diformylpropane; 1,5-pentanedial; glutaric aldehyde; glutaric acid dialdehyde; dioxopentane; glutardialdehyde; 1,5-pentanedione; Algicide®C

SMILES: C(CC=O)CC=O

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Physico-Chemical Properties of Glutaraldehyde

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa*	Sweetish smelling, clear water liquid	1	ECHA
Melting Point*	-33°C	1	ECHA
Boiling Point*	101.5°C @ 987.1 hPa	1	ECHA
Density*	1.13 kg/m^3	1	ECHA
Vapour Pressure*	30 hPa @ 26.3°C	1	ECHA
Partition Coefficient (log K_{ow})*	-0.36	1	ECHA
Water Solubility*	miscible	2	ECHA
Flash Point*	Not measurable	1	ECHA
Auto flammability*	395°C @ ~1,000hPa	1	ECHA
Viscosity*	12.75 mm^2/s (static) at 25°C	1	ECHA
Henry's Law Constant	0.011 Pa m^3/mol at 25°C [QSAR]	2	ECHA

*ca. 50% glutaraldehyde solution (in water)
1 ppm = 4.095 mg/m^3
1 mg/m^3 = 0.244 ppm

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Glutaraldehyde is considered readily biodegradable. It is also expected to have a low potential for bioaccumulation. The K_{oc} values for glutaraldehyde indicate that it will have low potential for adsorption to suspended solids and sediment in water and moderate adsorption to soil. Glutaraldehyde

is not expected to undergo hydrolysis in the environment. Overall, glutaraldehyde shows limited persistence in the environment.

B. Abiotic Degradation

Hydrolysis

In an OECD TG 111 test (hydrolysis as a function of pH), glutaraldehyde was hydrolytically stable at pH 4 and pH 7, but decomposed at pH 9 (ECHA). [Kl. score = 2]

Phototransformation in Water

Photolytic degradation of glutaraldehyde occurred in water under sensitised conditions: the half-life was 18 days when equivalent to 36 days of natural sunlight (12 hours/day; sensitised acetone system); and 49 days when equivalent to 34 days of natural sunlight (12 hours/day; sensitised acetonitrile system). There was no photodegradation of glutaraldehyde under darkness or non-sensitised conditions (ECHA). [Kl. score = 2]

C. Biodegradation

Glutaraldehyde was considered readily biodegradable in an OECD 301A (DOC die away test). Degradation was 90-100% in 28 days (ECHA). [Kl. score = 1]

In a simulation test involving aerobic sewage treatment [activated sludge units] (OECD TG 303A), glutaraldehyde degraded 97% after 73 days based on DOC removal (ECHA). [Kl. score = 1]

In an aerobic aquatic metabolism test, [^{14}C]-glutaraldehyde had a half-life of 10.6 hours in the water/sediment system. A minor transformation product was glutaric acid: the maximum yield was 18.9 to 21.5% at 12 hours, which then declined rapidly to 10.1 to 11% by 24 hours; and was not observed at the end of the study period in the aqueous phase (ECHA). [Kl. score = 1]

In an anaerobic aquatic metabolism test, [^{14}C]-glutaraldehyde was rapidly metabolised with the first-order half-life being 7.7 hours. Glutaraldehyde was transformed to 5-hydroxypentanal (ca 37% of applied radioactivity) on day 1; after that, it declined to <10%; it was not detected at all after 30 days. The second stable transformation product was 1,5-pentanediol (35% of radioactivity on Day 1), which accounted for 70% of the radioactivity at the end of the test. A minor transformation product was a compound formed via Aldol condensation, cyclisation and dehydration. This compound accounted for about 10-20% of total radioactivity from day 1 onwards (ECHA). [Kl. score = 1]

In an aerobic soil metabolism test, the half-life of the degradation of [^{14}C]-glutaraldehyde was calculated to be 1.7 days, indicating rapid degradation in soil by microbial biotransformation. Degradation products were measured but not identified. (ECHA). [Kl. score = 1]

D. Environmental Distribution

Adsorption/desorption

The organic carbon/water partition coefficients (K_{oc}) values were determined for sediment and four types of soil. The values are as follows: 120 for sediment; 210 for sandy loam; 500 for silty clay loam; 340 for silt loam; and 460 for loamy sand (ECHA; Leung et al., 2001). [Kl. score = 1]

Distribution Modelling

No fugacity calculations were performed as glutaraldehyde has limited persistence. Its environmental fate is primarily determined by degradation rather than equilibration between compartments (OECD-SIDS, 1995).

E. Bioaccumulation

Glutaraldehyde is not expected to bioaccumulate. The measured log K_{ow} at pH 5, 7 and 9 are -0.41, -0.36 and -0.80, respectively (ECHA).

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Glutaraldehyde has moderate-to-high acute toxicity by the oral route, low-to-moderate toxicity by the dermal route, and moderate-to-high toxicity by the inhalation route. Acute inhalation exposure may cause respiratory irritation. Glutaraldehyde is corrosive to the skin and eyes; it is also a skin and respiratory sensitizer. Repeated oral exposures via drinking water to rats have resulted in general systemic toxicity, but no target organ effects. In contrast, the upper respiratory tract, particularly the nasal cavity, is the target organ in rodents from repeated inhalation exposure. Glutaraldehyde may exhibit weak genotoxic effects in some *in vitro* tests, whereas the *in vivo* studies consistently show no genotoxic activity. Glutaraldehyde is not a reproductive toxicant; developmental toxicity can occur at maternally toxic doses, but there is no teratogenicity.

B. Toxicokinetics

Dermal Absorption

[1,5-^{14}C]-glutaraldehyde was applied to the skin of male and female F344 rats. Doses were 0.75% and 7.5%: this corresponds to approximately 6.5 and 63 mg/kg for males; and approximately 8.7 and 102 mg/kg for females. The dermal absorption data are presented below in Table 2. The results indicate that glutaraldehyde has a low rate of absorption by the dermal route (ECHA).

Table 2: Dermal Absorption Data in Rats on Glutaraldehyde (ECHA)

Sex	Absorption rate constant/hr		% of applied dose	
	Low Dose	High Dose	Low Dose	High Dose
Males	1.5	0.7	0.7	1.3
Females	1.8	0.9	0.3	2.1

An *in vitro* percutaneous absorption study was conducted on glutaraldehyde using excised skin from rats, rabbits, mice, guinea pigs, and humans. The skin samples were placed in a flow-through skin penetration chamber, and [^{14}C]-glutaraldehyde was added at doses of 0.75% and 7.5%. The results are presented below in Table 3. Glutaraldehyde did not penetrate any of the skin samples to a significant degree, suggesting that only minimal amounts of glutaraldehyde may be available for systemic uptake and distribution after skin exposure. The results also show that skin absorption was greater for the animal species used in toxicity tests than human skin (ECHA; Frantz et al., 1993).

Table 3: *In vitro* Percutaneous Absorption (mg/cm^2) of Glutaraldehyde (ECHA; Frantz et al., 1993)

Species	Low Dose	High Dose
Animal*	0.006	0.08

Human	0.002	0.02

*Percutaneous absorption in rats, mice, guinea pigs, mice and rabbits were similar to each and were reported as a single value.

C. Acute Toxicity

The oral LD_{50} values are: 123 to 820 mg/kg in rats; 100 to 352 mg/kg in mice; and 50 mg/kg in guinea pigs (NICNAS, 1994).

The dermal LD_{50} values are: 640 to 2,000 mg/kg in rabbits; >2,500 mg/kg in rats; and >4,500 mg/kg in mice (NICNAS, 1994).

The 4-hour inhalation LC_{50} values for glutaraldehyde are listed in the table below:

Table 4: Acute inhalation LC_{50} values for Glutaraldehyde

Test Material	LC_{50} (males) [mg/L]	LC_{50} (females) [mg/L]	LC_{50} (both sexes) [mg/L]	Reference
50% aq. aerosol	0.52	0.45	-	OECD, 1995
25% aq. aerosol	-	-	0.8	OECD, 1995
50% aq. aerosol	0.35	0.28	-	OECD, 1995
5% soln. vapour	0.096	0.164	-	OECD, 1995

During the exposure period, the animals showed signs of eye and respiratory irritation, as indicated by laboured and audible breathing, and wetness and encrustation around the nose and eyes.

D. Irritation

Glutaraldehyde is corrosive to the skin and eyes of rabbits (NICNAS, 1994; ECHA). Signs of irritation occurred at a concentration of 2% for skin and 0.2% for eyes (NICNAS, 1994). In the acute inhalation studies, rats exposed to aerosols or vapours of glutaraldehyde showed signs of eye and respiratory irritation (OECD, 1995).

E. Sensitisation

Glutaraldehyde is a skin sensitiser to guinea pigs and humans. Information on the individual studies can be found in NICNAS (1994) and in the ECHA REACH database (ECHA).

Asthmatic symptoms, such as wheezing, coughing, chest tightness, breathing difficulties and non-specific hyper-responsiveness have been reported to occur in humans occupationally exposed to glutaraldehyde (NICNAS, 1994). It is unclear whether the asthma is an allergic hypersensitivity response or a result of the aggravation of pre-existing asthma due to the irritating properties of glutaraldehyde. Nevertheless, glutaraldehyde should be considered a respiratory sensitiser, although one of low potency.

F. Repeated Dose Toxicity

Oral

Male and female Wistar rats were given in their drinking water 0, 100, 500, or 2,000 ppm glutaraldehyde for 90 days. The approximate daily intakes were 0, 3, 15, or 53 mg/kg-day for males, and 0, 4, 19, or 72 mg/kg-day for females. There were no signs of neurotoxicity at any dose level. There was slight impairment of food consumption in the 2,000 ppm animals, as well as slight

impairment of body weight and body weight gain. Impaired water consumption was seen in the 100 and 500 ppm females. The NOAEL for males is 500 ppm (15 mg/kg-day). The NOAEL for females is 100 ppm (4 mg/kg-day), since the impaired water consumption in the 100 ppm females was considered a palatability problem and not an adverse effect (ECHA). [Kl. score = 1]

Male and female F344 rats were given in their drinking water 0, 50, 250, or 1,000 ppm glutaraldehyde for 13 weeks. Additional groups of animals were given in their drinking water 0 or 1000 ppm glutaraldehyde for 13 weeks followed by a 4-week recovery period. The approximate daily intakes were 0, 5, 25, or 100 mg/kg-day for males; and 0, 7, 35, or 120 mg/kg-day for females. Water consumption was reduced in a dose-dependent manner in the ≥250 ppm males and 1,000 ppm females, which was attributed to an aversion to the taste and/or odour of glutaraldehyde in the water. There was also a reduction in food consumption in the 1,000 ppm animals with a parallel reduction in body weights. It is unclear whether the reduction in food consumption was related to the decreased water consumption. Urine volume was decreased with an increase in specific gravity, along with a slight increase in protein and ketone concentration, in the ≥250 ppm animals, which was probably related to the decreased water consumption. There were no treatment-related changes in the haematology parameters measured. Blood urea nitrogen was increased in a dose-related manner in the ≥250 ppm females at the 6-week time point, but at the 13-week or 17-week time points. Relative kidney weights were increased in a dose-related manner in the ≥250 ppm males and females, and increased absolute kidney weights in the females. Histopathological examination showed no treatment-related effects. The NOAEL is 50 ppm (5 and 7 mg/kg-day for males and females, respectively) based on dose-related increase in kidney weights at ≥250 ppm (ECHA). [Kl. score = 2]

Male and female Wistar rats were given in their drinking water 0, 100, 500, or 2000 ppm glutaraldehyde for 12 months. The approximate daily intakes were: 0, 6.4, 30.5, or 116.6 mg/kg-day for males; and 0. 9.6, 46, or 153 mg/kg-day for females. There was no treatment-related mortality. At 2,000 ppm, treatment-related effects included respiratory sounds (both sexes), decrease in body weight (males), decrease in body weight gain (both sexes), decrease in food consumption (both sexes), reduced water consumption (both sexes), lesions within the glandular stomach (both sexes showed erosion/ulceration of the glandular stomach), increased incidence of clear cell foci in the liver (males), and a single case of slight diffuse squamous metaplasia in the epithelium of the larynx (male). At 500 ppm, water consumption was reduced in males which was considered to be a palatability (bad taste) problem and not an adverse effect. No effects were seen in the 100 ppm animals. The NOAEL for this study is 500 ppm, which corresponds to 30.5 and 46 mg/kg-day for males and females, respectively (ECHA). [Kl. score = 1]

Male and female Fischer 344 rats were given in their drinking water 0, 50, 250, or 1000 ppm glutaraldehyde for 104 weeks. The mean glutaraldehyde consumption was 0, 4, 17, and 64 mg/kg-day for males and 0, 6, 25 ,and 86 mg/kg-day for females. There were no treatment-related mortalities or clinical symptoms of toxicity. In the 250 and 1,000 ppm groups, there was reduction in body weight and body weight gain; reduction in food and water consumption; increased statistically significant incidence of nucleated erythrocytes and of large monocytes; decreases in alanine aminotransferase (ALT), aspartate aminotransferase (AST), and glutamate dehydrogenase; dose-related decrease in urine volume accompanied by a dose-related increase in osmolality; changes in absolute and relative kidney weight; gastric irritation; increases in bone marrow hyperplasia; and increased incidence of renal tubular pigmentation. The decreased water consumption was considered to be due to the bad taste, smell and/or irritancy of the test substance in the drinking water; thus, it is of no toxicological relevance. As a result of reduced water intake, there are renal physiological adaptation, such as decreased urine, increased osmolality and changes in kidney weight. The haematological and clinical chemistry parameter changes were marginal and were considered to be of not toxicological relevance. The main haematological finding seen at the end of the study and which consisted of the appearance of nucleated erythrocytes and large monocytes in all treated groups (statistically significant for the ≥250 ppm males) was related to the incidence of large granular lymphocytic leukaemia (LGLL) in the spleen. The bone marrow hyperplasia and renal tubular pigmentation are related to the

occurrence/incidence of LGLL, and were considered by the authors of the study as being secondary to a low grade haemolytic anaemia in animals with LGLL. The NOAEL for this study is 50 ppm which corresponds to 4 and 6 mg/kg-day for males and females, respectively (Van Miller *et al.* 2002). [Kl. score = 2]

Inhalation

Male and female F344 rats were exposed by inhalation to 0, 0.0625, 0.125, 0.25, 0.5, or 1.0 ppm (0, 0.26, 0.5, 1, 2, or 4.1 mg/m^3) glutaraldehyde for 6.5 hours/day, 5 days/week for 13 weeks. The study focused on the respiratory tract, using histopathology and epithelial cell labelling index as end points. Histopathological lesions in the nasal passages and turbinates were seen at ≥0.25 ppm. Treatment-related effects were primarily the respiratory mucosa (nasal cavity and tips of the turbinates) and the olfactory epithelium (dorsal meatus). Hyperplasia, squamous metaplasia, olfactory degeneration, squamous exfoliation (accumulation of keratin, cell debris and bacteria in the lumen of the nasal vestibule) and focal erosions were reported for both sexes, and the severity and incidence of the findings increased with increasing concentration of glutaraldehyde. The NOAEL for this study is 0.125 ppm (Gross et al., 1994). [Kl. score = 1]

Male and female B6C3F$_1$ mice were exposed by inhalation to 0, 0.0625, 0.125, 0.25, 0.5, or 1.0 ppm (0, 0.26, 0.5, 1, 2, or 4.1 mg/m^3) glutaraldehyde for 6.5 hours/day, 5 days/week for 13 weeks. The study focused on the respiratory tract, using histopathology and epithelial cell labelling index as end points. Histopathologic lesions in the nasal passages and turbinates were seen at all exposure concentrations (≥0.0625 ppm). Treatment-related lesions were primarily the respiratory mucosa (nasal cavity and tips of the turbinates) and the olfactory epithelium (dorsal meatus). Hyperplasia, squamous metaplasia, olfactory degeneration, squamous exfoliation (accumulation of keratin, cell debris and bacteria in the lumen of the nasal vestibule) and focal erosions were reported for both sexes, and the severity and incidence of the findings increased with increasing test concentration. Furthermore, neutrophilic inflammation was seen at ≥0.062 ppm, and squamous metaplasia as well as necrosis were seen in the larynx at 1 ppm). The LOAEL for this study is 0.0625 ppm; a NOAEL was not established (Gross et al., 1994). [Kl. score = 1]

Male and female B6C3F$_1$ mice were exposed by inhalation to 0 or 0.1 ppm (0 or 0.41 mg/m^3) glutaraldehyde for 6 hours/day, 5 days/week for 52 and 78 weeks. Survival was similar between treated and control groups. Hyperplasia of the squamous epithelium lining of the dorsal wall of the nasal passages and the lateral aspect of the atrioturbinate was seen in a greater number of exposed females than in controls. Epidermal erosion and ulceration as well as squamous and inflammatory exfoliation were also seen in the nasal lumens. All of these changes were dependent on the length of glutaraldehyde exposure. The authors concluded that, since the induced lesions occurred in the more anterior part of the nasal passages, that they were likely the result of an irritation mechanism (Zissu et al., 1998). [Kl. score = 2]

Male and female Fischer 344 rats were exposed by inhalation to 0, 0.25, 0.5, or 0.75 ppm (0, 1, 2, or 3.1 mg/m^3) glutaraldehyde for 6 hours/day, 5 days/week for two years. Survival in the mid- and high-dose females was statistically significantly decreased compared to controls. Mean body weights of all exposed males and the mid- and high-dose females were generally less than those of the controls. Non-neoplastic lesions were limited primarily to the most anterior region of the nasal cavity. Effects included hyperplasia and inflammation of the squamous epithelium; hyperplasia, goblet cell hyperplasia, inflammation, and squamous metaplasia of the respiratory epithelium; and hyaline degeneration of the olfactory epithelium. The LOAEL for this study is 0.25 ppm based on hyperplasia and inflammation of the squamous epithelium of the nose in both sexes. A NOAEL was not established (van Birgelen et al., 2000). [Kl. score = 2]

Male and female B6C3F$_1$ mice were exposed by inhalation to 0, 0.0625, 0.125, or 0.25 ppm (0, 0.26, 0.5, or 1 mg/m^3) glutaraldehyde for 6 hours/day, 5 days/week for two years. Survival of the treated

animals was similar to controls. Mean body weights of the high-dose females were generally lower than the controls. Non-neoplastic lesions were limited primarily to the anterior region of the nasal cavity; the effects were qualitatively similar to those seen in the rats (see accompanying summary on the two-year rat study by van Birgelen et al., 2000). Squamous metaplasia of the respiratory epithelium was observed in both sexes of mice while female mice also had inflammation and hyaline degeneration of the respiratory epithelium. The incidence and severity grade (in parentheses) of the hyaline degeneration were: 16/50 (1.4), 35/49 (1.4), 32/50 (1.3), and 30/50 (1.1) for the 0, 0.0625, 0.125, and 0.25 ppm dose groups, respectively. The LOAEL for this study is 0.0625 ppm based on hyaline degeneration of the respiratory epithelium in female mice. A NOAEL was not established (van Birgelen et al., 2000). [Kl. score = 2]

Dermal

Applications of a 50% solution of glutaraldehyde was applied to the skin of male and female SD rats for 13 weeks. The doses were 0, 50, 100, and 150 mg/kg glutaraldehyde. At the application site, there were signs of irritation (scabs, desquamation and very slight or well-defined erythema). There was no treatment-related mortality, clinical signs, body weights, feed consumption, and ophthalmoscopic effects. There were no changes in the haematology and clinical chemistry parameters that were considered to be biologically or toxicologically relevant. Organ weights were similar between treated and control animals. Histopathological examination showed a treatment-related effects in the skin associated with chronic irritation; no other changes were noted that were considered to be treatment-related. The NOAEL for this study is 150 mg/kg, the highest dose tested (ECHA). [Kl. score = 1]

G. Genotoxicity

In Vitro Studies

Glutaraldehyde may exhibit weak genotoxic effects in some *in vitro* tests. The bacterial reverse mutation assays have been the most consistent. Variable results have been reported for the forward gene mutation tests; and for sister chromatid exchange (SCE), chromosomal aberration and Unscheduled DNA Synthesis (UDS) tests (Vergnes and Ballantyne, 2002).

In Vivo Studies

The *in vivo* studies conducted on glutaraldehyde are presented below in Table 5. All of the studies show that glutaraldehyde is not mutagenic or genotoxic.

Table 5: *In Vivo* Genotoxicity Studies on Glutaraldehyde

Test System	Results*	Klimisch Score	Reference
Rat bone marrow (chromosomal aberration)	-	1	ECHA
Rat bone marrow (chromosomal aberration)	-	2	ECHA
Mouse bone marrow (micronucleus)	-	1	ECHA
Rat bone marrow (chromosomal aberration)	-	2	ECHA
Rat germ cell cytogenetic assay (alkaline elution)	-	2	ECHA
Drosophila SLRL Test	-	2	ECHA
Rat liver UDS Assay	-	1	ECHA
Rat germ cell cytogenetic assay (alkaline elution)	-	2	ECHA
Mouse peripheral blood micronucleus study	-	2	Vernes and Ballantyne (2002)

Rat liver UDS Assay	-	2	Mirsalis *et al.* (1989)

a+, positive; -, negative

H. Carcinogenicity

Oral

Male and female Fischer 344 rats were given in their drinking water 0, 50, 250, or 1,000 ppm glutaraldehyde for 104 weeks. The mean glutaraldehyde consumption was 0, 4, 17, and 64 mg/kg-day for males and 0, 6, 25, and 86 mg/kg-day for females. Mortality rates were 25-30% and 19-23% for males and females, respectively, with no dose-related increase. The major cause of death in all dose groups including the controls was LGLL. There was an increased incidence of LGLL in the liver and spleen in all treated females (≥50 ppm). The incidence of LGLL was not significantly increased in the treated males compared to the controls. No other treatment-related increased incidence of tumours was seen (Van Miller et al., 2002). [Kl. score = 2]

Male and female Wistar rats were given in their drinking water 0, 100, 500, or 2,000 ppm glutaraldehyde for two years. The mean daily intake of glutaraldehyde was as follows: 0, 6.1, 31.9, and 120.7 mg/kg-day for males; and 0, 10.5, 48.5, and 176.4 mg/kg-day for females. In the high-dose animals, there was mortality (2 males and 9 females) from asphyxia, and mean terminal body weights were significantly decreased compared to the controls. There were no treatment-related neoplastic effects (ECHA). [Kl. score = 1]

Inhalation

Male and female $B6C3F_1$ mice were exposed by inhalation to 0 or 0.1 ppm (0 or 0.4 mg/m^3) glutaraldehyde for 6 hours/day, 5 days/week for 52 and 78 weeks. No exposure-related neoplastic lesions were observed in either males or females (Zissu et al., 1998). [Kl. score = 2]

Male and female Fischer 344 rats were exposed by inhalation to 0, 0.25, 0.5, or 0.75 ppm (0, 1, 2, or 3.1 mg/m^3) glutaraldehyde for 6 hours/day, 5 days/week for two years. Survival in the mid- and high-dose females was statistically significantly decreased compared to controls. Survival of the treated males was similar to controls. No exposure-related neoplastic lesions were observed in either males or females (van Birgelen et al., 2000). [Kl. score = 2]

Male and female $B6C3F_1$ mice were exposed by inhalation to 0, 0.0625, 0.125, or 0.25 ppm (0, 0.26, 0.5, or 1 mg/m^3) glutaraldehyde for 6 hours/day, 5 days/week for two years. Survival of the treated animals was similar to controls. No exposure-related neoplastic lesions were observed in either males or females (van Birgelen et al., 2000). [Kl. score = 2]

I. Reproductive Toxicity

A two-generation reproductive toxicity study was conducted in Wistar rats given 0, 100, 500 and 2000 ppm glutaraldehyde in their drinking water. The approximately mean daily intake is 0, 12, 58, and 199 mg/kg-day for the parental males and females of the F_0 and F_1 generation during premating. There were no adverse effects on reproductive performance or fertility. Oestrous cycle data, mating behaviour, conception, gestation, parturition, lactation and weaning as well as sperm parameters, sexual organ weights, gross and histopathological findings of these organs were similar between treated and control groups. In the high-dose animals, there was decreased water and/or food consumption; and decreased body weights and/or reduced body weight gains during the premating periods in the F_0 and F_1 parental females during premating, gestation and/or lactation. The high-dose F_1 parental females also had increased the number of erosions/ulcers with microscopic erosion(s) or inflammatory oedema in the mucosa/submucosa of the glandular stomach. There were no adverse effects in the 500 ppm animals except for slight decreases in water consumption due to a palatability

(bad taste) problem. Treatment-related signs of developmental toxicity were seen in the progeny of the high-dose F_0 and F_1 parental generation, and included impairment in body weight and consequently in organ weights in the respective F_1 and F_2 pups. The NOAEL for reproductive toxicity is 2,000 ppm (199 mg/kg-day), the highest dose tested. The NOAEL for parental systemic toxicity is 500 ppm (58 mg/kg-day). The NOAEL for developmental toxicity is 500 ppm or 58 mg/kg-day (ECHA). [Kl. score = 1]

A two-generation reproductive toxicity study was conducted in Crj: CD(SD) rats given 0, 50, 250 and 1,000 ppm glutaraldehyde in their drinking water. Mean daily intake was not calculated. Parental body weights and body weight gains were significantly reduced at 1,000 ppm at some periods, particularly during pre-mating. Food consumption was significantly reduced at 1,000 ppm for the F_0 and F_1 parental animals during pre-mating and gestation, and F_1 females during lactation. Water consumption was reduced throughout the pre-mating period for the F_0 and F_1 250 and 1,000 ppm parental animals. There was no indication of adverse effects on reproductive performance or fertility at any dose level. For the F_1 1,000 ppm offspring, body weights were reduced from lactation days 21-28. The NOAEL for reproductive toxicity is 1,000 ppm, the highest dose tested. The NOAEL for parental systemic toxicity is 50 ppm. The NOAEL for developmental toxicity is 250 ppm (Neeper-Bradley and Ballantyne, 2000). [Kl. score = 2]

J. Developmental Toxicity

Pregnant Wistar rats were given in their drinking water 0, 50, 250, or 750 ppm (0, 5, 26, or 68 mg/kg) glutaraldehyde from GD 6 to 16. Water consumption was reduced in a dose-related manner in the $\geq$250 ppm dams, and was considered not to be a toxic response, but due to the palatability (bad taste) of the drinking test solution. No other maternal effects were seen in the study. There were no significant differences between treated and controls in the sex distribution, placental weights, fetal weights, malformations or variations. The NOAEL for maternal and developmental toxicity in this study is 68 mg/kg-day, respectively (ECHA). [Kl. score = 1]

Pregnant Wistar rats were dosed by oral gavage with 0, 25, 50, or 100 mg/kg glutaraldehyde on GD 6 to 15. Mortality was significantly increased in the high-dose group (5/26); there were 2/21 deaths in the mid-dose group. Clinical signs (piloerection) occurred in all treated groups in a dose-dependent manner. Maternal body weight gain and feed consumption were significantly reduced in the high-dose dams, but not at the lower doses. The necropsy findings showed evidence of stomach irritation in almost all of the animals that died during the study and in 12/21 of the surviving dams in the high-dose group. The number of implantation per litter, resorptions and dead foetuses per litter, live foetuses per litter, and incidence of post-implantation loss per litter was similar across all groups. The mean foetal body weights for male and female foetuses were significantly reduced in the high-dose group; this was attributed to the reduced food consumption of the dams during gestation rather than a direct effect of treatment. There was no evidence of a treatment-related teratogenic effect. The NOAEL for maternal and developmental toxicity is 50 mg/kg-day, respectively (Ema et al., 1992). [Kl. score = 2]

Pregnant Himalayan rabbits were dosed by oral gavage with 0, 5, 15 or 45 mg/kg glutaraldehyde on GD 7 to 19. In the high-dose group, 5/15 died on GD 9-11. Food consumption and body weight gain were also significantly reduced in the high-dose group. Clinical observations in 12/15 high-dose does included soft faces, diarrhoea, and blood in the bedding. The mean gravid uterus weight was significantly reduced in the high-dose group. Post-implantation loss was greatly increased (94.3%) in the high-dose group: no viable foetuses in 9/15 of the high-dose does, only early resorptions; only one female gave 4 alive foetuses on the scheduled date. There were reduced placental and foetal body weights in the only four foetuses. No significant maternal or developmental effects were seen in the mid- and low-dose groups. The NOAEL for maternal and developmental toxicity in this study is 15 mg/kg-day (ECHA). [Kl. Score = 2]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for glutaraldehyde follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

The lowest NOAEL values from key toxicity studies on glutaraldehyde are listed below in Table 6.

Table 6: Lowest NOAEL Values from Key Toxicity Studies on Glutaraldehyde by the Oral Route

Species/Sex	Study Duration	mg/kg-day	Endpoint	Reference
Rats, female	90-days	4	Decreased body weights, food and water consumption	ECHA
Rats, male	13-wk (drinking water)	5	Increased kidney weights	ECHA
Rats, male	12-months (drinking water)	30.5	Clinical signs; decreased body weights and food consumption; increased clear cell foci in liver	ECHA
Rats, male	2-yr (drinking water)	4	Reduced body weight, body-weight gain, and food consumption	Van Miller *et al.* (2002)
Rats	2-generation (drinking water)	58	Systemic toxicity	ECHA
Rats	GD 6-16 (drinking water)	68	Developmental toxicity	ECHA
Rats	GD 6-15 (oral gavage)	50	Developmental toxicity	Ema *et al.* (1992)
Rabbits	GD 7-19 (oral gavage)	15	Developmental toxicity	ECHA

The lowest NOAEL from these studies is 4 mg/kg-day based on reduced body weights, body weight gain, and feed consumption in male rats from the two-year drinking water study (Van Miller et al., 2002). The NOAEL of 4 mg/kg-day will be used for determining the oral Reference Dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1

UF_D (database uncertainty) = 1

Oral RfD = 4/(10 x 10 x 1 x 1 x 1) = 4/100 = 0.04 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD: Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

Where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2 L (ADWG, 2011)

Drinking water guidance value = (0.04 x 70 x 0.1)/2 = 0.14 mg/L

B. Cancer

Increased incidence of large granular cell lymphatic leukaemia (LGLL) was observed in all groups of male and female Fischer 344 rats given glutaraldehyde in their drinking water, including the controls (Van Miller *et al.* 2002). For the males, the incidence of LGLL was not statistically significantly increased. However, for the females, the incidence of LGLL was significantly increased in all treated females (≥50 ppm). Inhalation exposure of Fischer 344 rats to glutaraldehyde did not result in an increased incidence of tumours, including LGLL.

LGLL, also known as mononuclear cell leukaemia, is an extremely common spontaneous neoplastic disease of the ageing F344 rat (Stromberg 1985, Ward *et al.* 1990; Thomas et al. 2007). Consistent features are splenomegaly, anaemia, thrombocytopenia and leukemic infiltration of the spleen, liver lung, and in an advanced stage, of several other organs. The incidence is variable but has been increasing progressively with time and can exceed 70% in controls in some studies. This compares with background incidence of less than 1% in other strains of commonly used laboratory rats (Haseman et al., 1998; Thomas et al., 2007). The incidence in F344 rats is modulated by a variety of factors not clearly related to carcinogenicity. Corn oil gavage, for example, has been shown consistently to reduce the incidence of MCL in male, but not female, controls (reviewed in Thomas et al., 2007).

The neoplastic mononuclear cells appear to be derived from large granular lymphocytes (LULs) (reviewed in Thomas et al., 2007). The tumour cell is of the NK type in most, if not all, cases. LGL leukaemia, although uncommon, does occur in humans. There are two types: T-LGL leukaemia which has a chronic course characterised by neutropenia, recurrent infections, splenomegaly and accompanying rheumatoid arthritis, and the much rarer NK-LGL leukaemia which has an acute course, more pronounced splenomegaly, and thrombocytopenia. The latter type appears to resemble more closely the disease in the F344 rat than the former. The aetiology of human LGL leukaemia is unknown. There is some evidence that viral infection may play a role but no evidence that a chemically-related increased of LGLL in the F344 rat is indicative of the potential to induce LGL leukaemia in humans.

To extrapolate results from an animal model that has a clear predisposition (high spontaneous rates) to a tumour type to humans, of which this is not the case, seems inappropriate if the mechanism(s) for LGLL formation in that strain is not understood. Although that rat strain may be useful for understanding the disease process in humans, it does not seem reasonable to use the results from that

rat strain for risk assessment purposes. There should be confirmation of a putative leukemogenic effect in the F344 rat in another strain before any conclusions are made about the use of this tumour type for human health risk assessment purposes.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Glutaraldehyde does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidising potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Glutaraldehyde has a moderate acute toxicity concern to fish and invertebrates, but is highly toxic to algae. It is of low toxicity concern to terrestrial invertebrates and plants. To birds, glutaraldehyde is moderately toxic on an acute basis and slightly toxic on a subacute dietary basis.

B. Aquatic Toxicity

Acute Studies

Table 7 lists the results of acute aquatic toxicity studies conducted on glutaraldehyde.

Table 7: Acute Aquatic Toxicity Studies on Glutaraldehyde

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Bluegill sunfish	96-hr LC_{50}	13	2	ECHA
Oncorhynchus mykiss	96-hr LC_{50}	10	2	ECHA
Daphnia magna	48-hr LC_{50}	14.87	2	ECHA
Daphnia magna	48-hr LC_{50}	14	2	ECHA
Scenedesmus subspicatus	72-hr EC_{50}	0.375 (biomass) 0.6 (growth rate) 0.025 (NOEC)	1	ECHA
Scenedesmus subspicatus	72-hr EC_{50}	0.92 (growth rate) 0.61(biomass) 0.33 (NOEC)	2	ECHA; Leung et al., 2001
Scenedesmus subspicatus	72-hr EC_{50}	0.61 (growth rate)	2	ECHA

Chronic Studies

The chronic aquatic toxicity studies conducted on glutaraldehyde are listed in Table 8.

Table 8: Chronic Aquatic Toxicity Studies on Glutaraldehyde

Test Species	Endpoint	Results (mg/L)	Kl. score	Reference
Oncorhynchus mykiss	97-day (OECD 210)	LOEC = 5 NOEC = 1.6	1	ECHA
Daphnia magna	21-day	NOEC = 5	1	ECHA

C. Terrestrial Toxicity

Table 9 lists the results of toxicity studies conducted on glutaraldehyde with earthworms, soil microorganisms, and birds.

Table 9: Terrestrial Toxicity Studies on Glutaraldehyde

Test Species (method)	Endpoint	Results	Kl. score	Reference
Earthworm *Eisenia fetida* (OECD 207)	14-d LC_{50}	>500 mg/kg soil dw	1	ECHA
Soil microorganisms* (OECD 216)	28-d EC_{50} 28-d EC_{10}	360 mg/kg soil dw 11.5 mg/kg soil dw	1	ECHA
Soil microorganisms* (OECD 217)	28-d EC_{50} 28-d EC_{10}	>593 mg/kg soil dw 1.5 mg/kg soil dw	1	ECHA
Mallard ducks	Single-dose (oral gavage) LC_{50}	206 mg/kg	2	ECHA
Mallard ducks	5-d (dietary) NOEC	>2,500 ppm	1	ECHA

*organic carbon content of soil = 1.34% dry weight

Glutaraldehyde has also been evaluated in a terrestrial plants test: seedling emergence and seedling growth test (OECD TG 208). The test material contained 48.9% glutaraldehyde. The results are as follows:

Avena sativa (oats): 19-day EC_{50} value is >1,000 mg/kg soil dry weight based on emergence rate, dry weight and shoot length. The NOECs for *Avena sativa* (oats) were $\geq$1,000 mg/kg dry weight on all three parameters tested

Brassica napus (rapeseed): 19-day EC_{50} is >1,000 mg/kg soil dry weight based on emergence rate and shoot length and 994 mg/kg soil dry weight based on dry weight. The NOECs were $\geq$1,000, 500, and 250 mg/kg soil dry weight for emergence rate, dry matter, and shoot length, respectively.

Vicia sativa (vetch): 19-day EC_{50} is >1,000 mg/kg soil dry weight based on emergence rate and shoot length, and 901 mg/kg soil dry weight based on dry weight. The NOECs were $\geq$1,000, 125, and 125 mg/kg soil dry weight for emergence rate, dry matter, and shoot length, respectively (ECHA). [Kl. score = 1]

D. Calculation of PNEC

The PNEC calculations for glutaraldehyde follow the methodology discussed in DEWHA (2009).

PNECwater

Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (10 mg/L), *Daphnia* (14 mg/L), and algae (0.375 mg/L). Results from chronic studies are also available for all three trophic levels, with the lowest NOEC being 0.025 mg/L for algae. On the basis that the data consists of short-term and long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported NOEC of 0.025 mg/L for algae. The $PNEC_{water}$ is 0.0025 mg/L.

PNECsediment

There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 0.006 mg/kg wet weight.

The calculations are as follows:

$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$
$= (3.1/1280) \times 1000 \times 0.0025$
$= 0.006$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$K_{sed\text{-}water} = 0.8 + [0.2 \times Kp_{sed}/1000 \times BD_{solid}]$
$= 0.8 + [(0.2 \times 4.8)/1000 \times 2400]$
$= 3.1$

Where:
Kpsed = solid-water partition coefficient (L/kg).
BDsolid = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$Kp_{sed} = K_{0c} \times f_{oc}$
$= 120 \times 0.04$
$= 4.8$

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for glutaraldehyde in sediment is 120.
F_{oc} = fraction of organic carbon suspended sediment = 0.04 [default].

PNECsoil

Experimental results are available for three trophic level. An acute LC_{50} value is available for earthworms (>500 mg/kg). Results from long-term studies are available for two trophic levels, with the lowest NOEC or EC_{10} being 1.5 mg/kg soil dry weight for soil organisms.

The EC_{10} value is corrected for bioavailability of glutaraldehyde in soil by normalising the organic carbon content in the soil using the following equation:

$EC_{10(std)} = EC_{10(exp)} \times Fom_{soil(std)}/Fom_{soil(exp)}$

Where:
$Fom_{soil(std)}$ = 1% (www.scew.gov.au/node/941)
$Fom_{soil(exp)}$ = 1.34% (see Table 9)

$EC_{10(std)}$ = 1.5 mg/kg x 1/1.34 = 1.12 mg/kg

On the basis that the data consists of one short-term from one trophic level and two long-term results from two additional levels, an assessment factor of 50 has been applied to the lowest reported long-

term EC_{10} of 1.12 mg/kg soil dry weight [corrected for organic carbon content] for soil organisms. The $PNEC_{soil}$ is 0.02 mg/kg soil dry weight.

VIII. PBT ASSESSMENT

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Glutaraldehyde is readily biodegradable and thus does not meet the screening criteria for persistence.

The log K_{ow} for glutaraldehyde at different pH values ranges from -0.36 to -0.80. Thus, glutaraldehyde does not meet the screening criteria for bioaccumulation.

The lowest NOEC value from chronic aquatic toxicity studies is <0.1 mg/L. Thus, glutaraldehyde meets the screening criteria for toxicity.

The overall conclusion is that glutaraldehyde is not a PBT substance.

IX. CLASSIFICATION AND LABELLING

A. Classification

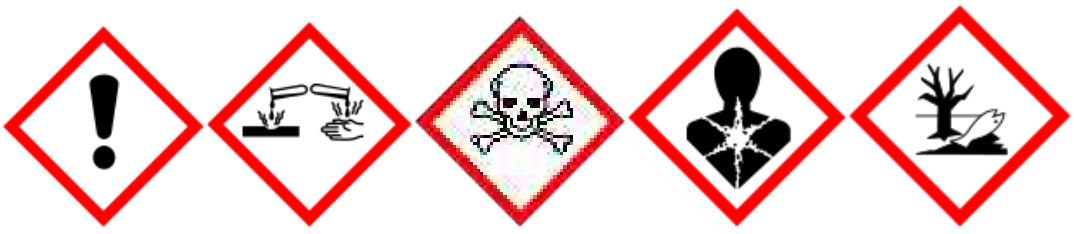
Acute Toxicity Category 3 [oral]
Acute Toxicity Category 2 [inhalation]
Skin Corrosion Category 1B
Eye Damage Category 1
Respiratory Sensitiser 1A
Skin Sensitiser 1A
STOT Single Exposure Category 3 [respiratory irritation]
Aquatic Acute Category 1
Aquatic Chronic Category 2

The appropriate hazard statements corresponding the GHS classifications are to be added to the SDS, including the non-GHS hazard statement “AUH071: Corrosive to the Respiratory Tract”.

B. Labelling

Danger

C. Pictograms



X. SAFETY AND HANDLING

A. First Aid

First aid information was obtained from the ECHA REACH database (ECHA).

Eye Contact

Wash immediately and continuously with flowing water for at least 30 minutes. Remove contact lenses after the first 5 minutes and continue washing. Obtain prompt medical consultation, preferably from an ophthalmologist. Eye wash fountain should be located in immediate work area.

Skin Contact

Take off contaminated clothing. Wash skin with soap and plenty of water for 15-20 minutes. Call a poison control centre or doctor for treatment advice. Wash clothing before reuse. Shoes and other leather items which cannot be decontaminated should be disposed of properly. Safety shower should be located in immediate work area.

Inhalation

Move person to fresh air. If a person is not breathing, call an emergency responder or ambulance, then give artificial respiration; if by mouth to mouth use rescuer protection (pocket mask, etc.). Call a poison control centre or doctor for treatment advice. If breathing is difficult, oxygen should be administered by qualified personnel.

Ingestion

If the person is fully alert and cooperative, have the person rinse mouth with plenty of water. In cases of ingestion have the person drink 4 to 10 ounces (120-300 mL) of water. Do not induce vomiting. Do not attempt mouth rinse if the person has respiratory distress, altered mental status, or nausea and vomiting. Call a physician and/or transport to an emergency facility immediately. See Note to Physician. Seek medical attention immediately.

Notes to Physician

Maintain adequate ventilation and oxygenation of the patient. May cause asthma-like (reactive airways) symptoms. Bronchodilators, expectorants, antitussives and corticosteroids may be of help. Glutaraldehyde may transiently worsen reversible airways obstruction including asthma or reactive airways disease. Chemical eye burns may require extended irrigation. Obtain prompt consultation, preferably from an ophthalmologist. If the burn is present, treat as any thermal burn, after decontamination. Due to irritant properties, swallowing may result in burns/ulceration of mouth, stomach and lower gastrointestinal tract with subsequent stricture. Aspiration of vomitus may cause lung injury. Suggest endotracheal/oesophagal control if lavage is done. Probable mucosal damage may contraindicate the use of gastric lavage. Inhalation of vapours may result in skin sensitization. In sensitised individuals, re-exposure to very small amounts of vapour, mist, or liquid may cause a severe allergic skin reaction. No specific antidote. Treatment of exposure should be directed at the control of symptoms and the clinical condition of the patient. Have the Safety Data Sheet, and if available, the product container or label with you when calling a poison control centre or doctor, or going for treatment.

Medical Conditions Aggravated by Exposure

Excessive exposure may aggravate pre-existing asthma and other respiratory disorders (e.g. emphysema, bronchitis, reactive airways dysfunction syndrome).

Emergency Personnel Protection

First Aid responders should pay attention to self-protection and use the recommended protective clothing (chemical resistant gloves, splash protection). If the potential for exposure exists, refer to Section 8 of the Safety Data Sheet for specific personal protective equipment.

B. Fire Fighting Information

Firefighting information was obtained from the ECHA REACH database (ECHA).

Extinguishing Media

Use water fog, carbon dioxide, dry chemical or foam to extinguish combustible residues of this product

Specific Exposure Hazards

This material will not burn until the water has evaporated. Residue can burn. Some components of this product may decompose under fire conditions. The smoke may contain unidentified toxic and/or irritating compounds. Combustion products may include and are not limited to carbon monoxide and carbon dioxide.

Special Protective Equipment for Firefighters

Wear positive-pressure self-contained breathing apparatus (SCBA) and protective firefighting clothing (includes firefighting helmet, coat, trousers, boots, and gloves). Avoid contact with this material during firefighting operations. If contact is likely, change to full chemical resistant firefighting clothing with self-contained breathing apparatus. If this is not available, wear full chemical resistant clothing with self-contained breathing apparatus and fight the fire from a remote location.

C. Accidental Release Measures

Information on accidental release measures was obtained from the ECHA REACH database (ECHA).

Personal Precautions

Use appropriate safety equipment. Evacuate area. Keep upwind of the spill. Ventilate area of leak or spill. Only trained and properly protected personnel must be involved in clean-up operations.

Environmental Precautions

Spills or discharge to natural waterways is likely to kill aquatic organisms. Prevent from entering into soil, ditches, sewers, waterways and/or groundwater.

Steps to be Taken if Material is Released or Spilt

Avoid making contact with spilt material; glutaraldehyde will be absorbed by most shoes. Always wear the correct protective equipment, consisting of splash-proof mono-goggles, or both safety glasses with side shields and a wraparound full-face shield, appropriate gloves and protective clothing. A self-contained breathing apparatus or respirator and absorbents may be necessary, depending on the size of the spill and the adequacy of ventilation. Small spills: Wear the correct protective equipment and cover the liquid with absorbent material. Collect and seal the material and the dirt that has absorbed the spilt material in polyethylene bags and place in a drum for transit to an

approved disposal site. Rinse away the remaining spilt material with water to reduce odour, and discharge the rinsate into a municipal or industrial sewer. Large spills: In the case of nasal and respiratory irritation, vacate the room immediately. Personnel cleaning up should be trained and equipped with a self-contained breathing apparatus, or an officially approved or certified full-face respirator equipped with an organic vapour cartridge, gloves, and clothing impervious to glutaraldehyde, including rubber boots or shoe protection. Deactivate with sodium bisulphite (2-3 parts [by weight] per part of active substance glutaraldehyde), collect the neutralised liquid and place in a drum for transit to an approved disposal site.

D. Storage and Handling

Information on storage and handling was obtained from the ECHA REACH database (ECHA).

General Handling

Do not get in eyes, on skin, on clothing. Avoid breathing vapour. Do not swallow. Keep container closed. Use with adequate ventilation. Wear goggles, protective clothing and butyl or nitrile gloves. Wash thoroughly with soap and water after handling. Remove contaminated clothing and wash before reuse.

Other Handling Precautions

Do not spray or aerosolize the undiluted form of the product. Full personal protective equipment (including skin covering and full-face SCBA respirator) is required for dilutions or mixtures of the product used in a spray application.

Storage

Do not store in: Aluminium. Carbon steel. Copper. Mild steel. Iron. Shelf life: Use within 12 Months.

E. Exposure Controls / Personal Protection

Occupational Exposure Standards

The workplace exposure standard for glutaraldehyde in Australia is 0.1 ppm (0.41 mg/m^3) as a peak limitation, with a sensitisation notation. A peak limitation is defined by Safe Work Australia as a maximum or peak airborne concentration of a substance determined over the shortest analytically practicable period of time which does not exceed 15 minutes.

The information below on exposure controls and personal protection was obtained from the Halliburton Safety Data Sheet (SDS) on ALDACIDE® G ANTIMICROBIAL (revision date: 11-Dec-2014).

Engineering Controls

Use in a well-ventilated area. Local exhaust ventilation should be used in areas without good cross ventilation. If vapours are strong enough to be irritating to the nose or eyes, the TLV is probably being exceeded, and special ventilation or respiratory protection may be required.

Personal Protection Equipment

Respiratory Protection: If engineering controls and work practices cannot keep exposure below occupational exposure limits or if exposure is unknown, wear an NIOSH-certified, European Standard EN 149, AS/NZS 1715:2009, or equivalent respirator when using this product. Selection of and

instruction on using all personal protective equipment, including respirators, should be performed by an Industrial Hygienist or other qualified professional. Full Facepiece Respirator with Organic vapour cartridge with particulate pre-filter.

Hand Protection: Chemical-resistant protective gloves (EN 374) Suitable materials for longer, direct contact (recommended: protection index 6, corresponding to > 480-minute permeation time as per EN 374): Butyl rubber gloves. (>= 0.7 mm thickness) This information is based on literature references and on information provided by glove manufacturers or is derived by analogy with similar substances. Please note that in practice the working life of chemical-resistant protective gloves may be considerably shorter than the permeation time determined in accordance with EN 374 as a result of the many influencing factors (e.g. temperature). If signs of wear and tear are noticed, then the gloves should be replaced. Manufacturer's directions for use should be observed because of the great diversity of types.

Skin Protection: Butyl coated apron or clothing.

Eye protection: Splash proof chemical mono-goggles or safety glasses with side shield in conjunction with a face shield. Do NOT wear contact lenses.

Other Precautions: Eyewash fountains and safety showers must be easily accessible.

F. Transport Information

For aqueous glutaraldehyde solutions at a concentration that is corrosive (i.e., 30% and higher):

Australia Dangerous Goods

UN3265, Corrosive Liquid, Acidic, Organic, N.O.S. (Contains Glutaraldehyde)
Class 8
Packing Group III

Environmentally Hazardous Substance

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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XIV. ACRONYMS AND GLOSSARY

°C	degrees Celsius
ADWG	Australian Drinking Water Guidelines
ALT	alanine aminotransferase
AST	aspartate aminotransferase
DEWHA	Department of the Environment, Water, Heritage and the Arts
ECHA	European Chemicals Agency
EU	European Union
GHS	Globally Harmonised System of Classification and Labelling of Chemicals
HHRA	enHealth Human Risk Assessment
IUPAC	International Union of Pure and Applied Chemistry
kg/m^3	kilogrammes per cubic metre
LGLL	large granular lymphocytic leukaemia
LOAEL	lowest observed adverse effect level
LULs	large granular lymphocytes
mg/kg	milligrams per kilogram
mg/L	milligrammes per litre
mg/m^3	milligrammes per cubic metre
NICNAS	The National Industrial Chemicals Notification and Assessment Scheme
NOAEL	no observed adverse effect level
NOEC	no observed effective concentration
OECD	Organisation for Economic Co-operation and Development
PBT	Persistent, Bioaccumulative and Toxic
ppm	parts per million
RfD	oral Reference Dose

SCE	sister chromatid exchange
SDS	Material Safety Data Sheet
SIDS	Screening Information Data Set
SMILES	simplified molecular-input line-entry system
UDS	Unscheduled DNA Synthesis
UVCB	unknown or variable composition, complex reaction product, or biological origin

GUAR GUM

This dossier on guar gum does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of guar gum in its use in drilling muds and hydraulic fracturing fluids. Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name: Guar Gum

CAS RN: 9000-30-0

Molecular weight: 200,000 to 300,000 daltons (Glickman, 1969)

Guar gum (CAS No. 9000-30-0) is a resinous material derived from milled endosperm from guar beans of the legume *Cyamopsis tetragonolobus*. Structurally, it is a galactomannan (high molecular weight carbohydrate polymer) consisting of a main chain of D-mannose with a side chain of D-galactose at approximately every second mannose unit. The mannose units are β-(l-4) linked, and the single D-galactose units are joined to the main chain by α-(1-6) linkages.

II. PHYSICO-CHEMICAL PROPERTIES

It is a beige powder.

III. ENVIRONMENTAL FATE PROPERTIES

Guar gum is a carbohydrate polymer consisting of D-mannose and D-galactose sugars from the guar plant or cluster bean. It is expected to be readily biodegradable and not bioaccumulate.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Guar gum is exhibits very low acute toxicity by the oral route. It is non-irritating to the skin and minimally irritating to the eyes. Repeated dose toxicity studies in rats showed minimal toxicity from exposure to guar gum in the diet. Guar gum is not genotoxic or carcinogenic. Oral exposure to guar gum did not affect fertility in rats; nor was there any indication of developmental toxicity in either rats or mice.

B. Acute Toxicity

The oral LD_{50} in rats was reported to be 7,060 mg/kg (Graham *et al.*, 1981). [Kl. score = 2]

C. Irritation

Guar gum is non-irritating to the skin and minimally irritating to the eyes (McCarty *et al.*, 1990).

D. Sensitization

There were reports of workers sensitized to guar gum in a carpet-manufacturing plant. Immediate skin reactivity to guar gum was observed in 8 out of 162 employees, and 11 of 133 participants had serum IgE antibodies to guar gum. These findings are difficult to interpret since carbohydrates, such as guar gum, are generally not associated with allergenicity (Maio, 1986).

E. Repeated Dose Toxicity

Oral

Male and female Osborne-Mendel rats were given diets containing 0, 1, 2, 4, 7.5, or 15% guar gum for 91 days. The average daily intakes are: 0, 580, 1,187, 2,375, 4,561, and 10,301 mg/kg-day for males; and 0, 691, 1,362, 2,762, 5,770, and 13,433 mg/kg-day for females. There were no deaths during the study. Body weights were significantly decreased in the $\geq$1% females and the $\geq$7.5% males; biologically significant changes (>10%) were seen in the 7.5% females and the 15% males. Liver weights were decreased in the $\geq$1% dietary groups. Kidney weights were decreased in the $\geq$7.5% dietary groups and were borderline significant in the 4% group. The 15% group males had reduced bone marrow cellularity; although the level was within normal limits, several of the rats were at the lower end of the normal range. The NOAEL for this study is 4% in the diet or 2,762 mg/kg-day based on reduced body weights in the female rats (Graham *et al.*, 1981). [Kl. score = 2]

Male and female F344 rats and $B6C3F_1$ mice were given diets containing 0, 6,300, 12,500, 25,000, 50,000 or 100,000 ppm guar gum for 13 weeks. Mean body weights were decreased in the 100,000 ppm male rats and in the $\geq$50,000 ppm female mice. A dose-related decrease in feed consumption was observed for male and female rats; male and female mice were comparable or higher than that of controls. There were no compound-related clinical signs or histopathological effects. The NOAELs for this study is 50,000 and 25,000 ppm for rats and mice, respectively. Using the fraction of body weight that rats and mice consume per day as food (0.05 and 0.13, respectively; U.S. EPA), the NOAELs corresponds to 2,500 mg/kg-day for rats and 3,250 mg/kg-day for mice (NTP, 1982). [Kl. score = 2]

Male and female F344 rats and B6C3F$_1$ mice were given diets containing 0, 25,000 ppm or 50,000 ppm guar gum for 103 weeks. Mean body weights of the high-dose females were lower than those of the controls after week 20 for mice and week 40 for rats. No compound-related clinical signs or adverse effects on survival were observed. Feed consumption by dosed rats and mice of either sex was lower than that of controls. There were no non-neoplastic histopathological effects in either rats or mice that were treatment-related. The NOAEL for both rats and mice is 25,000 ppm. Using the fraction of body weight that rats and mice consume per day as food (0.05 and 0.13, respectively; U.S. EPA), the NOAELs corresponds to 1,250 mg/kg-day for rats and 3,250 mg/kg-day for mice (NTP, 1982). [Kl. score = 2]

Inhalation

No studies are available.

Dermal

No studies are available.

F. Genotoxicity

In Vitro Studies

Guar gum was not mutagenic to *S. typhimurium* strains TA 97, TA 98, TA 100, TA 102, TA 104, TA 1535, TA 1537, and TA1538 in the presence or absence of metabolic activation (Zeiger *et al.*, 1992). [Kl. score = 2]

In Vivo Studies

Guar gum was inactive in a rat bone marrow cytogenetic assay at doses up to 5,000 mg/kg (CIR, 2015). [Kl. score = 4]

In a rat dominant lethal mutation test, rats were dosed by oral gavage with either a single or multiple doses of up to 5,000 mg/kg guar gum. There was no indication of a mutagenic effect by guar gum (Lee *et al.*, 1981). [Kl. score = 2]

G. Carcinogenicity

Male and female F344 rats were given diets containing 0, 25,000 ppm, or 50,000 ppm guar gum for 103 weeks in a NTP chronic bioassay. There were increased incidences of adenomas of the pituitary in male rats and pheochromocytomas of the adrenal medulla in female rats that were statistically significant, but these differences were considered to be unrelated to guar gum administration. When pituitary adenomas or carcinomas and when pheochromocytomas or malignant pheochromocytomas were combined, the statistical

differences disappeared. NTP concluded that, under conditions of this bioassay, guar gum was not carcinogenic for F344 rats (NTP, 1982). [Kl. score = 2]

Male and female $B6C3F_1$ mice were given diets containing 0, 25,000, or 50,000 ppm guar gum for 103 weeks in a NTP chronic bioassay. Hepatocellular carcinomas occurred in treated male mice at incidences that were significantly lower than that in controls. The combined incidence of male mice with either hepatocellular adenomas or carcinomas was also significantly lower in the high-dose group. NTP concluded that, under conditions of this bioassay, guar gum was not carcinogenic for $B6C3F_1$ mice (NTP, 1982). [Kl. score = 2]

H. Reproductive Toxicity

Oral

Male and female Osborne-Mendel rats were fed diets containing 0, 1, 3, 4, 7.5, or 15% guar gum for 13 weeks before mating, during mating and throughout gestation. The daily intakes for the female rats during gestation were 0, 700, 1,400, 2,700, 5,200, or 11,800 mg/kg-day. Fertility was unaffected by treatment. There were slightly fewer corpora lutea and implantations in the 15% dietary group, but implantation efficiency was unaffected. The NOAEL for reproductive toxicity is 5,200 mg/kg-day (Collins *et al.*, 1987). [Kl. score = 2]

I. Developmental Toxicity

Oral

Male and female Osborne-Mendel rats were fed diets containing 0, 1, 3, 4, 7.5, or 15% guar gum for 13 weeks before mating, during mating and throughout gestation. The daily intake for the female rats during gestation were 0, 700, 1,400, 2,700, 5,200, or 11,800 mg/kg-day. There were no deaths during the study. In the 15% group, the number of viable fetuses per litter were slightly reduced, but was not statistically significantly different from controls. The authors indicated that the reduction may have been an effect of the decreased number of corpora lutea because the number of resorptions was unaffected in this treatment group. There was no treatment-related effect on fetal development or sex distribution, and there were no teratogenic effects (Collins *et al.*, 1987). [Kl. score = 2]

Pregnant female rats were dosed by oral gavage with 0, 9, 42, 200, or 900 mg/kg guar gum on GD 6 to 15. There was no maternal or developmental toxicity at any dose level. The NOAEL for maternal and developmental toxicity is 900 mg/kg-day (FDRL, 1973). [Kl. score = 2]

Pregnant female CD-1 mice were dosed by oral gavage with 0, 8, 37, 170, or 800 mg/kg

guar gum on GD 6 to 15. A significant number of deaths (6 out of 29) occurred in the 800 mg/kg dose group. There were indications of maternal toxicity in the surviving high-dose dams. There was no developmental toxicity at any dose level. The NOAELs for maternal and developmental toxicity are 170 and 800 mg/kg-day, respectively (FDRL, 1973). [Kl. score = 2]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for guar gum follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

In a two-year NTP chronic bioassay, female rats and mice given 50,000 ppm guar gum in their feed had lower body weights. There were no treatment-related non-neoplastic lesions in either rats or mice. The NOAEL for this study is 25,000 ppm for rats and mice, which corresponds to 1,250 mg/kg-day for rats and 3,250 mg/kg-day for mice.

The NOAEL of 1,250 mg/kg-day will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 1,250/(10 x 10 x 1 x 1 x 1) = 1,250/100 = 13 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (13 x 70 x 0.1)/2 = 46 mg/L

B. Cancer

Guar gum was not carcinogenic to rats or mice in two-year dietary studies. Thus a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Guar gum does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Guar gum is a polysaccharide polymer. It has low acute toxicity concern for fish, but exhibits medium or possibly high acute toxicity to invertebrates (*Daphnia*).

B. Aquatic Toxicity

The 96-hour LC_{50} for *Oncorhynchus mykiss* is 218 mg/L (Biesinger *et al.*, 1976). [Kl. score = 2]

The 48-hour and 96-hour LC_{50} values for *Daphnia magna* are 42 mg/L and <6.2 mg/L, respectively (Biesinger *et al.*, 1976). [Kl. score = 2]

Chronic Studies

No studies are available.

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for guar gum follow the methodology discussed in DEWHA (2009).

PNEC water
Experimental results are available for two trophic levels. The acute $E(L)C_{50}$ values are available for fish (218 mg/L) and *Daphnia* (<6.2 mg/L). On the basis that the data consists of short-term results from two trophic levels, an assessment factor of 1,000 has been applied to the lowest reported $E(L)C_{50}$ value of 6.2 mg/L for *Daphnia*. The $PNEC_{water}$ is 0.006 mg/L.

PNEC sediment
No experimental toxicity data on sediment organisms are available. The K_{ow} and K_{oc} of guar gum cannot be calculated using EPISUITE because the molecular weight of guar gum greatly exceeds the limit of 1,000. Thus, the equilibrium partition method cannot be used to determine a $PNEC_{sediment}$ and the assessment of this compartment will be covered by the aquatic assessment.

PNEC soil
No experimental toxicity data on soil organisms are available. The K_{ow} and K_{oc} of guar gum cannot be calculated using EPISUITE because the molecular weight of guar gum greatly exceeds the limit of 1,000. Thus, the equilibrium partition method cannot be used to determine a $PNEC_{soil}$ and the assessment of this compartment will be covered by the aquatic assessment.

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Guar gum is a naturally occurring polysaccharide from the guar plant or cluster bean; it expected to be readily biodegradable. Thus it is not expected to meet the screening criteria for persistence.

The molecular weight of guar gum ranges from 200,000 to 300,000 daltons and is water-soluble. Thus guar gum is not expected to meet the criteria for bioaccumulation.

The 96-hour LC_{50} value for *Daphnia* is <6.2 mg/L. Thus guar gum may potentially meet the screening criteria for toxicity.

The overall conclusion is that guar gum is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

[Acute Aquatic Toxicity Category 2]

B. Labelling

No signal word.

C. Pictogram

None.

X. SAFETY AND HANDLING

Eye Contact
In case of contact, immediately flush eyes with plenty of water for at least 15 minutes.

Skin Contact
Remove contaminated clothing. Wash thoroughly with soap and water.

Inhalation
If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Ingestion
Rinse mouth with water and then drink plenty of water. Never give anything by mouth to an unconscious person.

Notes to Physician
May cause asthma-like (reactive airways) symptoms.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: carbon monoxide, carbon dioxide.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus for fire fighting.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Avoid dust formation.

Environmental Precautions
No special environmental precautions required.

Steps to be Taken if Material is Released or Spilled
Sweep up and dispose in suitable, closed containers.

D. STORAGE AND HANDLING

General Handling
Avoid creating or inhaling dust.

Storage
Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
Workplace Australia has not established an occupational exposure standard specifically for guar gum.

Engineering Controls
Ensure adequate ventilation.

Personal Protection Equipment

Respiratory Protection:
Respiratory protection is not required.

Hand Protection:
Handle with gloves.

Skin *Protection*:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Safety glasses with side-shields.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible.

F. TRANSPORT INFORMATION

Guar gum is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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HEMICELLULASE ENZYME

This dossier on hemicellulase enzyme does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of hemicellulase enzyme in its use in drilling muds and hydraulic fracturing fluids. The information presented in this dossier was obtained primarily from the Human & Environmental Risk Assessment on Ingredients of European Household Cleaning Products: Alcohol Ethoxylates (HERA, 2005), and from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name: Not applicable

CAS RN: 9025-56-3

Molecular weight: 20,000 to 80,000 daltons (based on cellulase enzymes)

Synonyms: Hemicellulases; hemicellulase enzymes

Hemicellulases are a group of enzymes that break down hemicellulose, which are polysaccharides that are present in cell walls of all terrestrial plants. These polysaccharides have a β-(1→4)-linked backbone and are composed of pentoses (xylose, arabinoses), hexoses (mannose, glucose, galactose), and sugar acids. Unlike cellulose which are polysaccharides consisting of linear chains of several hundred to over ten thousand β-(1→4) linked D-glucoses, hemicellulases are not chemically homogeneous. The best characterized hemicellulases are the 1,4- β -D-xylanases and, in particular, those derived from fungal sources presumably because their substrates, xylans, constitute the largest proportion of hemicelluloses in pasture plants.

No information was found on hemicellulase enzyme; however, because of their similarity, information will be read-across from cellulase enzymes (HERA, 2005). Cellulases cleave the ß-1,4-glycosidic bonds in cellulose, and are used in the pulp and paper industry, the textile industry, and in detergents to remove deposits and stains. The molecular weight of cellulase is 20,000 to 80,000 daltons.

Enzymes are catalytic proteins or polypeptides and consist of amino acid residues coupled via peptide bonds. They are primarily characterized by their biocatalytic or enzymatic activity. There is a broad range of detergent cellulases used both from fungal as well as from bacterial origin; all are characterized by ß-1,4-endoglucanase activity. For the purposes of risk assessment, the structure of hemicellulases would be expected to be similar to that of cellulases, given that hemicellulases and cellulases are both enzyme families that hydrolyze polysaccharides, although differing in their

substrates. Thus, the toxicity data on cellulases will be used as read-across to hemicellulases.

II. PHYSICO-CHEMICAL PROPERTIES

Cellulases, as pure enzyme, are white crystals or powder (HERA, 2005).

An octanol-water partition coefficient (K_{ow}) for cellulases is not available. However, the log K_{ow} of glucoamylase, which cleaves 1,4–α-D-glycosidic linkages, was experimentally determined to be <1.3 at 20ºC (ECHA). [Kl. score = 1]

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Cellulases are readily biodegradable; they are not expected to bioaccumulate or adsorb to soil.

B. Biodegradation

A cellulase enzyme was readily biodegradable in an OECD 301F test. There was ~10% degradation after one day; ~60% after 5 days; and 129% after 28 days (ECHA). [Kl. score = 1]

Three different cellulase enzymes were considered readily biodegradable based on the results of OECD 301C and 301E tests (HERA, 2005) [Kl. scores = 1]. In an OECD 301E test, there was 84% DOC removal of the enzyme Carezyme after 28 days. In another OECD 301E test, there was 92% DOC removal of the enzyme Clazinase® after 28 days. In an OECD 301C test, BOD/COD was 78% after 28 days (HERA, 2005).

C. Environmental Distribution

<u>Adsorption/desorption</u>

Proteins, such as cellulase enzyme, would not be expected to adsorb to soil. HERA (2005) listed a K_{oc} value of <1.3 for detergent amylases, cellulases, and lipases that was calculated according to the EU Technical Guidance Document (EC, 2003). No further information was provided. The K_{oc} value of 1.3 will be used to calculate the PNEC values for sediment and soil using the equilibrium partitioning method (see section XII. D.).

D. Bioaccumulation

No bioaccumulation studies have been conducted on cellulase enzymes. Cellulase enzymes are not expected to bioaccumulate due to their high molecular weight and their octanol-water partition coefficient (log K_{ow} is <1.3). Moreover, cellulases are rapidly biotransformation in an organism to lower molecular-weight protein fragments by proteolytic enzymes (proteases), and eventually to the basic amino acids by peptidase enzymes.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Cellulase enzyme has low acute toxicity by the oral, dermal, or inhalation routes. It is not askin or eye irritant; and it is not a skin sensitizer. Although there are no specific studies on cellulase enzyme, a number of enzymes from bacteria, plants, and fungi have the potential to cause occupational respiratory allergy, even asthma. Minimal toxicity was seen in rats given repeated oral doses of cellulase enzyme either by gavage or in their diet for up to 13 weeks. Cellulase enzyme is not genotoxic. There are no carcinogenicity, reproductive, or developmental toxicity studies on cellulase enzyme.

B. Acute Toxicity

The oral LD_{50} of a cellulase enzyme was calculated to be 8,000 mg/kg for mice and >10,000 mg/kg for rats (HERA, 2005) [Kl. score = 4]. The oral LD_{50} in rats for a cellulase enzyme was >2,880 mg/kg, measured as total organic soilds (ECHA) [Kl. score = 1].

The inhalation LC_{50} of a cellulase enzyme in rats was >3.48 mg/L. The mass mean aerodynamic diameter (MMAD) was 7.8 μm with a geometric standard deviation of 2.1 μm (HERA, 2005) [Kl. score = 4]. The 4-hour inhalation LC_{50} of a cellular enzyme in rats was >4.86 mg/L, which corresponds to 4.44 mg total organic solids/L). The respirable fraction was 80% (44.8% of the particles were <6 μm (ECHA) [Kl. score = 1].

No dermal toxicity studies are available.

C. Irritation

Application of 0.5 ml of a cellulase enzyme to the skin of rabbits for 4 hours under semi-occlusive conditions was minimally irritating (ECHA). [Kl. score = 1]

Instillation of 0.1 ml of a cellulase enzyme to the eyes of rabbits was non-irritating (ECHA). [Kl. score = 1]

D. Sensitization

A cellulase enzyme was not a skin sensitizer to guinea pigs in a Buehler sensitization test (HERA, 2005). [Kl. score = 2]

Although there are no specific studies on cellulase enzyme, a number of enzymes from bacteria, plants, and fungi have the potential to cause occupational respiratory allergy, even asthma (Basketter et al., 2015).

E. Repeated Dose Toxicity

Oral

Male and female rats were dosed by oral gavage with 0, 300, 1,000 or 3,000 mg/kg of a cellulase enzyme for 4 weeks. There were no treatment-related clinical signs, but a slight dose-related increase in body weight gain (approx. 7%) was seen in the males. No treatment-related changes were noted in the hematology or clinical chemistry. There were no gross or histopathologic changes that were considered treatment-related. The NOAEL is 3,000 mg/kg-day (HERA, 2005). [Kl. score = 2]

Male and female rats were fed a diet containing 0, 120, 600 or 3,000 mg/kg of a cellulase enzyme for 13 weeks. There were no treatment-related clinical signs. A reduction in body weight gain was seen in both sexes at the 3,000 mg/kg dose level (10% in males and 20% in females). A slight reduction in food consumption was also noted for the 3,000 mg/kg rats. Alkaline phosphatase was increased in the 600 and 3,000 mg/kg females in a dose-dependent manner. There were no gross or histopathologic changes that were considered treatment-related. The NOAEL for this study is 600 mg/kg-day (HERA, 2005). [Kl. score = 2]

Male and female Wistar rats were dosed by oral gavage with 0, 100, 300, or 1,000 mg/kg β-glucanase (measured as total organic solids) for 13 weeks. There were no treatment-related effects on mortality, clinical signs, body weights, food or water consumption, ophthalmoscopic findings, hematology, clinical chemistry, neurobehavior (functional observation battery), organ weights, gross or microscopic pathology. The NOAEL is 1,000 mg/kg-day expressed as total organic solids (ECHA). [Kl. score = 1]

Inhalation

No studies are available.

Dermal

No studies are available.

F. Genotoxicity

The *in vitro* genotoxicity studies on cellulase enzymes are shown in Table 1.

Table 1: *In vitro* Genotoxicity Studies on Cellulase Enzyme

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* and *E. coli* strains)	-	-	1	ECHA
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	HERA (2005)
Chromosomal aberration (human lymphocytes)	-	-	1	ECHA

*+, positive; -, negative

In vivo Studies

Male and female SD rats were dosed by oral gavage with 0, 300, 1,000, or 3,000 mg/kg of a cellulase enzyme for five consecutive days. Chromosomal aberrations, excluding gaps, were not significantly increased at any dose level compared to controls. Chromosomal aberrations including gaps were increased in females from all dose groups, but there was no clear dose-response relationship and the difference was only statistically significant at 3,000 mg/kg. There was no treatment-related effect on the mitotic capacity of the bone marrow. It was concluded that the cellular enzyme was not genotoxic under the conditions of the assay (HERA, 2005). [Kl. score = 2]

G. Carcinogenicity

No studies are available.

H. Reproductive Toxicity

No studies are available.

I. Developmental Toxicity

No studies are available.

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for hemicellulase enzyme follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

There are two 13-week rat studies on cellulase enzyme. In a dietary study, rats were given 0, 120, 600, or 3,000 mg/kg cellulase enzyme. The LOAEL for this study is 3,000 mg/kg based on significant reduction in body weight gain in both sexes; the NOAEL is 600 mg/kg-day (HERA, 2005). In an oral gavage study, rats were dosed with 0, 100, 300, or 1,000 mg/kg β-glucanase. There were no treatment-related effects and the NOAEL for this study is 1,000 mg/kg-day, the highest dose tested (ECHA).

The NOAEL of 1,000 mg/kg-day from the 13-week rat oral gavage study will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 3
UF_D (database uncertainty) = 1

Oral RfD = 1,000/(10 x 10 x 1 x 3 x 1) = 1,000/300 = 3 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (1.0 x 70 x 0.1)/2 = 12 mg/L

B. Cancer

There are no carcinogenicity studies on cellulase enzyme. Thus, a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Hemicellulase and cellulase enzymes do not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Cellulase enzyme has a moderate acute toxicity concern to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

Table 2 lists the results of acute aquatic toxicity studies on cellulase enzyme.

Table 2: Acute Aquatic Toxicity Studies on Cellulase Enzyme

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Oncorhynchus mykiss	96-h LC_{50}	>100* >52.1**	1	ECHA
Brachydanio rerio	96-h LC_{50}	330*	4	HERA (2005)

Daphnia magna	48-h EC_{50}	>100* >52.1**	1	ECHA
Daphnia magna	48-h EC_{50}	>1,000**	4	HERA (2005)
Daphnia magna	48-h EC_{50}	1,000**	4	HERA (2005)
Pseudokirchneriella subcapitata	72-h EC_{50}	>100* >52.1**	1	ECHA
Scenedesmus subspicatus	72-h EC_{50}	>1,000**	4	HERA (2005)

*Total organic solids.
**Active enzyme protein.

Chronic Studies

No studies are available.

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for cellulase enzyme follow the methodology discussed in DEWHA (2009).

PNEC water
Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (>52.1 mg aep/L), *Daphnia* (>52.1 mg aep/L), and algae (>52.1 mg aep/L). No chronic toxicity studies are available. On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 100 has been applied to the lowest reported $E(L)C_{50}$ value of 52.1 mg aep/L for fish. The $PNEC_{aquatic}$ is 0.5 mg/L.

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 0.3 mg/kg sediment wet weight.

The calculations are as follows:

$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$
$= (0.825/1280) \times 1000 \times 0.5$
$= 0.3$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$K_{sed\text{-}water} = 0.8 + [0.2 \times Kp_{sed}/1000 \times BD_{solid}]$
$= 0.8 + [0.2 \times 0.052/1000 \times 2400]$
$= 0.825$

Where:
Kp_{sed} = solid-water partition coefficient (L/kg).
BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$Kp_{sed} = K_{oc} \times f_{oc}$
$= 1.3 \times 0.04$
$= 0.052$

Where:
K_{oc} = organic carbon normalized distribution coefficient (L/kg). The K_{oc} for cellulase enzymes is calculated to be <1.3 L/kg.
F_{oc} = fraction of organic carbon in sediment = 0.04 [default].

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is 0.009 mg/kg soil dry weight.

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
$= (0.026/1500) \times 1000 \times 0.5$
$= 0.009$

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
$= 1.3 \times 0.02$
$= 0.026$

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for cellulase enzymes is calculated to be <1.3 L/kg.
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008). The following PBT assessment on hemicellulase enzyme is based on read-across from cellulase enzyme.

Hemicellulase enzyme is readily biodegradable; thus, it does not meet the screening criteria for persistence.

Hemicellulase enzyme has a high molecular weight (20 to 80 kD), hydrophilic properties (high water solubility, log K_{ow} <1.3), and is readily biotransformed in organisms by proteases and peptidases. Thus, hemicellulase enzyme does not meet the screening criteria for bioaccumulation.

There are no chronic toxicity studies on hemicellulase enzyme. The acute $E(L)C_{50}$ values are >1 mg/L in fish, invertebrates and algae. Thus, hemicellulase enzyme does not meet the criteria for toxicity.

The overall conclusion is that hemicellulase enzyme is not a PBT substances.

IX. CLASSIFICATION AND LABELING

A. Classification

Respiratory sensitizer Category 1

[Aquatic Acute Category 3]

B. Labelling

Danger

C. Pictogram



X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
In case of contact, immediately flush eyes with plenty of water for at least 15 minutes.

Skin Contact
Remove contaminated clothing. Wash thoroughly with soap and water.

Inhalation
If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Ingestion
Rinse mouth with water and then drink plenty of water. Never give anything by mouth to an unconscious person.

Notes to Physician
May cause asthma-like (reactive airways) symptoms.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: carbon monoxide, carbon dioxide, nitrogen oxides, sulfur oxides.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus for fire-fighting.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Use appropriate protective equipment. Ensure adequate ventilation. Do not breathe vapors, mists, or gas.

Environmental Precautions
Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled
Collect spilled material by non-dispersive methods or with a vacuum cleaner equipped with a high efficiency filter. After spillage avoid generating aerosols or dust from dried preparation. Do not sweep, brush, use compressed air, which can create aerosols. Avoid splashing and high pressure washing. Provide for sufficient ventilation. Wash with plenty of water.

D. STORAGE AND HANDLING

General Handling
Use personal protective clothing. Avoid dust formation. Ensure adequate ventilation. Provide appropriate exhaust ventilation at places where dust is formed. Do not breathe dust. Wear respiratory protection if ventilation is inadequate. Avoid contact with skin, eye, and clothing.

Other Handling Precautions
Avoid creating or inhaling dust.

Storage
Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
Workplace Australia has not established an occupational exposure standard specifically for hemicellulase enzyme. However, Workplace Australia has established an occupational exposure standard of 0.00006 mg/m^3 (peak exposure with a sensitization notation) for the proteolytic enzymes of *B. subtilisins* as 100% pure enzyme. A peak limitation is defined by Safe Work Australia as a maximum or peak airborne concentration of a substance determined over the shortest analytically practicable period of time which does not exceed 15 minutes.

Engineering Controls

Ensure adequate ventilation. Localized ventilation should be used to control dust levels below permissible exposure limits.

Personal Protection Equipment

Respiratory Protection:
Use respiratory protection when airborne concentrations are expected to exceed occupational exposure limits.

Hand Protection:
Chemical resistant protective gloves.

Skin *Protection*:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Safety glasses with side-shields.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible. Remove and wash contaminated clothing before re-use. Contaminated work clothing should not be allowed out of the workplace.

F. TRANSPORT INFORMATION

Hemicellulase enzyme is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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HYDROCHLORIC ACID

This dossier on hydrochloric acid does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of hydrochloric acid in its use in drilling muds and in water treatment systems. The majority of information presented in this dossier was obtained from OECD-SIDS documents (OECD, 2002a,b), and the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch et al., 1997).

I. SUBSTANCE IDENTIFICATION

Chemical Name (IUPAC): Chlorane

CAS RN: 7647-01-0

Molecular formula: HCl

Molecular weight: 36.46

Synonyms: Hydrochloric acid, HCl, chlorane, hydrogen chloride, muriatic acid, chlorohydric acid,

SMILES: Cl

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Hydrochloric Acid

Property	Value	Klimisch score	Reference
Physical state at 20ºC and 101.3 kPa	Colourless to slightly yellow gas of fuming liquid with pungent, irritating odour.	2	ECHA
Melting Point	-114.22ºC	2	ECHA
Boiling Point	-85ºC	4	ECHA
Density	1.639 g/L @ 0ºC (gas) 1.194 g/mL @ 26ºC (liquid)	4	ECHA
Vapour Pressure	4,104 kPa 4,723 kPa @ 25ºC	4	ECHA
Partition Coefficient (log K_{ow})	Not applicable	-	-
Water Solubility	Very soluble	4	ECHA
Viscosity	1.7 x 10^{-6} m^2s @ 20ºC	1	ECHA

Hydrochloric acid can exist in a gaseous phase at room temperature and pressure. Hydrochloric acid is also very soluble in water and is a strong acid that dissociates completely in water to hydrogen (H^+) and chloride (Cl^-) ions.

III. ENVIRONMENTAL FATE PROPERTIES

Due to its high water solubility and low vapour pressure, hydrochloric acid will be found predominantly in the aquatic environment where it dissociates completely to hydrogen (H^+) and chloride (Cl^-) ions. Both ions are ubiquitous in the environment (UNEP, 1995).

The addition of hydrochloric acid to an aquatic ecosystem may decrease the pH depending on the buffer capacity of the receiving water. In general, the buffer capacity is regulated by the equilibria between CO_2, HCO_3^- and CO_3^{2-}:

$CO_2 + H_2O \leftrightarrow HCO_3^- + H^+$ ($pKa_1 = 6.35$)

$HCO_3^- \leftrightarrow CO_3^{2-} + H^+$ ($pKa_2 = 10.33$)

A release of hydrochloric acid into the aquatic environment from the use of HCl could potentially increase the chloride concentration and decrease the pH in the aquatic environment. Table 2 shows the amount of hydrochloric acid that would need to be added to bicarbonate solutions to obtain pH values of 6.0 and 4.0. The UNEP (1995) study reported that the 10th percentile, mean, and the 90th percentile of bicarbonate concentrations in 77 rivers in North America, South America, Asia, Africa, Europe, and Oceania were 20, 106, and 195 mg/L, respectively. The data show that the decrease in pH depends on the buffer capacity (bicarbonate concentration) of the receiving water. The calculated values in Table 2 were confirmed experimentally.

Table 2: Buffer capacity to maintain the pH based on bicarbonate concentration from UNEP monitoring data (de Groot and van Dijk, 2002; taken from OECD, 2002b)

Initial concentration of HCO_3^-	Final pH	Concentration of HCl required to obtain the final pH value
		Calculated [mg/L]
20 mg/LHCO_3^- (10th percentile 77 rivers)	6.0	8.28
	4.0	11.9
106 mg/L HCO_3^- (mean value of 77 rivers)	6.0	43.9
	4.0	63.2
195 mg/L HCO_3^- (90th percentile 77 rivers)	6.0	80.7
	4.0	116.3

H^+ and Cl^- ions will not adsorb on the particulate matter or surfaces and will not accumulate in living tissues (OECD, 2002a,b).

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Hydrochloric acid is a corrosive liquid. Depending on the concentration, aqueous solutions of hydrochloric acid (HCl) are either corrosive, irritating, or non-irritating to the skin, eyes, and gastrointestinal tract. Vapours from aqueous solutions of HCl can cause respiratory irritation. HCl is not a skin sensitiser. Subchronic inhalation studies show localised irritation to the upper respiratory tract of rats and mice, but no systemic toxicity. No repeated dose toxicity studies have been conducted by the oral route. Positive findings have been reported in some *in vitro* genotoxicity studies, which are considered to be the result of the pH change in the test system. A lifetime inhalation study showed no carcinogenicity in rats exposed to HCl. No adequate reproductive or developmental studies have been conducted on HCl.

B. Acute Toxicity

The oral LD_{50} values in rats were reported to be 238 to 277 mg/kg and 700 mg/kg (OECD, 2002a,b). [Kl. scores = 2 and 4, respectively]

The lethal dose by dermal exposure is >5,010 mg/kg for rabbits (OECD 2002a,b). [Kl. score = 4]

The LC_{50} values in rats for HCl gas are 40,989 and 4,701 ppm for 5 and 30 minutes, respectively (ECHA) [Kl. score = 2]. The LC_{50} values in rats for HCl aerosol are 31,008 and 5,666 ppm (45.6 and 8.3 mg/L) for 5 and 30 minutes, respectively (ECHA) [Kl. score = 2].

C. Irritation

Application of a 37% aqueous solution of HCl for 1 or 4 hours was corrosive to the skin of rabbits (OECD, 2002a,b) [Kl. score = 2). Application of 0.5 mL of a 17% solution of aqueous solution of HCl for 4 hours was corrosive to the skin of rabbits (OECD, 2002a,b) [Kl. score = 3]. Moderate skin irritation was observed in rabbits following an application of 0.5 mL of a 3.3% aqueous solution of HCl for five days; no irritation was observed with 0.5 mL of a 1% aqueous solution (OECD, 2002a,b) [Kl. score = 2]. In humans, an aqueous solution of 4% of HCl was slightly irritating, while a 10% solution was sufficiently irritating to be classified as a skin irritant (OECD, 2002a,b).

Instillation of 0.1 mL of a 10% aqueous solution of HCl to the eyes of rabbits resulted in severe eye irritation (ECHA) [Kl. score = 2]. Instillation of 0.1 mL of a 5% solution of HCl produced corneal opacity, iridial lesions, conjunctival redness and chemosis in 3/3 animals at 1 hour and at day one post-instillation. There was no recovery in any animal and the study was terminated on day two (ECHA) [Kl. score = 1].

D. Sensitisation

Hydrochloric acid was not a skin sensitiser in a guinea pig maximisation test (ECHA). [Kl. score = 2]

E. Repeated Dose Toxicity

Oral

No adequate studies were located.

Inhalation

Male and female SD rats and F344 rats were exposed by inhalation to 0, 10, 20, or 50 ppm 6 hours/day, 5 days/week for up to 90 days. Clinical signs were mainly indicative of the irritant/corrosive nature of HCl. Body weights were significantly decreased in the 50 ppm male F344 rats. There were no treatment-related effects on the haematology or clinical chemistry parameters or urinalysis. At study termination, heart, kidney and testes weights were increased in the 100 and/or 50 ppm groups; these changes were considered to be mainly related to the treatment-related effect on body weight. Histopathological examination showed minimal to mild rhinitis in the $\geq$20 ppm dose groups of both strains of rats (both sexes). The NOAELs for systemic toxicity and localised irritation (site-of-contact) are 20 and 10 ppm, respectively (ECHA). [Kl. score = 1]

Male and female $B6C3F_1$ mice were exposed by inhalation to 0, 10, 20, or 50 ppm HCl, 6 hours/day, 5 days/week for up to 90 days. Clinical signs were mainly indicative of the irritant/corrosive nature of HCl. Body weights were significantly decreased in the 50 ppm groups. At study termination, absolute liver weights were decreased in the 50 ppm males. Histopathologic examination showed only

eosinophilic globules in the nasal epithelium in the 50 ppm animals. The NOAEL for this study is 20 ppm (ECHA). [Kl. score = 1]

Male SD rats were exposed by inhalation to 0 or 10 ppm HCl 6 hours/day, 5 days/week for 128 weeks. Survival and body weights were similar between treated and control groups. There was a higher incidence of hyperplasia of the larynx compared to control, but no serious irritating effects of the nasal epithelium (ECHA). [Kl. score = 2]

Dermal

No studies were located.

F. Genotoxicity

In Vitro Studies

Table 3 presents the *in vitro* genotoxicity studies on hydrochloric acid.

Table 3: In Vitro Genotoxicity Studies on Hydrochloric Acid

Test System	Results[a]		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* and *E. coli* strains)	-	-	2	ECHA
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	-	+	2	ECHA
Chromosomal aberration (CHO cells)	+	+	2	ECHA
Saccharomyces cerevisiae (mitotic recombination	-	-	2	ECHA
E. coli W3110 (pol A+) and P3078 (pol A-) repair assay	-	-	2	ECHA

a+, positive; -, negative

In the mouse lymphoma assay, the mutant frequency increased as the pH was lowered to 6.5 to 6.0 (from increased HCl) in the presence of metabolic activation. A decrease in pH from the addition of HCl to the medium also resulted in clastogenic effects to CHO cells in the absence or presence of metabolic activation. The positive findings in these two studies are considered to be the result of the pH change in the test media.

In Vivo Studies

No adequate studies were located.

G. Carcinogenicity

Oral

No studies were located.

Inhalation

Male SD rats were exposed by inhalation to 0 or 10 ppm HCl 6 hours/day, 5 days/week for 128 weeks. Survival and body weights were similar between treated and control groups. There was a

higher incidence of hyperplasia of the larynx compared to control, but no serious irritating effects of the nasal epithelium. There was no increased incidence of tumours in the HCl-treated rats compared to controls (ECHA). [Kl. score = 2]

H. Reproductive Toxicity

No studies were located.

I. Developmental Toxicity

No adequate studies were located.

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

Repeated dose, reproductive, and developmental toxicity studies by the oral route have not been conducted on hydrochloric acid. These toxicity studies would have questionable usefulness because of the corrosive/irritating nature of hydrochloric acid, which would limit the amount of absorbed HCl. Hydrochloric acid dissociates to hydrogen and chloride ions in bodily fluids, and a significant amount of these ions are already ingested in foods. Furthermore, both ions are present in the body and are highly regulated by homeostatic mechanisms. Thus, an oral toxicological reference and drinking water guidance values were not derived from hydrochloric acid.

The Australian drinking water guideline values for pH (6.5 to 8.5) and chloride (250 ppm, aesthetics) may be applicable (ADWG, 2011).

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Hydrochloric acid does not exhibit the following physico-chemical properties:

- • Explosivity
- • Flammability
- • Oxidising potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

The hazard of hydrochloric acid for aquatic organisms is caused by the hydrogen ion (H^+). The toxicity values in terms of mg/L are not relevant because of the varying buffering capacity of different test systems and different aquatic ecosystems.

B. Aquatic Toxicity

Acute Studies

The acute aquatic toxicity studies on hydrochloric acid are listed in Table 4.

Table 4: Acute Aquatic Toxicity Studies on Hydrochloric Acid

Test Species	Endpoint	Results	Klimisch score	Reference
Oncorhynchus mykiss	96-hr LC_{50}	pH 4.12 (hard water) pH 3.98 (soft water)	2	ECHA; OECD 2002a,b

Test Species	Endpoint	Results	Klimisch score	Reference
Lepomis macrochirus	96-hr LC_{50}	pH 3.25 – 3.5	2	ECHA; OECD 2002a,b
Daphnia magna	48-hr EC_{50}	pH 4.92	1	ECHA
Chlorella vulgaris	72-hr EC_{50} 72-hr NOEC	pH 4.7 [growth rate] pH 4.82 [biomass] pH 5 [yield/growth rate	1	ECHA

Chronic Studies

No chronic studies are available.

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

PNEC values were not derived from hydrochloric acid because factors such as the buffer capacity, the natural pH, and the fluctuation of the pH are very specific for a certain ecosystem.

VIII. PBT ASSESSMENT

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Hydrochloric acid is an inorganic salt that dissociates completely to hydrogen and chloride ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both hydrogen and chloride ions are also ubiquitous and are present in water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria are not considered applicable to this inorganic salt.

Hydrogen and chloride ions are essential to all living organisms, and their intracellular, and extracellular concentrations are actively regulated. Thus, hydrochloric acid is not expected to bioaccumulate.

No chronic toxicity data exist on hydrochloric acid; however, the acute $E(L)C_{50}$ values are >1 mg/L in fish, invertebrates and algae. Thus, hydrochloric acid does not meet the screening criteria for toxicity.

The overall conclusion is that hydrochloric acid is not a PBT substance.

IX. CLASSIFICATION AND LABELLING

A. Classification

For HCl concentrations of >25%:

- Metal Corrosive Category 1
- Skin Corrosive 1B
- STOT SE Category 3 [Respiratory irritant]

In addition to the hazard statements corresponding the GHS classification for corrosive, the following non-GHS hazard statement is to be added to the SDS: AUH071: Corrosive to the Respiratory Tract.

B. Labelling

Danger

C. Pictogram



X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact

Immediately flush open eyes with plenty of water for at least 15 minutes. Remove contacts, if present and easy to do. Get medical attention immediately, preferably a physician for an ophthalmologic examination.

Skin Contact

For minor skin contact, avoid spreading material on unaffected skin. Remove and isolate contaminated clothing. Wash the contaminated area of the body with soap and fresh water. Get medical attention immediately.

Inhalation

Move person to fresh air. Administer oxygen if breathing is difficult. Do not use mouth-to-mouth method if victim inhaled the substance; give artificial respiration with the aid of a pocket mask equipped with a one-way valve or another proper respiratory medical device. Give artificial respiration if the victim is not breathing. Get medical attention immediately.

Ingestion

Rinse mouth and lips with plenty of water if a person is conscious. Do not induce vomiting. Do not use mouth-to-mouth method if the victim had ingested the substance. Obtain medical attention immediately if ingested.

Notes to Physician

Treat as a corrosive due to pH of the material. All treatments should be based on observed signs and symptoms of distress in the patient.

B. FIRE FIGHTING INFORMATION

Extinguishing Media

Use dry chemical, carbon dioxide, water spray or fog, or foam.

Specific Exposure Hazards

Containers may explode when heated. Emits toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following materials: halogenated compounds, may release dangerous gases (chlorine).

Special Protective Equipment for Firefighters

Structural firefighter's protective clothing provides limited protection in fire situations only; it is not effective in spill situations where direct contact with the substance is possible. Wear chemical protective clothing that is specifically recommended by the manufacturer. It may provide little or no thermal protection. Wear positive pressure self-contained breathing apparatus (SCBA). Move containers from fire area if you can do it without risk.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions

Ventilate enclosed areas. Do not walk through spilt material. Do not touch damaged containers or spilt material unless wearing appropriate protective clothing. Wear appropriate personal protective equipment, avoid direct contact. Do not breath mist, vapours, or spray. Do not get in eyes, on skin, or on clothing.

Environmental Precautions

Prevent entry into waterways, sewers, basements or confined areas.

Steps to be Taken if Material is Released or Spilt

ELIMINATE all ignition sources (no smoking, flares, sparks or flames in immediate area). As an immediate precautionary measure, isolate spill or leak area for at least 50 meters in all directions. Keep unauthorised personnel away. Stay upwind. Keep out of low areas. Do not get water inside container.

D. STORAGE AND HANDLING

General Handling

Handle and open container with care. Use only with adequate ventilation. Keep away from heat. Use caution when combining with water. DO NOT add water to corrosive liquid, ALWAYS add corrosive liquid to water while stirring to prevent the release of heat, steam, and fumes. Wear appropriate personal protective equipment, avoid direct contact. Do not breath mist, vapours, or spray. Do not get in eyes, on skin, or on clothing. Do not ingest. Wash thoroughly with soap and water after handling and before eating, drinking, or using tobacco.

Storage

Keep contain tightly closed. Store in a cool, dry, well-ventilated place. Keep away from incompatible materials. Keep from direct sunlight. Separate from alkalis. Do not store above 49^{o}C/120^{o}F.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards

The workplace exposure standard for hydrochloric acid in Australia is 5 ppm (7.5 mg/m^3 as a peak limitation, with a sensitisation notation. A peak limitation is defined by Safe Work Australia as a maximum or peak airborne concentration of a substance determined over the shortest analytically practicable period of time which does not exceed 15 minutes.

Engineering Controls

Good general ventilation should be used. Ventilation rates should be matched to conditions. If applicable, use process enclosures, local exhaust ventilation, or other engineering controls to maintain airborne levels below recommended exposure limits.

Personal Protection Equipment

Respiratory Protection: If workers are exposed to concentrations above the exposure limit, they must use appropriate, certified respirators. Use a properly fitted, air-purifying or air-fed respirator complying with an approved standard if a risk assessment indicates this is necessary. Respirator selection much is based on known or anticipated exposure levels, the hazard of the product and the safe working limits of the selected respirator.

Hand Protection: Chemical-resistant, impervious gloves complying with an approved standard should be worn at all times when handling chemical products if a risk assessment indicates this is necessary. Considering the parameters specified by the glove manufacturer, check during use that the gloves are still retaining their protective properties. It should be noted that the time to breakthrough for any glove material may be different for different glove manufacturers. In the case of mixtures, consisting of several substances, the protection time of the gloves cannot be accurately estimated.

Skin Protection: Personal protective equipment for the body should be selected based on the task being performed and the risks involved and should be approved by a specialist before handling hydrochloric acid.

Eye Protection: Wear chemical splash goggles and face shield.

Other Precautions: Wash hands, forearms, and face thoroughly after handling chemical products, before eating, smoking, and using the lavatory and at the end of the working period. Appropriate techniques should be used to remove potentially contaminated clothing. Wash contaminated clothing before reusing. Ensure that eyewash stations and safety showers are close to the workstation location.

F. TRANSPORT INFORMATION

Australian Dangerous Goods

UN 1789 (HYDROCHLORIC ACID)
Class: 8
Packing Group: II or III

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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XIV. ACRONYMS AND GLOSSARY

°C	degrees Celsius
ADWG	Australian Drinking Water Guidelines
API	American Petroleum Institute
DEWHA	Department of the Environment, Water, Heritage and the Arts
EC	effective concentration
ECHA	European Chemicals Agency
EU	European Union
GHS	Globally Harmonised System of Classification and Labelling of Chemicals

HHRA	enHealth Human Risk Assessment
HPV	High Production Volume
IUPAC	International Union of Pure and Applied Chemistry
Kl	Klimisch scoring system
LOAEL	lowest observed adverse effect level
mg/kg	milligrams per kilogram
mg/L	milligrammes per litre
mg/m^3	milligrammes per cubic metre
MW	molecular weight
NICNAS	The National Industrial Chemicals Notification and Assessment Scheme
NIOSH	National Institute for Occupational Safety and Health
NOAEC	No Observed Adverse Effect Concentration
NOAEL	no observed adverse effect level
NOEC	no observed effective concentration
OECD	Organisation for Economic Co-operation and Development
PBT	Persistent, Bioaccumulative and Toxic
PNEC	Predicted No Effect Concentration
ppm	parts per million
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RfD	Reference Dose
SDS	Material Safety Data Sheet
SMILES	simplified molecular-input line-entry system
TGD	Technical Guidance Document
USEPA	United States Environmental Protection Agency
UVCB Materials	Unknown or Variable Composition, Complex Reaction Products and Biological
WAFs	water accommodated fractions
WHO	World Health Organisation
µm	micrometre

HYDROXYPROPYL GUAR

This dossier on hydroxylpropyl guar does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of hydroxypropyl guar in its use in drilling muds and hydraulic fracturing fluids. Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name: Hydroxylpropyl Guar

CAS RN: 39421-75-5

Molecular weight: 200,000 to 300,000 daltons (Glickman, 1969)

Hydroxypropyl guar a propylene glycol ether derivative of guar gum. Guar gum is a resinous material derived from milled endosperm from guar beans of the legume *Cyamopsis tetragonolobus*. Structurally, it is a galactomannan (high molecular weight carbohydrate polymer) consisting of a main chain of D-mannose with a side chain of D-galactose at approximately every second mannose unit. The mannose units are β-(l-4) linked, and the single D-galactose units are joined to the main chain by α-(1-6) linkages.

SYNONYMS: Hydroxypropyl guar; hydroxypropyl guar gum; guar gum, 2-hydroxypropyl ether

II. PHYSICO-CHEMICAL PROPERTIES

Hydroxypropyl guar is a white to yellow fine powder that is very slightly soluble in water (Johnson et al., 2015).

III. ENVIRONMENTAL FATE PROPERTIES

No biodegradation studies are available on hydroxypropyl gum. Hydroxypropyl guar is the propylene glycol derivative of a carbohydrate polymer consisting of D-mannose and D-galactose sugars from the guar bean. It is expected to be readily biodegradable.

Hydroxypropyl guar is not expected to bioaccumulate based on its large molecular weight.

IV. HUMAN HEALTH HAZARD ASSESSMENT

As the propylene glycol derivative of guar gum, hydroxypropyl guar would be expected to have similar toxicological properties to guar gum. Thus, the toxicity data on guar gum have been used to read-across to hydroxypropyl guar.

A. Summary

There are no mammalian toxicity data available on hydroxypropyl guar, except for one *in vitro* genotoxicity study; thus data on guar gum have been used to read-across to hydroxypropyl guar. Guar gum is exhibits very low acute toxicity by the oral route. It is non-irritating to the skin and minimally irritating to the eyes. Repeated dose toxicity studies showed minimal toxicity in dietary studies. Unlike guar gum, hydroxylpropyl guar was mutagenic in an Ames test in the presence, but not absence, of metabolic activation. Oral exposure to guar gum did not affect fertility in rats; nor was there any indication of developmental toxicity in rats or mice.

B. Acute Toxicity

There are no acute toxicity studies available for hydroxypropyl guar. The oral LD_{50} for guar gum in rats was reported to be 7,060 mg/kg (Graham et al., 1981). [Kl. score = 2]

C. Irritation

There are no irritation studies available for hydroxypropyl guar. Guar gum is non-irritating to the skin, and minimally irritating to the eyes (McCarty *et al.*, 1990).

D. Sensitization

There are no animal sensitization studies available for either hydroxypropyl guar or guar gum.

E. Repeated Dose Toxicity

Oral

There are no repeated dose toxicity studies available for hydroxypropyl guar.

Male and female Osborne-Mendel rats were given diets containing 0, 1, 2, 4, 7.5, or 15% guar gum for 91 days. The average daily intakes are: 0, 580, 1,187, 2,375, 4,561, and 10,301 mg/kg-day for males; and 0, 691, 1,362, 2,762, 5,770, and 13,433 mg/kg-day for females. There were no deaths during the study. Body weights were significantly decreased in the $\geq$1% females and the $\geq$7.5% males. Liver weights were decreased in the $\geq$1% dietary groups. Kidney weights were decreased in the $\geq$7.5% dietary groups and were borderline significant in the 4% group. The 15% males had reduced bone marrow cellularity; although the level was within normal limits, several of the rats were at the

lower end of the normal range. The LOAEL for this study is 691 mg/kg-day based on reduced body weights in the female rats (Graham et al., 1981). [Kl. score = 2]

Male and female F344 rats and $B6C3F_1$ mice were given diets containing 0, 6,300, 12,500, 25,000, 50,000 or 100,000 ppm guar gum for 13 weeks. Mean body weights were decreased in the 100,000 ppm male rats and in the $\geq$50,000 ppm female mice. A dose-related decrease in feed consumption was observed for male and female rats; male and female mice were comparable or higher than that of controls. There were no compound-related clinical signs or histopathological effects. The NOAELs for this study is 50,000 and 25,000 ppm for rats and mice, respectively. Using the fraction of body weight that rats and mice consume per day as food (0.05 and 0.13, respectively; U.S. EPA), the NOAELs corresponds to 2,500 mg/kg-day for rats and 3,250 mg/kg-day for mice (NTP, 1982). [Kl. score = 2]

Male and female F344 rats and $B6C3F_1$ mice were given diets containing 0, 25,000 ppm or 50,000 ppm guar gum for 103 weeks. Mean body weights of the high-dose females were lower than those of the controls after week 20 for mice and week 40 for rats. No compound-related clinical signs or adverse effects on survival were observed. Feed consumption by dosed rats and mice of either sex was lower than that of controls. There were no non-neoplastic histopathological effects in either rats or mice that were treatment-related. The NOAEL for both rats and mice is 25,000 ppm. Using the fraction of body weight that rats and mice consume per day as food (0.05 and 0.13, respectively; U.S. EPA), the NOAELs corresponds to 1,250 mg/kg-day for rats and 3,250 mg/kg-day for mice (NTP, 1982). [Kl. score = 2]

Inhalation

No studies are available.

Dermal

No studies are available.

F. Genotoxicity

In Vitro Studies

Hydroxypropyl guar was not mutagenic to *S. typhiumurium* strains TA 98, TA 100, TA 1535, TA 1537, and TA 1538 in the absence of metabolic activation. In the presence of metabolic activation hydroxypropyl guar was mutagenic to S. typhimurium strains TA 98, TA 100, TA 1537, and TA 1538, but not to TA 1535 (Johnson et al., 2015).

In Vivo Studies

There are no studies available for hydroxypropyl guar.

G. Carcinogenicity

There are no studies available for hydroxypropyl guar.

H. Reproductive Toxicity

Oral

There are no studies available for hydroxypropyl guar.

Male and female Osborne-Mendel rats were fed diets containing 0, 1, 3, 4, 7.5, or 15% guar gum for 13 weeks before mating, during mating and throughout gestation. The daily intake for the female rats during gestation were 0, 700, 1,400, 2,700, 5,200, or 11,800 mg/kg-day. Fertility was unaffected by treatment. There were slightly fewer corpora lutea and implantations in the 15% dietary group, but implantation efficiency was unaffected. The NOAEL for reproductive toxicity is 5,200 mg/kg-day (Collins et al., 1987). [Kl. score = 2]

I. Developmental Toxicity

Oral

There are no studies available for hydroxypropyl guar.

Male and female Osborne-Mendel rats were fed diets containing 0, 1, 3, 4, 7.5, or 15% guar gum for 13 weeks before mating, during mating and throughout gestation. The daily intake for the female rats during gestation were 0, 700, 1,400, 2,700, 5,200, or 11,800 mg/kg-day. There were no deaths during the study. In the 15% group, the number of viable fetuses per litter were slightly reduced, but was not statistically significantly different from controls. The authors indicate that the reduction may have been an effect of the decreased number of corpora lutea because the number of resorptions was unaffected in this treatment group. There was no treatment-related effect on fetal development or sex distribution, and there was no teratogenic effects (Collins *et al.*, 1987). [Kl. score = 2]

Pregnant female rats were dosed by oral gavage with 0, 9, 42, 200, or 900 mg/kg guar gum on GD 6 to 15. There was no maternal or developmental toxicity at any dose level. The NOAEL for maternal and developmental toxicity is 900 mg/kg-day (FDRL, 1973). [Kl. score = 2]

Pregnant female CD-1 mice were dosed by oral gavage with 0, 8, 37, 170, or 800 mg/kg guar gum on GD 6 to 15. A significant number of deaths (6 out of 29) occurred in the 800 mg/kg dose group. There was indications of maternal toxicity in the surviving high-

dose dams. There was no developmental toxicity at any dose level. The NOAELs for maternal and developmental toxicity is 170 and 800 mg/kg-day, respectively (FDRL, 1973). [Kl. score = 2]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for guar gum follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

In a two-year NTP chronic bioassay, female rats and mice given 50,000 ppm guar gum in their feed had lower body weights. There were no treatment-related nonneoplastic lesions observed in either rats or mice. The NOAEL for this study is 25,000 ppm for rats and mice, which corresponds to 1,250 mg/kg-day for rats and 3,250 mg/kg-day for mice.

The NOAEL of 1,250 mg/kg-day will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 1,250/(10 x 10 x 1 x 1 x 1) = 1,250/100 = 13 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (13 x 70 x 0.1)/2 = 46 mg/L

B. Cancer

There are no carcinogenicity studies on hydroxypropyl guar. Thus, a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Hydroxypropyl guar does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

No studies are available on the aquatic or terrestrial toxicity of hydroxypropyl guar. As the hydroxypropyl derivative of guar gum, it would be expected to have similar properties to a non-ionic polymer and exhibit low to potentially moderate acute toxicity to aquatic organisms.

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Hydroxypropyl guar is a derivative of a naturally occurring polysaccharide from the guar plant or cluster bean; it expected to be readily biodegradable. Thus, it is not expected to meet the screening criteria for persistence.

The molecular weight of hydroxypropyl guar ranges from 200,000 to 300,000 daltons. Thus, guar gum is not expected to meet the criteria for bioaccumulation.

No aquatic toxicity data are available on hydroxypropyl guar. It is not possible to determine whether hydroxypropyl guar meets the toxicity criteria.

The overall conclusion is that hydroxypropyl guar is unlikely to be a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Not classified.

B. Labelling

No signal word.

C. Pictogram

None.

X. SAFETY AND HANDLING

Eye Contact
In case of contact, immediately flush eyes with plenty of water for at least 15 minutes.

Skin Contact
Remove contaminated clothing. Wash thoroughly with soap and water.

Inhalation
If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Ingestion
Rinse mouth with water and then drink plenty of water. Never give anything by mouth to an unconscious person.

Notes to Physician
May cause asthma-like (reactive airways) symptoms.

B. FIRE FIGHTING INFORMATION

Extinguishing Media

Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: carbon monoxide, carbon dioxide.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus for fire fighting.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Avoid dust formation.

Environmental Precautions
No special environmental precautions required.

Steps to be Taken if Material is Released or Spilled
Sweep up and dispose in suitable, closed containers.

D. STORAGE AND HANDLING

General Handling
Avoid creating or inhaling dust.

Storage
Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
Workplace Australia has not established an occupational exposure standard specifically for hydroxypropyl guar.

Engineering Controls
Ensure adequate ventilation.

Personal Protection Equipment

Respiratory Protection:
Respiratory protection is not required.

Hand Protection:

Handle with gloves.

Skin *Protection*:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Safety glasses with side-shields.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible.

F. TRANSPORT INFORMATION

Hydroxypropyl guar is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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LACTOSE

This dossier on lactose does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of lactose in its use in drilling muds and hydraulic fracturing fluids. Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC): β-D-galacto-hexopyranosyl-(1→4)-α-D-glucose

CAS RN: 63-42-3

Molecular formula: $C_{12}H_{22}O_{11}$

Molecular weight: 342.3

Synonyms: Lactose; alpha-lactose; lactose anhydrous; β-D-galacto-hexopyranosyl-(1->4)-α-D-gluco-hexopyranose; β-D-galactopyranosyl-4)-α-D-glucopyranose; α-D-glucopyranose, 4-O- β-D-galactopyranosyl-

SMILES: O=CC(O)C(O)C(OC(OC(C(O)C1O)CO)C1O)C(O)CO

Lactose is a disaccharide sugar composed of galactose and glucose. It is naturally synthesized in the mammary gland of virtually all mammals, occurring in milk at levels between 1 and 7%. Commercially, lactose is extracted from the whey of cow's milk (whey is the residual liquid of milk following cheese and casein production) and is purified extensively to remove fats, proteins, vitamins and minerals (Baldrick and Bamford, 1997; Goodhart, 1994).

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Lactose

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	White, crystalline powder	4	Lide (2007)
Melting Point	254°C	4	Lide (2007)
Density	1.59 g/cm^3 @ 20°C	4	Lide (2007)
Partition Coefficient (log	-5.03 (estimated)	-	EPA (2017)

K_{ow})			

III. ENVIRONMENTAL FATE PROPERTIES

No biodegradation studies were found on lactose. As a disaccharide of galactose and glucose sugars, lactose would be expected to be readily biodegradable. It would also not be expected to bioaccumulate or adsorb to sediments or soil.

Using KOCWIN in EPISUITE™ (EPA, 2017), the estimated K_{oc} values from the molecular connectivity index (MCI) is 1 L/kg.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Lactose has essentially no acute toxicity by the oral route. Many of the findings from the oral rat studies on lactose are due to high dietary levels used in the studies, which results in a significant proportion reaching the cecum and colon where it is readily fermented by the intestinal microflora. Consequently, there is increased production of volatile fatty acids and lactic acid, and a lowering of the pH and increased osmotic pressure. These changes facilitate calcium absorption. Lactose is not genotoxic. Animal studies show no reproductive or developmental toxicity from dietary intake of lactose.

B. Pharmacokinetics/Metabolism

Following oral ingestion, lactose is readily hydrolyzed in the gastrointestinal tract to galactose and glucose by the enzyme lactase (Hansen, 1974; Williams, 1986). Lactase is a β-galactosidase found in the brush border of the intestinal epithelium. Once hydrolyzed, the monosaccharides are then readily absorbed. Lactose can also be hydrolyzed by other enzymes, such as acid β-galactosidase.

C. Acute Toxicity

The acute oral LD_{50} in rats has been reported to be >10,000 mg/kg (Baldrick and Bamford, 1997).

D. Irritation

No studies are available.

E. Sensitization

No studies are available.

F. Repeated Dose Toxicity

Oral

Male and female Wistar rats were fed diets containing 20% lactose for 12 weeks before mating, and during pregnancy and lactation. At weaning, the animals were fed the same diet and the study was terminated at week 130. There were low body weights; increased blood alkaline phosphatase and urinary calcium; decreased pH of cecum contents; enlargement/increased weight of the cecum; pelvic nephrocalcinosis of the kidneys; and increased proliferation of the bile ducts; and adrenal medullary hyperplasia. The LOAEL is 20,000 ppm lactose. Using 0.05 as the fraction of body weight that rats consume per day as food (U.S. EPA), the NOAELs corresponds to 1,000 mg/kg-day (Sinkeldam *et al.*, 1992a).

Similar findings were also observed in another study in which rats were fed 20% lactose in their diet for 130 weeks. Findings included loose feces (week one and two only); decreased pH of the feces; low body weights; increased food and water consumption; increased blood alkaline phosphatase and decreased bicarbonate; increased calcium concentration and excretion; reduced urinary pH; increased cecum weight; mineralization of the renal pelvis; increased incidence of basophilic cell foci in the adrenal medulla; and Leydig cell hyperplasia. The LOAEL is 20,000 ppm lactose. Using 0.05 as the fraction of body weight that rats consume per day as food (U.S. EPA), the NOAELs corresponds to 1,000 mg/kg-day (De Groot *et al.*, 1995).

Inhalation

A brief summary of inhalation studies conducted in rats, dogs, monkeys, and macaques showed no findings of toxicological significance (Baldrick and Bamford, 1997).

Dermal

No studies were available.

G. Genotoxicity

In Vitro Studies

Lactose was negative in an *in vitro* chromosomal aberration study with cultured human lymphocytes with or without metabolic activation (Sinkeldam *et al.*, 1992a).

In Vivo Studies

No studies are available.

H. Carcinogenicity

Male and female Wistar rats were fed diets containing 20% lactose for 12 weeks before mating, during mating, and during pregnancy and lactation. At weaning, the animals were fed the same diet and the study was terminated at week 130. There were increased adrenal medulla pheochromocytomas and Leydig cell tumors (males only) in the treated rats (Sinkeldam *et al.*, 1992a).

I. Reproductive Toxicity

In a multi-generation study, rats were fed diets containing 20% lactose over three successive generations. There were no adverse effects on fertility or reproductive performance. There was a slight decrease in the number of pups born alive, litter size at birth, viability index and pup weight for F_0 and F_1 offspring. There were signs of low body weights in the parental animals, and enlargement and increased weight of the cecum (Sinkeldam *et al.*, 1992b).

J. Developmental Toxicity

Pregnant mice were given 10,000 mg/kg lactose during gestation days 8-12. No maternal toxicity was observed and there were no effects on litter size, body weight on days 1 and 3, or neonate survival (Seidenberg *et al.*, 1986).

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for lactose follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

<u>Oral</u>

Many of the findings from the oral studies on lactose are due to high dietary levels used in the studies, which results in a significant proportion reaching the cecum and colon where it is readily fermented by the intestinal microflora. Consequently, there is increased production of volatile fatty acids and lactic acid, and a lowering of the pH and increased osmotic pressure. These changes facilitate calcium absorption.

Non-neoplastic adverse effects were noted in rats given 20% in their diet for 130 weeks (Sinkeldam *et al.*, 1992a; De Groot *et al.*, 1995). The LOAEL from these studies are 1,000 mg/kg-day. Since only one dose level was used in these studies, a NOAEL was not identified. The LOAEL of 1,000 mg/kg-day will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 10
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 1,000/(10 x 10 x 10 x 1 x 1) = 1,000/1,000 = <u>1.0 mg/kg-day</u>

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (1 x 70 x 0.1)/2 = <u>3.5 mg/L</u>

B. Cancer

Increased adrenal medulla pheochromocytomas and Leydig cell tumors were noted rats given lactose in their diet for 130 weeks (Sinkeldam *et al.*, 1992a). The adrenal medulla pheochromocytomas tumors from high dietary administration of low digestible carbohydrates (includes lactose) are thought to be secondary to increased calcium absorption from the intestine. This appears to be rat-specific; altered calcium

homeostasis does not appear to occur in humans ingesting carbohydrates such as lactose (Lynch *et al.*, 1996). Thus, the adrenal medulla pheochromocytomas are unlikely to be relevant to human. Increased Leydig cell tumors in male rats are also of questionable relevance to humans. Thus a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Lactose does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Lactose is expected to be of low toxicity concern to aquatic organisms based on QSAR modeling results.

B. Aquatic Toxicity

Acute Studies

No aquatic toxicity studies were found on lactose.

Using ECOSAR, the 96-hour LC_{50} in fish was estimated to be 93,396 mg/L; the 48-hour LC_{50} in *Daphnia* and the 96-hour EC_{50} in green algae exceed the estimated water solubility of 111,000 mg/L (U.S. EPA, 2017).

Chronic Studies

No studies are available.

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for lactose follow the methodology discussed in DEWHA (2009).

PNEC water

No experimental results are available for lactose. Acute $E(L)C_{50}$ estimates using the QSAR model ECOSAR are: fish (93,396 mg/L), *Daphnia* (>111,000 mg/L), and algae (>111,000 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported $E(L)C_{50}$ value of 93,396 mg/L for fish. The $PNEC_{water}$ is 93 mg/L.

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 59.6 mg/kg sediment wet weight.

The calculations are as follows:

$$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$$
$$= (0.82/1280) \times 1000 \times 93$$
$$= 59.6$$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$$K_{sed\text{-}water} = 0.8 + [0.2 \times Kp_{sed})/1000 \times BD_{solid}]$$
$$= 0.8 + [0.2 \times 0.04/1000 \times 2400]$$
$$= 0.82$$

Where:
Kp_{sed} = solid-water partition coefficient (L/kg).
BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$$Kp_{sed} = K_{oc} \times f_{oc}$$
$$= 1 \times 0.04$$
$$= 0.04$$

Where:
K_{oc} = organic carbon normalized distribution coefficient (L/kg). The K_{oc} for lactose calculated from EPISUITE™ using lthe MCI is 1.0 L/kg .
F_{oc} = fraction of organic carbon in sediment = 0.04 [default].

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is 1.24 mg/kg soil dry weight.

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
$= (0.02/1500) \times 1000 \times 93$
$= 1.24$

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
$= 1 \times 0.02$
$= 0.02$

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for lactose calculated from EPISUITE™ using the MCI is 1.0 L/kg .
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

No biodegradation data are available on lactose. Lactose is a disaccharide found in milk and consists of D-galactose and D-glucose sugars. it is expected to be readily biodegradable; therefore, it does not meet the screening criteria for persistence.

Lactose is a disaccharide that has an estimated log K_{ow} of -5. It is water-soluble and is rapidly metabolized by enzymes. It is not expected to bioaccumulate.

The estimated acute $E(L)C_{50}$ value in fish is >1 mg/L. Thus it does not meet the screening criteria for toxicity.

The overall conclusion is that lactose is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Not classified.

B. Labelling

No signal word.

C. Pictogram

None.

X. SAFETY AND HANDLING

Eye Contact
Immediately flush eyes with plenty of water.

Skin Contact
Wash with soap and water.

Inhalation
If inhaled, remove from area to fresh air. If not breathing, give artificial respiration. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Ingestion
Do not induce vomiting. Rinse mouth with water and then drink a small amount of water. Get medical attention. Never give anything by mouth to an unconscious person.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
Combustible dust. May form dust explosion hazard in air. May emit toxic fumes under fire conditions.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus and chemical-protective clothing.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions

Use appropriate protective equipment. Avoid creating and breathing dust.

Environmental Precautions

No special precautions needed.

Steps to be Taken if Material is Released or Spilled

Scoop and remove.

D. STORAGE AND HANDLING

General Handling

Avoid creating or inhaling dust. Take precautionary measures against static charge.

Storage

Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
Workplace Australia has not established an occupational standard for lactose.

Engineering Controls

Use in a well-ventilated area. Avoid creating dust. Take precautionary measures against static charge.

Personal Protection Equipment

Respiratory Protection: Respiratory protection is not required.

Hand Protection: Use gloves.

Skin Protection: Body protection must be chosen depending on activity and possible exposure.

Eye Protection: Safety glasses with side-shields.

Other Precautions: Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible.

F. TRANSPORT INFORMATION

Lactose is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods Code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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HYDROCARBONS, C12-C15, N-ALKANES, ISOALKANES, CYCLICS, <2% AROMATICS

This dossier on hydrocarbons, C12-C15, n-alkanes, isoalkanes, cyclics, <2% aromatics (C12-C15 aliphatic hydrocarbons (<2% aromatics)) does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of C12-C15 aliphatic hydrocarbons (<2% aromatics) in its use in drilling muds and hydraulic fracturing fluids. The information presented in this dossier was obtained primarily from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name: Hydrocarbons, C12-C15, n-alkanes, isoalkanes, cyclics, <2% aromatics

CAS RN: 64742-47-8 [CAS No. 869062-45-3; EC No. 920-107-4]

Historically, hydrocarbons, C12-C15, n-alkanes, isoalkanes, cyclics, <2%aromatics was included within the CAS RN 64742-47-8 for distillates, (petroleum), hydrotreated, light. This CAS RN is broadly defined as "A complex combination of hydrocarbons obtained by treating a petroleum fraction with hydrogen in the presence of a catalyst. It consists of hydrocarbons having carbon number predominantly in the range of C9 to C16 and boiling in the range of approximately 150^{o}C to 290^{o}C (302^{o} to 554^{o}F)." This CAS RN can include hydrocarbon streams and solvents that can vary widely in their compositions, processing, and classifications. The EU Hydrocarbon Solvents Producers Association (HSPA), for the purposes of REACH registrations, established more precise definitions for hydrocarbon solvents and established a new substance identification and naming convention.[1] Hydrocarbons, C12-C15, n-alkanes, isoalkanes, cyclics, < 2% aromatics would have the CAS RN 869062-45-3 and EC. No. 920-107-4 and would be within the HSPA category for C9-C14 Aliphatics ($\leq$2% aromatics).

Molecular formula: Not available (UVCB substance)

Molecular weight: Not available (UVCB substance)

Synonyms: Hydrocarbons, C12-C15, n-alkanes, isoalkanes, cyclics, <2% aromatics; distillates, petroleum, hydrotreated, light; C12-C15 aliphatic hydrocarbons (<2% aromatics)

SMILES: Not available (UVCB substance)

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of C12-C15 Aliphatic Hydrocarbons (<2% Aromatics)

[1] https://www.reachcentrum.eu/Consortia%20Documents/P-I163/Other/20110401160024-HSPA_CAS_April__2011.pdf.

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Colorless to faint yellow with a slight odor.	2	ECHA
Melting point	-30°C	2	ECHA
Boiling point	233 to 266°C	2	ECHA
Density	0.79 to 0.85 g/cm^3 @ 15°C	2	ECHA
Vapor pressure	0.003 kPa @ 20°C (calculated)	2	ECHA
Partition coefficient (log K_{ow})	Not determined (UVCB substance)	-	-
Water solubility	Not determined (UVCB substance)	-	-
Flash point	102°C	2	ECHA
Auto flammability	>200°C	2	ECHA
Viscosity	3.56 mm^2/s @ 20°C	2	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

There are no biodegradation data on C11-C15 aliphatic hydrocarbons (<2% aromatics). However, a hydrocarbons, C11-14, n-alkanes, isoalkanes, cyclics (<2% aromatics) hydrocarbon fluid was shown to be readily biodegradable. The C12-C15 aliphatic hydrocarbons (<2% aromatics) are expected to highly absorb to sediment and soil. The C12-C15 aliphatic hydrocarbons (<2% aromatics) is expected to have constituents with the potential to bioaccumulate.

B. Biodegradation

No biodegradation data are available on C12-C15 aliphatic hydrocarbons (<2% aromatics).

In an OECD 301F test, degradation of hydrocarbons, C11-14, n-alkanes, isoalkanes, cyclics (<2% aromatics) hydrocarbon fluid was 69% after 28 days (ECHA) [Kl. score = 1]. The results indicate that this substance is readily biodegradable even though it did not meet the 10-day window because the criterion does not apply to multi-component substance when assessing their ready biodegradability (ECHA) [Kl. score = 1].

D. Environmental Distribution

C12-C15 aliphatic hydrocarbons (<2% aromatics) and C9-C14 aliphatic hydrocarbons (≤2% aromatics) are UVCB substances. The standard tests to determine the K_{oc} are for single substances and not for UVCB substances. Therefore, a K_{oc} value for C12-C15 aliphatic hydrocarbons (<2% aromatics) was not determined.

The calculate K_{oc} values for linear aliphatic hydrocarbons dodecane (C12) and tetradecane (C14) are 110,000 and 759,000 L/kg, respectively, using SPARC v4.2 program in the Concawe Library of Petrorisk (ECHA). These values suggest that C12-C15 aliphatic hydrocarbons (<2% aromatics) will highly absorb to sediment and soil.

E. Bioaccumulation

C12-C15 aliphatic hydrocarbons (<2% aromatics) and C9-C14 aliphatic hydrocarbons (≤2% aromatics) are UVCB substances. The calculated BCF values for linear aliphatic hydrocarbons undecane (C11), dodecane (C12), and tetradecane (C14) are 337.8, 790.9, and 962.9 L/kg, respectively using the BCFWIN V2.16 model within EPISuite 3.12. The predicted BCFs for hydrocarbons are considered to be generally overly conservative because biotransformation is not quantitatively taken into account. For these linear aliphatic hydrocarbons, the values indicate that they are not expected to bioaccumulate. However, both C12-C15 aliphatic hydrocarbons (<2% aromatics) and C9-C14 aliphatic hydrocarbons (≤2% aromatics) contain branched and cyclic aliphatic hydrocarbons that are expected to have a greater potential to bioaccumulate.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

The acute toxicity of C9-C14 aliphatic hydrocarbons (≤2% aromatics) is low by the oral, dermal, and inhalation route. It is, however, an aspiration hazard. C9-C14 aliphatic hydrocarbons (≤2% aromatics) are neither skin nor eye irritants or a dermal sensitizer. Repeated inhalation exposure of rats to a C9-C14 aliphatic (≤2% aromatic) hydrocarbon fluid showed no target organ effects; oral exposures to very high doses of these hydrocarbons showed irritation to the gastrointestinal tract and effects in the liver that likely represent an adaptive response to the metabolism of the hydrocarbons and not a toxic response. C9-C14 aliphatic hydrocarbons (≤2% aromatics) are not genotoxic; nor do they exhibit and evidence of reproductive or developmental toxicity in rats.

B. Acute Toxicity

The oral LD_{50} in rats for C9-C14 aliphatic, ≤2% aromatic hydrocarbon fluids is >5,000 mg/kg (ECHA) [Kl. score = 2.

The 4-hour inhalation LC_{50} in rats for C9-C14 aliphatic, ≤2% aromatic hydrocarbon fluids is > 4,951 mg/m^4 (ECHA) [Kl. scores =1 and 2].

The dermal LD_{50} in rats for C9-C14 aliphatic, ≤2% aromatic hydrocarbon fluids is >5,000 mg/kg (ECHA) [Kl. score = 2].

C. Irritation

C9-C14 aliphatic, ≤2% aromatic hydrocarbon fluids are neither skin nor eye irritants (ECHA) [Kl. scores = 1 and 2].

D. Sensitization

C9-C14 aliphatics, <2% aromatic hydrocarbon fluids were not skin sensitizers when tested in guinea pig maximization tests (ECHA) [Kl. score = 2].

A C9-C14 aliphatic, <2% aromatic hydrocarbon fluid showed no indication of skin sensitization in a human repeated insult patch test (ECHA).

E. Repeated Dose Toxicity

Oral

Male and female rats were dosed by oral gavage with 0, 500, 2,500 or 5,000 mg/kg with a C9-C14 aliphatic, <2% aromatic hydrocarbon fluid 7 days/week for 13 weeks. Additional groups of animals were dosed with 0 or 5,000 mg/kg for 13 weeks, followed by a 4-week recovery period. There were dose-related changes in the hematology and serum chemistry parameters which were consistent with changes seen in the liver. Hepatocellular hypertrophy (liver cell enlargement) were seen in both males and females in all dose groups and were reversible. The liver effects were not considered to be an indication of toxicity but an adaptive response due to the metabolism of the hydrocarbons. There were also mucosal thickening and other signs of irritation to the stomach and anus, which appeared to be the direct result of high-dose intubation of a locally irritating material. All treatment-related effects were reversible within the 4-week recovery period. The NOAEL for systemic effects in this study is considered to be 5,000 mg/kg-day (ECHA) [Kl. score = 1].

Inhalation

Male and female rats were exposed by inhalation to 0, 2,600, 5,200, or 10,400 mg/m^3 of a C9-C14 aliphatic (<2% aromatic) hydrocarbon fluid, 6 hours/day, five days/week for 13 weeks. There was no mortality or effects in either the hematology or the serum chemistry parameters. The male rats at all dose levels had increased liver and kidney weights; male heart weights were also increased at 10,400 mg/m^3; and kidney weights were increased in the 10,400 mg/m^3 group. Kidney effects indicative of alpha-2u-globulin nephropathy was observed at all dose levels. There were no other effects that were considered to be treatment-related. The alpha-2u-nephropathy in the male rats was not considered to be relevant to humans; for the organ weight changes other than the male kidneys, there were no corresponding histopathologic changes. The NOAEL for this study is 10,400 mg/m^3, the highest exposure concentration tested (ECHA) [Kl. score = 1].

Dermal

No studies are available.

F. Genotoxicity

In Vitro Studies

The key *in vitro* genotoxicity studies on C9-C14 aliphatic hydrocarbons (≤2% aromatics) are presented in Table 2.

Table 2: *In vitro* Genotoxicity Studies on C9-C14 Aliphatic Hydrocarbons (≤2% Aromatics)

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* and *E. coli* strains)	-	-	1	ECHA
Mammalian cell gene mutation (Chinese hamster V 79 cells)	-	-	2	ECHA
Chromosomal aberration (human lymphocytes)	-	-	1	ECHA

*+, positive; -, negative

In Vivo Studies

In two separate studies involving two different C9-C14 aliphatic (<2% aromatic) hydrocarbon fluids, male and female CD-1 mice were given a single oral gavage dose at concentrations of 0, 1,250, 2,500, or 5,000 mg/kg. The frequency of micronucleated polychromatic erythrocytes was not significantly increased in the treated mice compared to that in the controls (ECHA) [Kl. score = 1].

In two separate dominant lethal studies involving two different C9-C14 aliphatic (<2% aromatic) hydrocarbon fluids, male rats were exposed for 6 hours/day for five consecutive days to exposure concentrations of 0, 300, or 900 ppm. There was no evidence of a mutagenic response in the treated rats (ECHA) [Kl. score = 2].

G. Carcinogenicity

No carcinogenicity studies are available on the C9-C14 aliphatic (<2% aromatic) hydrocarbon fluids.

H. Reproductive Toxicity

A C9-C14 aliphatic (<2% aromatic) hydrocarbon fluid was tested in a combined repeated dose toxicity study with a reproductive/developmental toxicity screening test (OECD 422). Male and female SD rats were given oral gavage doses of 0, 25, 150, or 1,000 mg/kg-day. There was no

indication of reproductive toxicity at any dose level. The NOAEL for reproductive toxicity is 1,000 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 1].

A C9-C14 aliphatic (<2% aromatic) hydrocarbon fluid was tested in a reproductive/developmental toxicity screening test (OECD 421). Male and female SD rats given oral gavage doses of 0, 100, 300, or 1,000 mg/kg-day. There was no indication of reproductive toxicity or any effects on the endocrine system at any dose level. The NOAEL for reproductive toxicity is 1,000 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 1].

I. Developmental Toxicity

A C9-C14 aliphatic (<2% aromatic) hydrocarbon fluid was tested in a rat pre-natal developmental toxicity study. Pregnant female rats were exposed by inhalation to 0, 300 or 900 ppm for 6 hours/day during gestation days 6 to 15. There was no evidence of maternal or developmental toxicity at either exposure level. The NOAEL for this study is 900 ppm (ECHA) [Kl. score = 1].

Another C9-C14 aliphatic (<2% aromatic) hydrocarbon fluid was tested in a rat pre-natal developmental toxicity study. Pregnant female rats were exposed by inhalation to 0, 300 or 900 ppm for 6 hours/day during gestation days 6 to 15. There was no evidence of maternal or developmental toxicity at either exposure level. The NOAEL for this study is 900 ppm (ECHA) [Kl. score = 1].

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for C12-C15 aliphatic hydrocarbons (<2% aromatics) follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

A 13-week oral gavage study was conducted on a C9-C14 aliphatic (<2% aromatic) hydrocarbon fluid in rats. There were no adverse effects at 5,000 mg/kg-day, the highest dose tested. The NOAEL of 5,000 mg/kg-day will be used to derive the oral reference dose and the drinking water guidance value for C12-C15 aliphatic hydrocarbons (<2% aromatics).

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 3

UF_D (database uncertainty) = 1

Oral RfD = 5,000/(10 x 10 x 1 x 3 x 1) = 5,000/300 = 17 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (17 x 70 x 0.1)/2 = 60 mg/L

B. Cancer

No carcinogenicity studies are available on C9-C14 aliphatic (<2% aromatic) hydrocarbon fluids. Thus, a cancer reference value was not derived for C12-C15 aliphatic hydrocarbons (<2% aromatics).

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

C12-C15 aliphatic hydrocarbons (<2% aromatics) do not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

C12-C15 aliphatic hydrocarbons (<2% aromatics) has a low acute toxicity concern to aquatic life.

B. Aquatic Toxicity

Acute Studies

There are no aquatic toxicity data on C12-C15 aliphatic hydrocarbons (<2% aromatics). Table 3 lists the results of acute aquatic toxicity studies conducted on a C11-C14 aliphatic hydrocarbon fluid (<2% aromatics).

Table 3: Acute Aquatic Toxicity Studies on C11-C14 Aliphatic Hydrocarbon Fluid (<2% Aromatics)*

Test Substance	Test Species	Endpoint	Results (mg/L) [WAF]	Kl. score
C11-C14, n-alkanes, isoalkanes, cyclics (<2% aromatics)	*Oncorhynchus mykiss*	96-h LL_{50}	>1,000	1
C11-C14, n-alkanes, isoalkanes, cyclics (<2% aromatics)	*Daphnia magna*	48-h LL_{50}	>1,000	1
C11-C14, n-alkanes, isoalkanes, cyclics (<2% aromatics)	*Pseudokirchnerella subcapitata*	72-h LL_{50} 72-hr NOELR	>1,000	1

*All studies used the water accommodated fractions (WAFs) of the test substance.

Chronic Studies

The value for NOELRs were estimated by QSAR model – Petrotox. This model combines a partitioning model used to calculate the aqueous concentration of hydrocarbon components with the Target Lipid Model used to calculate acute and chronic toxicity of non-polar narcotic chemicals. Petrotox computes toxicity based on the summation of the aqueous-phase concentrations of hydrocarbon block(s) that represent a hydrocarbon substance and membrane-water partition coefficients that describe the partitioning of the hydrocarbons between the water and organisms.

The 28-day NOELR (No-Observed-Effect-Loading-Rate) for hydrocarbons, C12-15, aliphatic hydrocarbons (<2% aromatics) in freshwater fish is estimated to be >1,000 mg/L based on growth (ECHA) [Kl. score = 2].

The 28-day NOELR (No-Observed-Effect-Loading-Rate) for hydrocarbons, C12-15, aliphatic hydrocarbons (<2% aromatics) in freshwater invertebrates is estimated to be >1,000 mg/L based on reproduction (ECHA) [Kl. score = 2].

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for C12-C15 aliphatic hydrocarbons (<2% aromatics) follow the methodology:

PNEC water
Using the QSAR model PETRORISK v7.04, the estimated $PNEC_{water}$ value for C11-15-iso- is 0.001 mg/L (CONCAWE) [Kl. score = 2].

PNEC sediment
Using the QSAR model PETRORISK, v7.04 the estimated $PNEC_{sediment}$ value for C11-15-iso- range from 42 to 260 mg/kg soil wet weight (CONCAWE), depending on the composition of the hydrocarbon classes (n- or iso-paraffins and type of cyclic paraffins) (CONCAWE) [Kl. score = 2].

PNEC soil
Using the QSAR model PETRORISK v7.04, the estimated $PNEC_{sediment}$ value for C11-15-iso- is 17 to 100 mg/kg soil wet weight (CONCAWE), depending on the composition of the hydrocarbon classes (n- or iso-paraffins and type of cyclic paraffins) (CONCAWE) [Kl. score = 2].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Hydrocarbons, C11-14, n-alkanes, isoalkanes, cyclics (<2% aromatics) hydrocarbon fluid was readily biodegradable. Thus, C12-C15 aliphatic hydrocarbons (<2% aromatics) is not expected to meet the screening criteria for persistence.

C12-C15 aliphatic hydrocarbons (<2% aromatics) is an UVCB substance that contains constituents that have the potential to bioaccumulate. Thus, C12-C15 aliphatic hydrocarbons (<2% aromatics) meets the screening criteria for bioaccumulation.

Hydrocarbons, C11-14, n-alkanes, isoalkanes, cyclics (<2% aromatics) hydrocarbon fluid did not exhibit acute toxicity to fish, invertebrates, or algae at WAF up to 1,000 mg/L. Thus, C12-C15 aliphatic hydrocarbons (<2% aromatics) is not expected to meet the screening criteria for toxicity.

The overall conclusion is that C12-C15 aliphatic hydrocarbons (<2% aromatics) is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Aspiration Toxicity Category 1

B. Labelling

Danger

C. Pictogram



X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
Immediately flush open eyes with plenty of water for at least 15 minutes. Remove contacts, if present and easy to do. If irritation occurs, get medical attention.

Skin Contact
Wash the contaminated area of with soap and water. Remove and isolate contaminated clothing. Launder contaminated clothing before reuse.

Inhalation
Move person to fresh air. If respiratory irritation, dizziness, nausea, or unconsciousness occurs, seek immediate medical assistance. Give artificial respiration if victim is not breathing.

Ingestion
Do not induce vomiting. Get medical attention immediately.

Notes to Physician
If ingested, material may be aspirated into the lungs and may cause chemical pneumonitis. Treat appropriately.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Use water spray or fog, foam, dry chemical or carbon dioxide. Do not use straight streams of water.

Specific Exposure Hazards
May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: carbon monoxide, carbon oxides.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus and chemical-protective clothing.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Isolate area. Keep unnecessary and unprotected personnel from entering the area. Use personal protective clothing. Ensure adequate ventilation. Wear respiratory protection if ventilation is inadequate. Do not breath mist, vapors, or spray Avoid contact with skin, eye, and clothing.

Environmental Precautions
Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled
Pick up with non-combustible absorbent material and transfer to a container for chemical waste. For large amounts: dike spillage and pump off product into container for chemical waste. Dispose of contaminated material as prescribed.

D. STORAGE AND HANDLING

General Handling
Avoid breathing vapor or aerosol. Keep away from open flames, hot surfaces and sources of ignition. Provide sufficient ventilation in work area.

Storage
Keep container tightly closed and in a dry, well-ventilated place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards

Workplace Australia has not established an occupational exposure standard for C12-C15 aliphatic hydrocarbons (<2% aromatics).

Engineering Controls
Use adequate ventilation to control air-borne concentrations.

Personal Protection Equipment

Respiratory Protection:
If workers are exposed to concentrations at a level that is not adequate to protect work health, they must use appropriate, certified respirators. The following type of respirator should be considered for this material: particulate, dust or mists. For high airborne concentrations, use an approved supplied-air respirator, operated in positive pressure mode.

Hand Protection:
Use gloves chemically resistant to this material. Consult the SDS for appropriate glove barrier materials.

Skin Protection:

Use protective clothing chemically resistant to this material. Selection of specific items such as face shield, boots, apron, or full body suit will depend on the task.

Eye protection*:*
Use chemical goggles.

Other Precautions:
Wash hands, forearms, and face thoroughly after handling chemical products, before eating, smoking, and using the lavatory and at the end of the working period. Appropriate techniques should be used to remove potentially contaminated clothing. Wash contaminated clothing before reusing. Ensure that eyewash stations and safety showers are close to the workstation location.

F. TRANSPORT INFORMATION

C12-C15 aliphatic hydrocarbons (<2% aromatics) is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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METHANOL

This dossier on methanol does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of methanol in its use in drilling muds and hydraulic fracturing fluids. The information presented in this dossier was obtained primarily from the OECD-SIDS documents on methanol (OECD, 2004a, b), and the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch et al., 1997).

I. SUBSTANCE IDENTIFICATION

Chemical Name (IUPAC): Methanol

CAS RN: 67-56-1

Molecular formula: CH_4O

Molecular weight: 32.04

Synonyms: Methyl alcohol, carbinol, wood spirits, wood alcohol, methylol, wood, columbian spirits, colonial spirit, columbian spirit, methyl hydroxide, monohydroxymethane, pyroxylic spirit, wood naphtha.

SMILES: CO

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Physico-Chemical Properties of Methanol

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Colourless liquid	2	ECHA
Melting Point	-97.8°C	2	ECHA
Boiling Point	64.7°C	2	ECHA
Density	0.79 g/cm^3	2	ECHA
Vapour Pressure	169.27 hPa	2	ECHA
Partition Coefficient (log Pow)	-0.77	2	ECHA
Water Solubility	>1,000 g/L [miscible]	2	ECHA
Flash Point	9.7°C	2	ECHA
Auto flammability	455°C @ 1013 hPa	2	ECHA
Viscosity	0.544 – 0.59 mPa s (dynamic)	2	ECHA
Henry's Law Constant	0.461 Pa m^3/mol	2	ECHA

Methanol is a highly flammable liquid.

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Methanol is readily bioavailable. It has a low adsorptive capacity to soils and is unlikely bioaccumulate.

B. Biodegradation

Methanol is readily biodegradable. In a closed bottle test using seawater, there was 84% and 95% degradation after 10 and 20 days, respectively (Price et al., 1974; ECHA). [Kl. score = 2]

In a soil test using [^{14}C]-methanol, there was 53.4% degradation under aerobic conditions after 5 days, as measured by CO_2 evolution; and 46.3% degradation under anaerobic conditions after 5 days, as measured by CO_2 evolution (Scheunert et al., 1987; ECHA). [Kl. score = 2]

C. Environmental Distribution

Adsorption/desorption

The adsorption of methanol was investigated in three different soil types at 6°C (Lokke, 1984; ECHA). There was slight adsorption with the sandy soils tested (percentage organic matter of 0.09% and 0.1% in the samples) and with the clay soil (percentage organic matter was 0.22%). Methanol solutions of concentrations of 0.1, 1.0, 9, and 90 mg/L were used in one-hour exposure adsorption studies; the K_{oc} values were between 0.13 and 0.61 for all soil types and at all concentrations.

D. Bioaccumulation

The BCF of methanol in *Cyprinus carpio* was determined to be 1.0 (Gluth et al. 1985); in *Leuciscus idus*, the BCF was <10 (Hansch and Leo, 1985; Freitag et al. 1985).

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Methanol has a low order of acute toxicity (as measured by lethality) by the oral, dermal, and inhalation routes of exposure, as measured by lethality. Sublethal doses, however, have been shown to produce central nervous system (CNS) effects and ocular injury that may result in blindness. This effect has been seen in primates but not in rodents, and is considered to be due to the differences in blood levels of the metabolites. Acute toxicity in humans is characterized in a well-defined pattern, that includes CNS effects, ocular symptoms, and acidosis. Methanol is not irritating to the skin, but it is slightly irritating to the eyes. Repeated exposures by the oral and inhalation routes have not resulted in any systemic toxicity to rodents. Methanol was not carcinogenic to rats or mice in chronic inhalation studies. Increased tumours from methanol in drinking water were reported by Soffritti et al. (2002); however, there are methodological problems with this study and questions have been raised about the validity of the results. Methanol is generally inactive in a variety of *in vitro* and *in vivo* genotoxicity studies. Conflicting results have been obtained concerning the effect of methanol on testicular hormones in rats; nevertheless, methanol does not appear to a male reproductive toxicant. The primate data indicates that methanol is unlikely to be a reproductive hazard in females. Methanol causes developmental effects at very high exposure levels in both rats (≥ 10,000 ppm) and mice (≥ 2000 ppm). There is also some evidence that it is a developmental neurotoxicant in rodents, but not in primates.

B. Toxicokinetics and Metabolism

Several reviews on the metabolism and pharmacokinetics of methanol are available (Kavet and Nauss, 1990; Liesivuori and Savolainen, 1991; Tephly, 1991; IPCS, 1997; OECD, 2004a, b). Methanol is first oxidized to formaldehyde. This initial metabolic step involves different enzymes in rats than in primates and humans, although the rates are similar. A catalase–peroxidase system is primarily responsible for the initial step in rats, whereas alcohol dehydrogenase plays a major role in humans

and monkeys. Methanol oxidation can also occur via hepatic microsomal oxidation involving the cytochrome P450 system.

Formaldehyde is converted to formic acid, which is converted to formate and a hydrogen ion. Conversion to formic acid is a two-step process, the second step is irreversible. In the first reaction, formaldehyde combines with reduced glutathione (GSH) to form S-formylglutathione. This is mediated by an NAD-dependent formaldehyde dehydrogenase. In the second reaction, thiolase catalyzes the hydrolysis of S-formylglutathione to form formic acid and GSH. A folate-dependent pathway in the liver is responsible for formate metabolism in both rats and primates. Formate first forms a complex with tetrahydrofolate (THF) that is sequentially converted to 10-formyl-THF (by formyl-THF synthetase) and then to CO2 (by formyl-THF dehydrogenase). THF is derived from folic acid in the diet and is also regenerated in the folate pathway. Although the folate pathway metabolizes formate in both rats and monkeys, rats use the pathway more efficiently.

The dermal uptake rate of liquid methanol applied to the forearm of human volunteers was 11.5 mg/cm^2/hr (Dutkiewicz et al., 1980). The dermal flux for methanol in human skin (epidermis) *in vitro* is 8.29 mg/cm^2/hr (Schueplein and Blank, 1971). When 12 human volunteers immersed one hand into a vessel containing neat methanol for up to 16 min, the maximum methanol concentration in blood was reached 1.9 $\pm$ 1.0 hr after exposure. Delivery rates from the skin into blood lagged exposure by 0.5 hours, and methanol continued to enter the blood for 4 hours following exposure. The average derived dermal absorption rate absorption rate was 8.1 $\pm$ 3.7 mg/cm^2/hr. The authors calculated that the maximum concentration of methanol in blood following immersion of one hand in methanol for approximately 20 min is comparable to that reached following inhalation exposures to 200 ppm methanol (Batterman and Franzblau, 1997).

C. Acute Toxicity

The acute oral LD_{50} for rats range from 6,200 to 13,000 mg/kg (Kimura et al., 1971; Welch and Slocum, 1943; Deichman and Mergard, 1948; Smyth et al., 1941). The acute dermal LD_{50} for rabbits was reported to be 20 mL/kg (Rowe and McCollister 1982). The inhalation 4- and 6-hour LC_{50} values in rats are 128.2 and 87.5 mg/L, respectively (BASF, 1980a, b). Sublethal doses, however, produce CNS effects and ocular injury that may result in blindness. This effect has been seen in primates, but not in rodents, and has been attributed to the differences in blood levels of the metabolite, formic acid.

Methanol is metabolized to formate, which is considered to be the ultimate toxicant in acute methanol intoxication in humans. Acute methanol toxicity in humans is characterized by CNS depression, followed by acidosis and ocular injury. Generally, transient CNS effects appear above methanol levels of 200 mg/L and serious ocular symptoms appear above 500 mg/L (OECD, 2004). This blood concentration can transiently be achieved in an adult person (70 kg) by ingestion of 0.4 ml methanol/kg (approximately 0.32 mg/kg). The minimal acute methanol dose to humans that can result in death is considered to be 300 to 1,000 mg/kg by ingestion, and fatalities have occurred in untreated patients with initial methanol blood levels in the range of 1500-2000 mg/L (OECD, 2004). However, such high blood methanol levels able to cause death are not likely to be achieved through inhalation exposure.

D. Irritation

Methanol is not irritating to the skin of rabbits (BASF, 1975), but it is slightly irritating to the eyes of rabbits (BASF, 1975).

E. Sensitization

Methanol was not considered a skin sensitiser to guinea pigs (BASF, 1979).

F. Repeated Dose Toxicity

Oral

Male and female Sprague–Dawley rats were dosed by oral gavage with 0, 100, 500, or 2,500 mg/kg of methanol for 90 days. There were no differences in body weight gain and food consumption between treated and control animals. Brain weights were decreased in both sexes in the 2,500 mg/kg dose group. Elevated serum glutamic pyruvate transaminase and alkaline phosphatase were noted in the 2,500 mg/kg dose group, but there were no adverse treatment-related effects in the gross pathology and histopathological evaluation. The NOAEL is 500 mg-kg-day (USEPA, 1986).

Sprague-Dawley rats were given in their drinking water 0, 500, 5,000 or 20,000 ppm methanol for 104 weeks, and then the animals were maintained until natural death. The study was conducted by the Ramazzini Foundation which uses their own testing guideline for carcinogenicity studies and not an internationally accepted guideline. Treatment with methanol did not decrease survival. However, there was considerable early mortality; by 18 months, 30% of the male controls had died. In females, there were no differences in survival between controls and treated groups. There was still more early mortality in the females than expected, but it was less pronounced that the males. There was no obvious effect of methanol exposure on water consumption. The 20,000 ppm males and females weighed more than the controls (up to 14% and 7%, respectively) throughout the study. The 5,000 ppm females also weighed more (4%) than the controls at 24 months, but not at earlier time points. There were no body weight differences between the remaining treatment groups and the controls. The calculated methanol doses based on water intake were: 0, 55, 542, and 1,840 mg/kg-day for males; and 0, 67, 630, and 2,250 mg/kg-day for females. Nearly all rats in all dose groups had some pathology in the lung. The finding of lung pathology was consistent regardless of the age at death (not an old age response). The lung pathology included inflammation, dysplasia, or tumours). Lung pathology was present in 70-100% of the first 10% of deaths in each group, including controls (70, 80, 80, 100% in males; and 90, 90, 100, 100% in females at 0, 500, 5,000, and 20,000 ppm). The degree of inflammation in the lungs is difficult to assess because no other lung information was recorded for the rats when a neoplasm in the lung was recorded (Soffritti et al., 2002; Cruzan, 2009; USEPA, 2013a). [Kl. score = 3]

Inhalation

Cynomolgus monkeys or Sprague–Dawley rats were exposed by inhalation to 0, 500, 2,000, or 5,000 ppm (0, 660, 2,620, or 6,552 mg/m3) methanol for 6 h/day, 5 days/ week for 4 weeks. There was no mortality and no clinical signs of toxicity among the monkeys, but there a few signs of eye and nose irritation in the rats. No differences were seen between treated and control groups in body weight gain and organ weights, with the exception being decreased absolute adrenal weight in the 5,000 ppm female monkeys and increased relative spleen weights in the 2,000 ppm female rats. These changes were not considered by the authors to be of biological significance. There were no treatment-related effects on the ophthalmoscopy, gross pathology or histopathology. The NOAEL for this study is 5,000 ppm (6,552 mg/m^3) (Andrews et al., 1987). [Kl. score = 4]

Groups of four male rats were exposed by inhalation to 0, 200, 2000, or 10,000 ppm (o, 262, 2,621, or 13,104 mg/m3) methanol for 6 hours/day, 5 days/week for 1, 2, 4, or 6 weeks. Additional groups of animals were exposed for 6 weeks followed by a 6-week recovery period. Evaluation of a number of parameters including lung weights, surfactant levels, and enzyme activities did not reveal any adverse effects on the lung. No histopathological examinations were performed (White et al. 1983). [Kl. score = 2]

Male and female F344 rats were exposed by inhalation to 0, 10, 100, or 1,000 ppm methanol 19.5 hours/day, 7 days/week for 104 weeks. The average methanol doses were: 0, 3.7, 37, and 369 mg/kg-day in males; and 0, 5.9, 60, and 599 mg/kg-day for females. There were no treatment-related clinical

signs and no effect on survival or food consumption. Lower body weights were seen in the 1,000 ppm females beginning around day 259, but after day 574, there was no difference from controls. Body weights in males were similar across all groups. There were no treatment-related effects on urinalysis, hematology, or clinical biochemistry. Nor was there any treatment-related effects on organ weights or gross lesions. Histopathologic examination showed no statistically significant differences between treated and control animals (NEDO, 1985a). [Kl. score = 2]

Male and female B6C3F1 mice were exposed by inhalation to 0, 10, 100, or 1,000 ppm methanol 19.5 hours/day, 7 days/week for 78 weeks. The average methanol doses were: 0, 9.8, 95, and 947 mg/kg-day in males; and 0, 8.1, 106, and 1,071 mg/kg-day for females. There were no treatment-related clinical signs and no effect on survival or body weight. Food consumption was decreased slightly between months 7 and 12 in the 1,000 ppm females. Urinalysis, hematology, and clinical biochemistry were similar across all groups. No differences were seen in organ weights, gross lesions, or histopathology between treated and control mice. (NEDO, 1985b). [Kl. score = 2]

Dermal

No studies were identified.

G. Genotoxicity

In Vitro Studies

Methanol was not mutagenic to *Salmonella* strains TA97, TA98, TA100, TA1535, TA1537, and TA1538 in *in vitro* bacterial mutation assays with or without metabolic activation (De Flora et al., 1984a, b; Florin et al., 1980; Gocke et al.,1981). Equivocal results were obtained with *Salmonella* strain TA102 in the presence of metabolic activation (De Flora et al. 1984b). Methanol was not mutagenic in a DNA-repair test using various strains of *Escherichia coli* WP2 (De Flora et al. 1984a) and in a forward mutation assay using *Schizosaccharomyces pombe* (Abbondandolo et al. 1980).

Methanol did not induce micronuclei in Chinese hamster lung V79 cells in vitro (Lasne et al., 1984). Methanol was mutagenic in the mouse lymphoma assay in the presence of metabolic activation (McGregor et al., 1985), but it was not mutagenic in a Basc test or in a Drosophila, sex-linked, recessive lethal mutation assay (Gocke et al., 1981). Treatment of primary cultures of Syrian golden hamster embryo cells with methanol did not lead to cell transformation (Heidelberger et al., 1983).

In Vivo Studies

Male C57BL/6J mice were exposed by inhalation 0, 800 or 4,000 ppm methanol, 6 hours/day for five days. There were no increased frequencies of micronuclei in blood cells; sister chromatid exchanges, chromosomal aberrations, or micronuclei in lung cells; or synaptosomal complex damage in spermatocytes (Campbell et al., 1991).

Normal or folate-deficient mice were given four daily intraperitoneal injections of up to 2,500 mg/kg of methanol. There was no increase in micronucleated erythrocytes in the treated mice compared to the controls (O'Loughlin et al., 1992).

Male and female NMRI mice were given a single intraperitoneal injection of 0, 1,920, 3,200, or 4,480 mg/kg methanol. There was no increase in micronuclei was observed in the bone marrow at any dose level (Gocke et al., 1981).

H. Carcinogenicity

The carcinogenicity studies conducted on methanol were reviewed by Cruzan (2009) and by the USEPA (2013).

Oral

Male and female SD rats were given in their drinking water 0, 500, 5,000, or 20,000 ppm methanol for 104 weeks. This study was conducted by the Ramazzini Foundation, which uses a unique methodology and not the standardized international testing guidelines. There was excessive early mortality, and lung pathology (inflammation, dysplasia, or tumours) was present in 87 to 94% of those dying anytime during the study. An increase in lympho-immunoblastic lymphomas was reported (Soffritti et al., 2002; Cruzan, 2009; USEPA, 2013). [Kl. score = 3]

Inhalation

Male and female F344 rats were exposed by inhalation to 0, 10, 100, or 1,000 ppm methanol 19.5 hours/day, 7 days/week for 104 weeks. The average methanol doses were: 0, 3.7, 37, and 369 mg/kg-day in males; and 0, 5.9, 60, and 599 mg/kg-day for females. There was no increase in tumours in the methanol-exposed rats and mice (NEDO, 1985a). [Kl. score = 2]

Male and female B6C3F1 mice were exposed by inhalation to 0, 10, 100, or 1,000 ppm methanol 19.5 hours/day, 7 days/week for 78 weeks. The average methanol doses were: 0, 9.8, 95, and 947 mg/kg-day in males; and 0, 8.1, 106, and 1,071 mg/kg-day for females. There was no increase in tumours in the methanol-exposed mice (NEDO, 1985b). [Kl. score = 2]

I. Reproductive Toxicity

The reproductive and developmental toxicity studies were reviewed by the NTP Centre for Evaluation of Risks to Human Reproduction (NTP-CERHR, 2003). Conflicting results have been obtained concerning the effect of methanol on testicular hormones in rats; nevertheless, methanol does not appear to a male reproductive toxicant. The primate data indicates that methanol is unlikely to be a reproductive hazard in females. Methanol causes developmental effects at very high exposure levels in both rats (≥ 10,000 ppm) and mice (≥ 2000 ppm); there is also some evidence that it is a developmental neurotoxicant in rodents, but not in primates.

NICNAS concluded in their human health Tier II assessment for methanol: "Based on the data available, [methanol] is not considered to have reproductive or developmental toxicity in humans."

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for methanol follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

A 90-day oral gavage rat study showed elevated serum enzymes and decreased brain weights in the 2,500 mg/kg-day dose group with a NOAEL of 500 mg/kg-day (USEPA, 1986). The NOAEL of 500 mg/kg-day will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 10
UF_D (database uncertainty) = 1

Oral RfD = 500/(10 x 10 x 1 x 10 x 1) = 500/1000 = 0.2 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD: Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2 L (ADWG, 2011)

Drinking water guidance value = (0.5 x 70 x 0.1)/2 = 1.8 mg/L

B. Cancer

Methanol was not carcinogenic to rats or mice in chronic inhalation studies. Increased tumours from methanol in drinking water were reported by Soffritti et al. (2002); however, there are methodological problems with this study and questions have been raised about the validity of the results. No cancer reference value was derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Methanol is a highly flammable liquid.

It does not exhibit the following physico-chemical properties:

- Explosivity
- Oxidising potential.

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Methanol exhibits a low toxicity concern for aquatic organisms, terrestrial invertebrates, and plants.

B. Aquatic Toxicity

Acute Studies

Table 2 lists the results of acute aquatic toxicity studies conducted on methanol.

Table 2: Acute Aquatic Toxicity Studies on Methanol

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Bluegill	96-hr LC_{50}	15,400	1	Poirer et al. 1986
Salmo gairdneri	96-hr LC_{50}	20,100	1	Call et al., 1983
Pimphales promelas	96-hr LC_{50}	28,100	1	Call et al., 1983
Daphnia magna	96-hr EC_{50}	18,260	2	Dorn et al., 2012; ECHA
Daphnia magna	48-hr EC_{50}	>10,000	2	Kuehn et al., 1989
Selenastrum capricornutum	96-hr EC_{50}	~22,000	2	Cho et al., 2008; ECHA
Chlorella pyrenoidosa	10-14 d EC_{50}	28,400	2	Stratton and Smith, 1988

Chronic Studies

No adequate chronic studies were identified.

C. Terrestrial Toxicity

The terrestrial toxicity studies on methanol are listed below in Table 3.

Table 3: Terrestrial Toxicity Studies on Methanol

Test Species (Method)	Endpoint	Results (mg/kg soil dw)	Klimisch score	Reference
Earthworm *Eisenia fetida* (OECD 222)	35-d EC_{50} 63-d EC_{50}	17,199 26,646	2	ECHA
Folsomia candida (OECD 232)	28-d EC_{25} 28-d NOEC* (reproduction)	2,842 1,000	1	ECHA
Hordeum vulgare (OECD 208)	14-d EC_{50} 14-d NOEC* (seedling emergence)	15,492 12,000	1	ECHA
	14-d EC_{25} 14-d NOEC* (shoot dry mass)	2,538 1,555		
	14-d EC_{25} 14-d NOEC* (root dry mass)	2,823 2,592		
	14-d EC_{25} 14-d NOEC* (shoot length)	4,885 2,592		
	14-d EC_{25} 14-d NOEC* (root length)	5,752 4,320		

* Since only EC_{25} values were available from the test results, NOECs were derived graphically from the representing treatment means.

D. Calculation of PNEC

The PNEC calculations for methanol follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (15,400 mg/L), *Daphnia* (>10,000 mg/L), and algae (22,000 mg/L). There are no well-conducted long-term studies on methanol. Therefore, an assessment of 1,000 has been applied to the lowest reported effect concentration of 10,000 mg/L for *Daphnia*. The $PNEC_{water}$ is 10 mg/L.

PNEC sediment

There are no adequate toxicity studies on sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 6.3 mg/kg wet weight.

The calculations are as follows:

$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$
$= (0.81/1280) \times 1000 \times 10$
$= 6.3$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$K_{sed\text{-}water} = 0.8 + [0.2 \times Kp_{sed}/1000 \times BD_{soilid}]$
$= 0.8 + [0.2 \times 0.02/1000 \times 2400]$
$= 0.81$

Where:
Kp = solid-water partition coefficient (L/kg).
BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$Kp_{sed} = K_{oc} \times f_{oc}$
$= 0.61 \times 0.04$
$= 0.02$

Where:
K_{oc} = organic carbon normalized distribution coefficient (L/kg). The K_{oc} for methanol is 0.61.
F_{oc} = fraction of organic carbon suspended sediment = 0.04 [default].

PNEC soil

Experimental results from chronic studies are available for three trophic levels. The lowest NOEC is 1,000 mg/kg soil dry weight for the arthropod *Folsomia candida*. On the basis that the data consists of long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported long-term NOEC of 1,000 mg/kg soil dry weight. The $PNEC_{soil}$ is 100 mg/kg soil dry weight.

VIII. PBT ASSESSMENT

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009, ECHA, 2008).

Methanol is readily biodegradable and thus it does not meet the screening criteria for persistence.

Based on an experimental BCF of <10 in fish, methanol does not meet the criteria for bioaccumulation.

There are no adequate chronic toxicity studies on methanol. The acute E(L)C_{50} values of methanol in fish, invertebrates and algae is >1 mg/L; thus, it does not meet the screening criteria for toxicity.

The overall conclusion is that methanol is not a PBT substance.

IX. CLASSIFICATION AND LABELLING

A. Classification

Flammable Liquid Category 2
Acute Toxicity Category 3 [Oral]
Acute Toxicity Category 3 [dermal]
Acute Toxicity Category 3 [inhalation]
STOT SE Category 1 [optic nerve, central nervous system]

In the EU, there are concentration limits for the STOT SE classification of methanol. This may or may not apply to GHS classifications for Australian SDS.

Concentration range (%):	
>10	STOT SE Category 1
>3 and <10	STOT SE Category 2

B. Labelling

Danger

C. Pictograms



The health hazard pictogram is omitted if the STOT SE classification for methanol does not apply. (i.e., concentration of methanol is below the concentration limits).

X. SAFETY AND HANDLING

Methanol is used in the drilling mud product ALDACIDE® G ANTIMICROBIAL at a concentration of 0.1% to 1%. The safety and handling of methanol at this concentration in ALDACIDE® G

ANTIMICROBIAL will be provided in the dossier on glutaraldehyde, the major constituent of ALDACIDE® G ANTIMICROBIAL.

Occupational Exposure Standards

The workplace exposure standard for methanol in Australia is 200 ppm (262 mg/m^3 as an 8-hr TWA and 250 ppm (328 mg/m^3) as a 15-min STEL. There is also a skin notation indicating that absorption through the skin may be a significant source of exposure.

A. Transport Information

Methanol is used drilling mud product ALDACIDE® G ANTIMICROBIAL at a concentration of 0.1 to 1%. The transportation information for ALDACIDE® G ANTIMICROBIAL will be provided in the dossier on glutaraldehyde, the major constituent of ALDACIDE® G ANTIMICROBIAL.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

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XIV. ACRONYMS AND GLOSSARY

°C	degrees Celsius
ADWG	Australian Drinking Water Guidelines
BMD	benchmark dose
CERHR	Centre for Evaluation of Risks to Human Reproduction
CNS	central nervous system
DEWHA	Department of the Environment, Water, Heritage and the Arts
ECHA	European Chemicals Agency
EU	European Union
FOB	functional observation battery
GHS	Globally Harmonised System of Classification and Labelling of Chemicals
HHRA	enHealth Human Risk Assessment
IRIS	Integrated Risk Information System
IUPAC	International Union of Pure and Applied Chemistry
kg/m^3	kilograms per cubic metre
LOAEL	lowest observed adverse effect level
$mg/cm^2/hr$	milligrams per square centimetre per hour
mg/kg	milligrams per kilogram
mg/L	milligrams per litre
mg/m^3	milligrams per cubic metre
NICNAS	The National Industrial Chemicals Notification and Assessment Scheme
NOAEL	no observed adverse effect level
NOEC	no observed effective concentration
NPT	National Toxicology Program
OECD	Organisation for Economic Co-operation and Development
PBT	Persistent, Bioaccumulative and Toxic
ppm	parts per million
RfD	oral Reference dose
SIDS	Screening Information Data Set
SMILES	simplified molecular-input line-entry system
STOT SE	Specific Target Organ Toxicity - Single Exposure
THF	tetrahydrofolate
TLV	threshold limit value
USEPA	United States Environmental Protection Agency

MONOETHANOLAMINE BORATE

This dossier on monoethanolamine borate does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of monoethanolamine borate in its use in drilling muds and hydraulic fracturing fluids. The majority of information presented in this dossier was obtained from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name: Monoethanolamine borate

CAS RN: 26038-87-9 (EC No. 701-025-6)

Molecular formula: $C_2H_7NO.xBH_3O_3$ [UVCB substance]

Synonyms: Monoethanolamine borate; orthoboric acid, compound with 2-aminoethanol; boric acid (H_3BO_3), reaction products with ethanolamine; MEA polyborate

In this dossier, data on CAS No. 68512-53-8 (Boric acid, reaction products with monoethanolamine [MEA] and triethanolamine [TEA]) has been used to read-across to monoethanolamine borate.

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Monoethanolamine Borate

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Liquid	2	ECHA
Density	$\leq$1.245 g/cm^3 @ 20°C	2	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Monoethanolamine borate is readily biodegradable. It will not adsorb significantly to suspended solids and sediments in water and would be highly mobile in soil. No information is available on the potential for monoethanolamine borate to bioaccumulate.

B. Biodegradation

Monoethanolamine borate 1:1 is readily biodegradable. In a modified Sturm test (OECD 301B), degradation was 73% after 28 days; the 10-day window was met (ECHA). [Kl. score = 1]

Monoethanolamine borate 1:3 is readily biodegradable. In a modified Sturm test (OECD 301B), degradation was 75% after 28 days; the 10-day window was met (ECHA).

D. Environmental Distribution

Adsorption/desorption

The log K_{oc} was determined for monoethanolamine borate 1:1 and monoethanolamine borate 1:3 on soil and on sewage sludge using high performance liquid chromatography (HPLC). Both the monoethanolamine and the polyborate part of both substances did not significantly adsorb to soil. The experimental log K_{oc} was determined to be approximately 1.26 [K_{oc} = 18.2 L/kg] (ECHA). [Kl. score = 1]

E. Bioaccumulation

No bioconcentration studies are available. No information is available on the octanol-water partition coefficient for monoethanolamine borate.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Limited toxicity data are available for monoethanolamine borate. Data on CAS No. 68512-53-8 (boric acid reaction product with MEA and TEA) has been used to read-across to monoethanolamine borate. Monoethanolamine borate exhibits low acute toxicity by the oral and dermal routes. Monoethanolamine borate is not irritating to the skin and eyes, and has a low potential for skin sensitization. Repeated oral exposures of CAS No. 68512-53-8 to rats showed no adverse effects. Monoethanolamine borate is not genotoxic. No carcinogenicity, reproductive or developmental toxicity studies have been conducted on monoethanolamine borate or CAS No. 68512-53-8.

B. Acute Toxicity

The acute oral LD_{50} in rats is >2,000 mg/kg (ECHA) [Kl. score = 1].

No acute inhalation studies are available on monoethanolamine borate.

There are no dermal toxicity studies on monoethanolamine borate. The acute dermal LD_{50} of CAS 68512-53-8 (boric acid reaction product with MEA and TEA) in rats is >2,000 mg/kg (ECHA). [Kl. score = 1]

C. Irritation

Application of 0.5 g monoethanolamine borate to the skin of rabbits for 4 hours under semi-occlusive conditions was essentially non-irritating. The mean of the 24, 48, and 72 hour scores were approximately 0.1 for erythema and 0.00 for edema (ECHA) [Kl. score = 1).

Monoethanolamine borate 1:1 and monoethanolamine borate 1:3 were tested for eye irritancy using the Bovine Corneal Opacity and Permeability test (BCOP test). Minimal to no ocular irritation was observed in both studies (ECHA) [Kl. scores = 1].

D. Sensitization

There are no skin sensitization studies on monoethanolamine borate. CAS No. 68512-53-8 (boric acid reaction product with MEA and TEA) was not a skin sensitizer to guinea pigs using the Buehler method (ECHA) [Kl. score = 2).

E. Repeated Dose Toxicity

Oral

No studies are available on monoethanolamine borate.

Male and female SD rats were dosed daily by oral gavage with 0, 62.5, 250 or 1,000 mg/kg CAS No. 68512-53-8 (boric acid reaction product with MEA and TEA) for 28 days. There were no deaths during the study. Clinical signs, body weights, feed consumption, and neurobehavior (FOB, motor activity) were unaffected by treatment. Hematology parameters, clinical chemistry, and urinalysis were within normal range for treated and control animals. There were no treatment-related effects on organ weights, and gross necropsy findings and histopathologic examination showed no effects attributed to treatment. The NOAEL for this study is 1,000 mg/kg-day (ECHA) [Kl. score = 1].

Inhalation

No studies are available.

Dermal

No studies are available.

F. Genotoxicity

The results of in vitro genotoxicity studies on monoethanolamine borate and structurally similar substance CAS No. 68512-53-8 (boric acid reaction product with MEA and TEA) are shown in Table 2.

In Vitro Studies

Table 2: *In vitro* Genotoxicity Studies on Monoethanolamine Borate and CAS No. 68512-53-8 (Boric Acid Reaction Product with MEA and TEA)

Test System	Test Substance	Results*		Klimisch Score	Reference
		-S9	+S9		
Bacterial reverse mutation (S. typhimurium strains)	CAS No. 68512-53-8**	-	-	1	ECHA
Mammalian cell gene mutation (CHL V79 cells)	CAS No. 68512-53-8**	-	-	1	ECHA
Chromosomal aberration (Human lymphocytes)	Monoethanolamine borate 1:1	-	-	1	ECHA
Chromosomal aberration (human lymphocytes)	Monoethanolamine borate 1:3	-	-	1	ECHA

*+, positive; -, negative
** Boric acid reaction product with MEA and TEA.

In Vivo Studies

No studies are available.

G. Carcinogenicity

No studies are available.

H. Reproductive Toxicity

No studies are available.

I. Developmental Toxicity

No studies are available.

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for monoethanolamine borate follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

The were no adverse effects seen in rats given oral gavage doses of CAS No. 68512-53-8 (boric acid, reaction products with MEA and TEA) for 28 days (ECHA). The NOAEL for this study is 1,000 mg/kg-day, the highest dose tested. The NOAEL from this study will be used for determining the oral Reference dose (RfD) and the drinking water guidance value for monoethanolamine borate.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 10
UF_D (database uncertainty) = 1

Oral RfD = 1,000/(10 x 10 x 1 x 10 x 1) = 1,000/1,000 = 1.0 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,

Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (1.0 x 70 x 0.1)/2 = 3.5 mg/L

B. Cancer

No studies have been conducted on monoethanolamine borate. Therefore, a cancer reference value has not been derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Monoethanolamine borate does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Monoethanolamine borate has moderate acute toxicity concern to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies conducted on monoethanolamine borate.

Table 3: Acute Aquatic Toxicity Studies on Monoethanolamine Borate

Test Species	Test Substance	Endpoint	Results (mg/L)	Klimisch score	Reference
Danio rario	Monoethanol-amine borate	96-h LC_{50}	>100	1	ECHA

	1:1				
Carp	Monoethanol-amine borate 1:3	96-h LC_{50}	617	1	ECHA
Daphnia magna	Monoethanol-amine borate 1:3	48-h EC_{50}	496	1	ECHA
Daphnia magna	Monoethanol-amine borate 1:1	48-h EC_{50}	423	1	ECHA
Pseudokirchneriella subcapitata	Monoethanol-amine borate 1:3	72-h EC_{50} NOEC	67 (growth rate) 72 (biomass) 18 (growth rate)	1	ECHA
Pseudokirchneriella subcapitata	Monoethanol-amine borate 1:1	72-h EC_{50}	26 (growth rate) 13 (biomass) 3.2 (growth rate)	1	ECHA

Chronic Studies

No studies are available.

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for monoethanolamine borate follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (617 mg/L), *Daphnia* (423 mg/L), and algae (26 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported $E(L)C_{50}$ value of 26 mg/L for algae. The $PNEC_{water}$ is 0.026 mg/L.

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 0.02 mg/kg sediment wet weight.

The calculations are as follows:

$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$
$= (1.15/1280) \times 1000 \times 0.026$
$= 0.02$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$K_{sed\text{-}water} = 0.8 + [0.2 \times Kp_{sed})/1000 \times BD_{solid}]$
$= 0.8 + [0.2 \times 0.73/1000 \times 2400]$
$= 1.15$

Where:
Kp_{sed} = solid-water partition coefficient (L/kg).
BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$Kp_{sed} = K_{oc} \times f_{oc}$
$= 18.2 \times 0.04$
$= 0.73$

Where:
K_{oc} = organic carbon normalized distribution coefficient (L/kg). The experimental K_{oc} for monoethanolamine borate is 18.2 L/kg.
F_{oc} = fraction of organic carbon in sediment = 0.04 [default].

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is 0.006 mg/kg soil dry weight.

The calculations are as follows:

$PNEC_{soil}$ = (Kp_{soil}/BD_{soil}) x 1000 x $PNEC_{water}$
= (0.36/1500) x 1000 x 0.026
= 0.006

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

Kp_{soil} = K_{oc} x f_{oc}
= 18.2 x 0.02
= 0.36

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The experimental K_{oc} for monoethanolamine borate is 18.2 L/kg.
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Monoethanolamine borate is readily biodegradable; thus it does not meet the screening criteria for persistence.

No bioconcentration studies have been conducted on monoethanolamine borate. It is a UVCB substance and a log K_{ow} has not been determined. Thus the bioaccumulation potential for monoethanolamine borate is not known.

No chronic aquatic toxicity studies are available for monoethanolamine borate. The acute E(L)C_{50} values in fish, invertebrates and algae are >1 mg/L. Thus monoethanolamine borate does not meet the criteria for toxicity.

The overall conclusion is that monoethanolamine borate is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

[Acute Aquatic Toxicity Category 3]

B. Labelling

No signal word.

C. Pictogram

None

X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
Immediately flush open eyes with plenty of water for at least 15 minutes. Remove contacts, if present and easy to do. If effects occur, get medical attention immediately, preferably a physician for an ophthalmologic examination.

Skin Contact
Remove contaminated clothing. Wash thoroughly with soap and water. Seek medical attention if irritation persists.

Inhalation
If inhaled, remove from area to fresh air. Give artificial respiration if victim is not breathing. Get medical attention.

Ingestion
Rinse mouth with water and then drink a small amount of water. Get medical attention. Never give anything by mouth to an unconscious person.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: nitrogen oxides, carbon monoxide, carbon dioxide.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus and chemical-protective clothing.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Use appropriate protective equipment. Handle in accordance with good industrial hygiene and safety practice. Avoid contact with skin, eyes, and clothing.

Environmental Precautions
Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled
For large amounts: dike spillage and pump off product. For residues: pick up with suitable absorbent material. Dispose of contaminated material as prescribed.

D. STORAGE AND HANDLING

General Handling
Ensure adequate ventilation, especially in confined areas. Avoid breathing vapors.

Storage
Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
Workplace Australia has not established an occupational exposure standard for monoethanolamine borate.

Engineering Controls
Good general ventilation should be used.

Personal Protection Equipment

Respiratory Protection:
Use respiratory protection in case of vapor or aerosol release.

Hand Protection:
Chemical resistant protective gloves.

Skin *Protection*:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Safety glasses with side-shields.

Other Precautions:

Handle in accordance with good industrial hygiene and safety practice. Wearing of closed work clothing is recommended. Ensure that eyewash stations and safety showers are close to the workstation location.

F. TRANSPORT INFORMATION

Monoethanolamine borate is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

Department of the Environment, Water, Heritage and the Arts [DEWHA] (2009). Environmental risk assessment guidance manual for industrial chemicals, Department of the Environment, Water, Heritage and the Arts, Commonwealth of Australia.

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SILICON DIOXIDE

This dossier on silicon dioxide does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of silicon dioxide in its use in drilling muds and hydraulic fracturing fluids. The majority of information presented in this dossier was obtained from the OECD-SIDS documents on synthetic amorphous silica and silicates (OECD 2004a,b), and the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC): Silicon dioxide

CAS RN: 112926-00-8

Molecular formula: $nSiO_2$

Molecular weight: 60.08

Synonyms: Silicon dioxide; synthetic amorphous silica; silica gel; precipitated silica, crystalline-free

SMILES: O=[Si]=O

Silicon dioxide is the IUPAC name for synthetic amorphous silica (SAS) [CAS No. 7631-86-9]; it can be produced by a "wet process" or by a "thermal or fumed process." Silica gel and precipitated silica, crystalline-free (CAS No. 112926-00-8) is a SAS prepared by the "wet process." Silica, amorphous, fumed, crystalline-free (CAS No. 112945-52-5) is a SAS prepared by flame hydrolysis.

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Silicon Dioxide

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Powder, granules, pellets	2	ECHA
Melting Point	1,713°C	2	ECHA

Boiling Point	2.2 g/cm^3	2	ECHA
Water Solubility	76 – 128 mg/L* (slightly soluble)	1	ECHA

*Based on dissolved SiO_2.

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Silicon oxides are the most abundant compounds in the earth's crust mass. Silicon dioxide (CAS No. 112926-00-8) released into the environment is expected to combine indistinguishably with the soil layer or sediment due to their chemical similarity with inorganic soil matter (OECD, 2004a).

Biodegradation is not applicable to silicon dioxide (CAS No. 112926-00-8). The bioavailable form of silicon dioxide (CAS No. 112926-00-8) is the dissolved form which exists exclusively monosilicic [$Si(OH)_4$] acid under environmental pH (OECD, 2004a). Although the water-soluble fraction of silicon dioxide (CAS No. 112926-00-8) acts as weak acid, pH changes are not likely to occur in the environment due to low aquatic releases and sufficient natural buffer capacities (OECD, 2004a).

Bioaccumulation of silicon dioxide (CAS No. 112926-00-8) is generally unlikely to occur. However, dissolved silica can be actively assimilated by some marine and terrestrial organisms as normal natural processes mainly related to structural function.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

The oral bioavailability of silicon dioxide in animals and humans is low. Absorbed silicon dioxide is rapidly eliminated and there is no accumulation in the body. The bioavailablity of silicon dioxide by the inhalation route is low. While there is deposition in the lungs following inhalation exposure to silicon dioxide, it is rapidly eliminated. The acute toxicity of silicon dioxide is low by the oral, inhalation, and dermal routes. Silicon dioxide is not irritating to the skin and eyes. Repeated oral exposures to rodents showed no adverse effects. Repeated inhalation exposure to high respirable levels of silicon dioxide resulted in an inflammatory response in the respiratory tract and lungs, which was reversible following cessation of exposure. Silicon dioxide is not genotoxic. Although the study was of poor quality, there was no evidence of adverse effects on reproduction in rats given silicon dioxide in the diet. Animal studies showed no adverse effects on fetal development from oral exposure to silicon dioxide.

B. Toxicokinetics/Metabolism

The oral bioavailability of silicon dioxide in animals and humans is low. Absorbed silicon dioxide is rapidly eliminated and there is no accumulation in the body. The bioavailablity of silicon dioxide by the inhalation route is low. While there is deposition in the lungs following inhalation exposure to silicon dioxide, it is rapidly eliminated (OECD, 2004a,b).

C. Acute Toxicity

The oral LD_{50} of silicon dioxide (CAS No. 112926-00-8) in rats from two different studies is >5,000 mg/kg (ECHA) [Kl. scores = 1].

The 4-hour inhalation LC_{50} in rats for an aerosol of silicon dioxide (CAS No. 112926-00-8) is >0.69 mg/L, which was the maximum technically attainable concentration. The mass median aerodynamic diameter (MMAD) was approximately 0.6 μm, and approximately 65% of the mass was <6 μm (ECHA) [Kl. score = 2].

The 4-hour inhalation LC_{50} in rats for an aerosol of silicon dioxide (CAS No. 112945-52-5) is >2.08 mg/L. The mass median aerodynamic diameter (MMAD) was approximately 0.76 μm, and approximately 98-99.4% of the mass was <10 μm (ECHA) [Kl. score = 2].

The 4-hour inhalation LC_{50} in rats for an aerosol of silicon dioxide (CAS No. 112945-52-5) from a nose-only exposure is >0.14 mg/L, which was the maximum technically attainable concentration. The mass median aerodynamic diameter (MMAD) was 3.2 μm, and 47-50% of the mass was <6 μm (ECHA) [Kl. score = 2].

The dermal LD_{50} in rabbits is >5,000 mg/kg (no deaths) (ECHA) [Kl. score = 2].

D. Irritation

Application of 0.5 g silicon dioxide (CAS No. 112926-00-8) to the skin of rabbits for 4 hours under occlusive conditions was not irritating. (ECHA) [Kl. score = 1].

Instillation of 0.1 g silicon dioxide (CAS No. 112926-00-8) to the eyes of rabbits was minimally irritating (ECHA) [Kl. score = 1].

E. Sensitization

No studies are available.

F. Repeated Dose Toxicity

Oral

Male and female Wistar rats were given diets containing silicon dioxide (CAS No. 112926-00-8) for 90 days. The dietary concentrations as silica concentrations were 0, 0.4-0.7, 1.7-1.9, or 6.5-7.0% silica; this equates to 0, 300-330, 1,200-1,400, or 4,000-4,500 mg/kg CAS No. 112926-00-8. There were no treatment-related effects. The NOAEL is 4,000 to 4,500 mg/kg-day (ECHA). [Kl. score = 1]

Male and female CD rats were given diets containing silicon dioxide (CAS No. 112926-00-8) for 6 months. The estimated daily intakes were 0, 2,170, and 7,950 mg/kg-day for males, and 0, 2,420, and 8,980 mg/kg-day for females. There were no treatment-related effects. The NOAEL is 7,950 and 8,980 mg/kg-day for males and females, respectively (ECHA). [Kl. score = 1]

Male and female Fischer 344 rats were fed a diet containing a synthetic amorphous silica (CAS No. not stated) for 102 weeks. The dose levels were 0, 12,500, 25,000, and 50,000 ppm. There were no treatment-related effects on body weight gain, feed consumption, survival, or hematology parameters. Liver weights were lower (up to 15%) in the $\geq$25,000 ppm females from 12 to 24 months; a dose-related trend was not apparent. The NOAEL is 50,000 ppm. Using 0.05 as the fraction of body weight that rats consume per day as food (U.S. EPA), the NOAEL corresponds to 2,500 mg/kg-day (Takizawa *et al.*, 1988) [Kl. score = 2].

Male and female $B6C3F_1$ mice were fed a diet containing a synthetic amorphous silica (CAS No. not stated) for 93 weeks. The dose levels were 0, 12,500, 25,000, and 50,000 ppm. There were no treatment-related effects on survival or clinical signs. Body weight gain was lower in the 5% group from week 15 to week 50 for the males and from 30 to 50 for the females. Mean body weights for 5% group animals for the remainder of the study were similar to controls. The NOAEL is 50,000 ppm in the diet. Using 0.13 as the fraction of body weight that mice consume per day as food (U.S. EPA), the NOAELs corresponds to 6,500 mg/kg-day (Takizawa et al., 1988). [Kl. score = 2]

Inhalation

Male and female Wistar rats were exposed by inhalation to 0, 1, 6, or 30 mg/m^3 silicon dioxide (CAS No. 112945-52-5) 6 hours/day, 5 days/week for 13 weeks. There were no deaths during the study. Respiration rates were increased in a concentration-dependent manner. Body weight and body weight gain were unaffected in females, but were lower in the males with the 30 mg/m^3 groups significantly affected throughout the study. At $\geq$6 mg/m^3, there were hematological changes, increased lung weights, and histopathologic changes in the lungs (including collagen increase and sporadic focal fibrosis). At 1 mg/m^3, there was a slight, but fully reversible, pulmonary response indicative of an inflammatory reaction. The NOAEC for this study is 1.3 mg/m^3 (ECHA) [Kl. score = 1].

Dermal

No adequate studies are available.

G. Genotoxicity

In Vitro Studies

The results of *in vitro* genotoxicity studies on silicon dioxide are presented below in Table 2.

Table 2: *In vitro* Genotoxicity Studies on Silicon Dioxide

Test System	Test substance	Results*		Klimisch Score	Reference
		-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* strains)	CAS No. 112926-00-8	-	-	2	Prival *et al.* (1991)
Bacterial reverse mutation (*E. coli* strains)	CAS No. 112926-00-8	-	-	2	Prival *et al.* (1991)
Bacterial reverse mutation (*S. typhimurium* strains)	CAS No. 112945-52-5	-	-	1	ECHA
Mammalian cell gene mutation (CHO cells)	CAS No. 112945-52-5	-	-	1	ECHA
Chromosomal aberration (Human embryonic lung cells, WI-38)	CAS No. 112926-00-8	NA	-	2	ECHA
Chromosomal aberration (CHO cells)	CAS No. 112945-52-5	-	-	1	ECHA
Unscheduled DNA synthesis (primary rat hepatocytes)	CAS No. 112945-52-5	NA	-	1	ECHA

*+, positive; -, negative; NA, not applicable.

In Vivo Studies

Male F344 rats were exposed by inhalation to 0 or 50 mg/m^3 silicon dioxide (CAS No. 112945-52-5) 6 hours/day, 5 days/week for 13 weeks. When tested in a HPRT assay,

there was no increase in mutation frequency in the alveolar Type II cells from exposed rats compared to controls (ECHA) [Kl. score = 2].

Male SD rats were given by oral gavage either a single dose of 0, 1,4, 14, or 140 mg/kg silicon dioxide (CAS No. 112926-00-8), or five consecutive daily doses of 0, 500, or 5,000 mg/kg silicon dioxide (CAS No. 112926-00-8). Chromosomal aberrations were not significantly increased in the treated animals compared to controls (ECHA) [Kl. score = 2].

In a dominant lethal mutation assay, male SD rats were given by oral gavage either a single dose of 0, 1,4, 14, or 140 mg/kg silicon dioxide (CAS No. 112926-00-8), or five consecutive daily doses of 0, 500, or 5,000 mg/kg silicon dioxide (CAS No. 112926-00-8). There was no indication of a mutagenic effect by silicon dioxide (CAS No. 112926-00-8) (ECHA) [Kl. score = 2].

H. Carcinogenicity

Oral

Male and female Fischer 344 rats were fed a diet containing a synthetic amorphous silica (CAS No. not stated) for 102 weeks. The dose levels were 0, 12,500, 25,000, and 50,000 ppm. The incidence of tumors was similar between treated and control animals. The number of animals used in this study was small (Takizawa *et al.*, 1988). [Kl. score = 2]

Male and female $B6C3F_1$ mice were fed a diet containing a synthetic amorphous silica (CAS No. not stated) for 93 weeks. The incidence of tumors was similar between treated and control animals (Takizawa *et al.*, 1988). [Kl. score = 2].

I. Reproductive Toxicity

A one-generation reproductive toxicity study has been conducted on silicon dioxide (CAS No. 112945-52-5). Male and female Wistar rats were given diets containing 0 or 497 mg/kg-day (males) or 509 mg/kg-day (females). In the parental animals, there were no treatment-related effects on mortality, clinical symptoms, feed consumption, body weight gain, and measured hematology parameters. There was no reproductive or developmental toxicity (ECHA) [Kl. score = 3].

J. Developmental Toxicity

Pregnant female rats were given by oral gavage doses up to 1,350 mg/kg silicon dioxide (CAS No. 112926-00-8) on GD 6-15. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity is 1,350 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 2].

Pregnant female mice were given by oral gavage doses up to 1,340 mg/kg silicon dioxide (CAS No. 112926-00-8) on GD 6-15. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity is 1,340 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 2].

Pregnant female rabbits were given by oral gavage doses up to 1,600 mg/kg silicon dioxide (CAS No. 112926-00-8) on GD 6-18. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity is 1,600 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 2].

Pregnant female Syrian hamsters were given by oral gavage up to 1,600 mg/kg silicon dioxide (CAS No. 112926-00-8) on GD 6-10. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity is 1,600 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 2].

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for silicon dioxide (CAS No. 112945-00-8) follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

There were no adverse effects seen in rats or mice fed a diet containing up to 50,000 ppm silicon dioxide (CAS No. not stated) for 102 and 93 weeks, respectively (Takizawa *et al.*, 1988). The NOAELs for rats and mice were 2,500 and 6,500 mg/kg-day, respectively. The lowest NOAEL of 2,500 mg/kg-day will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 2,500/(10 x 10 x 1 x 1 x 1) = 2,500/100 = 25 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (25 x 70 x 0.1)/2 = 88 mg/L

B. Cancer

Silicon dioxide was not carcinogenic to rats or mice in chronic dietary studies. Hence, a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Silicon dioxide does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Silicon dioxide has a low acute toxicity concern to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies conducted on silicon dioxide.

Table 3: Acute Aquatic Toxicity Studies on Silicon Dioxide

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Danio rerio	96-h LL_0	10,000*	1	ECHA
Danio rerio	96-h LL_0	10,000	1	ECHA
Daphnia magna	48-h EL_{50}	>1,000**	2	ECHA
Daphnia magna	24-h EL_{50}	>10,000	2	ECHA

*Silica, amorphous, fumed, crystalline-free (CAS No. 112945-52-5)
**Mortality may have occurred may have occurred from physical effects of unfiltered medium.

Chronic Studies

No studies are available.

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for silicon dioxide follow the methodology discussed in DEWHA (2009).

PNEC water

Silicon dioxide is a solid in powder form, which is slightly soluble in water. Acute aquatic toxicity studies on fish and *Daphnia* using excess loadings of silicon dioxide showed no acute toxicity (Table 3). Physical effects of silicon dioxide on *Daphnia* were seen in tests using unfiltered test medium (OECD, 2004a,b; ECHA). Because of the physico-chemical properties of silicon dioxide, the $PNEC_{water}$ was not determined.

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. The $PNEC_{sed}$ cannot be derived using the equilibrium partitioning method.

PNEC soil

There are no toxicity data for terrestrial or soil organisms. The $PNEC_{soil}$ cannot be derived using the equilibrium partitioning method.

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Silicon dioxide (CAS No. 111945-00-8) released into the environment is expected to combine indistinguishably with the soil layer or sediment due to their chemical similarity with inorganic soil matter. Biodegradation is not applicable to silicon dioxide (CAS No. 112926-00-8). For the purposes of this PBT assessment, the persistent criteria is not considered applicable to silicon dioxide (CAS No. 112926-00-8).

Silicon dioxide (CAS No. 112926-00-8)is an inorganic substance that is a slightly soluble powder. Bioaccumulation of silicon dioxide (CAS No. 112926-00-8) is generally unlikely to occur, given its low bioavailability. However, dissolved silica can be actively assimilated by some marine and terrestrial organisms as normal natural processes mainly related to structural function. For the purposes of this PBT assessment, silicon dioxide (CAS No. 112926-00-8) does not meet the criteria for bioaccumulation.

The acute toxicity of the water-soluble fraction of silicon dioxide (CAS No. 112926-00-8) is >1 mg/L. Thus, it does not meet the criteria for toxicity.

The overall conclusion is that silicon dioxide (CAS No. 112926-00-8) is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

No classified.

B. Labelling

No signal word.

C. Pictogram

None.

X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. If symptoms persist, seek medical advice.

Skin Contact
Wash thoroughly with soap and water.

Inhalation
If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Ingestion
Rinse mouth with water and then drink plenty of water. Never give anything by mouth to an unconscious person. If symptoms develop, seek medical advice.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
No data are available.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Use appropriate protective equipment.

Environmental Precautions
Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled

Scoop up and remove.

D. STORAGE AND HANDLING

General Handling
No special measures necessary provided product is used correctly.

Other Handling Precautions
Avoid eye and skin contact. Avoid creating or inhaling dust.

Storage
Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
The workplace exposure standard for silica gel (silicon dioxide, CAS No. 112926-00-8) in Australia is 10 mg/m^3 as an 8-hour TWA.

Engineering Controls
Good general ventilation should be used.

Personal Protection Equipment

Respiratory Protection:
Use respiratory protection if airborne dust levels are expected to exceed the occupational exposure guidance value.

Hand Protection:
Use gloves.

Skin *Protection*:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Safety glasses with side-shields.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible.

F. TRANSPORT INFORMATION

Silicon dioxide is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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SODIUM BISULFITE

This dossier on sodium bisulfite does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of sodium bisulfite in water treatment systems. The information presented in this dossier was obtained mainly from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC): Sodium hydrogen sulfite

CAS RN: 7631-90-5

Molecular formula: $NaHSO_3$

Molecular weight: 104.1

Synonyms: Sodium bisulfite; sodium hydrogen sulfite; sodium hydrogensulfite; monosodium sulfite; sodium sulfhydrate; hydrogen sodium sulfite; sulfurous acid, monosodium salt

SMILES: OS(=O)[O].[Na]

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Physico-chemical Properties of Sodium Bisulfite

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	White, crystalline, solid	-	HSDB
Melting Point	Decomposes	-	HSDB
Density	1.348 g/cm^3	1	ECHA
Vapor Pressure	Not applicable	-	-
Partition Coefficient (log K_{ow})	Not applicable	-	-
Water Solubility	Very soluble	2	ECHA

Sodium bisulfite is a weak acid with a pK_a of 6.97. Its conjugate base is the sulfite ion (SO_3^{2-}).

$NaHSO_3 \leftrightarrow Na^+ + HSO_3^-$

$HSO_3^- \leftrightarrow H^+ + SO_3^{2-}$

At neutral pH, a mixture of 50% sulfite (SO_3^{2-}) and 50% bisulfite (HSO_3^{2-}) is present.

In surface waters, sulfite is oxidized to sulfate either catalytically by air oxygen or by microbial action (OECD, 2008). The presence of cations like iron, copper or manganese in the environment accelerates the oxidation rate significantly.

Dissociation of sodium bisulfite in aqueous solutions can also liberate sulfur dioxide (SO_2), which is a gas.

III. ENVIRONMENTAL FATE PROPERTIES

At environmental pHs, sodium bisulfite dissociates in water to form sodium (Na^+) ions, bisulfite ions (HSO_3^-), sulfite (SO_2^{3-}) ions, and sulfur dioxide (SO_2) which is a gas.

Sodium bisulfite is not expected to bioaccumulate in the environment because of its dissociation to ionic species and a gas. Furthermore, sulfite will oxidize to sulfate, which is ubiquitous in the environment.

Sodium bisulfite and its dissociated species are expected to have a low potential to adsorb to soil and sediment.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Limited toxicity data are available on sodium bisulfite; therefore, structural analogues have been used to read-across to sodium bisulfite. Sodium sulfite has low acute toxicity by the oral, inhalation, and dermal routes. Sodium sulfite is minimally irritating to the skin and slightly irritating to the eyes. Sodium sulfite is not a skin sensitizer. No systemic toxicity was seen in rats when given sodium metabisulfite in their diet over a lifetime. There were, however, indications of stomach lesions as a result of localized irritation from the ingestion of sodium metabisulfite. Sodium bisulfite is not expected to be genotoxic. No reproductive or developmental toxicity was observed in any of the animal studies on sodium bisulfite or its structural analogues.

B. Acute Toxicity

No acute toxicity studies are available for sodium bisulfite.

The oral LD_{50} value in rats for sodium sulfite is 2,610 mg/kg (ECHA) [Kl. score = 2]. The oral LD_{50} values in rats for sodium metabisulfite are 1,420 mg/kg (males), 1,630 mg/kg (females), and 1,540 mg/kg (combined sexes) (ECHA) [Kl. score = 2].

The 4-hour inhalation LC_{50} in rats for sodium sulfite is >5.5 mg/L (ECHA). [Kl. score = 2]

The dermal LD_{50} in rats for sodium sulfite is >2,000 mg/kg (ECHA). [Kl. score = 2]

C. Irritation

No studies are available on sodium bisulfite.

Application of 0.5 mL of sodium sulfite to the skin of rabbits for 4 hours under occlusive conditions was minimally irritating. The mean of the 24, 48, and 72 scores were: 0.5 for erythema and 0.0 for edema (ECHA). [Kl. score = 2]

Instillation of 0.1 mL of sodium sulfite (with 0.5% cobalt sulfate) into the eyes of rabbits produced slight irritation. The mean of the 24, 48, and 72 hour scores are as follows: 0.5 for conjunctival redness; 0.5 for conjunctival chemosis; 0.0 for corneal lesions; and 0.0 for iridial lesions (ECHA). [Kl. score = 2]

D. Sensitization

No studies are available on sodium bisulfite.

Sodium bisulfite was not considered a skin sensitizer in a mouse local lymph node assay (ECHA). [K. score = 1]

E. Repeated Dose Toxicity

Oral

No studies are available on sodium bisulfite.

A study is available on sodium metabisulfite. Sodium metabisulfite dissociates in water to form sodium (Na^+) ions, disulfite ($S_2O_5^{2-}$) ions, and sulfur dioxide (SO_2). The disulfite ions can form bisulfite (HSO_3^-) and sulfite ions (SO_2^{3-}); at neutral pH, a mixture of 50% sulfite (SO_3^{2-}) and 50% bisulfite (HSO_3^{2-}) is present.

Male and female Wistar rats were fed in their diet 0, 0.125, 0.25, 0.5, 1.0, or 2.0% sodium metabisulfite for up to two years and over three generations. The diet was enriched with thiamine to prevent thiamine deficiency as a result of sulfite-induced destruction of this vitamin. During storage up to the time of consumption, the losses of sulfite from the feed containing sodium metabisulfite at levels of 0.125, 0.25, 0.5, 1.0, and 2.0% averaged 22, 14,12, 8, and 4.5%, respectively, while the decrease in thiamine was 2.7, 1.7, 8.3, 14.5, and 15.4%, respectively. Addition of thiamine to the diet prevented thiamine deficiency in rats at all dose levels based on measurements of thiamine levels in the urine and liver. The general condition of the rats was good during the first 72 weeks in the F_0 generation, as well as the other two generations. After 72 weeks, there was a rapid increase in mortality in all groups. Survival in the treated groups were generally higher than the controls, except for the 2% F_1 males; no deaths occurred in the 2% F_2 females. A marginal reduction in body weight gain was observed in the 2% dose group (both sexes) in the F_1 and F_2 generations. Feed consumption was similar between treated and control groups. There were no changes in hematology and clinical chemistry parameters and urinalysis that were considered toxicologically significant. The $\geq$1% dietary groups had occult blood in their feces. Relative kidney weights were increased in the 2% F_2 females, but there were no pathological changes noted in the kidneys from this group. Hyperplastic changes in the fore- and glandular stomachs were noted in the $\geq$1% groups in all three generations. Some slight alterations were also noted in stomachs of the 0.5% F_2 rats. The NOAEL for systemic toxicity is 1.91% in the diet. This was estimated to be 955 mg/kg-day based on a rat body weight of 400 g and a daily feed intake of 20 g. The histopathologic effects on the stomach and the occult blood in feces are considered to be the result of localized irritation (a site-of-contact effect) from the ingestion of sodium metabisulfite (Til et al., 1972; ECHA). [Kl. score = 2]

Inhalation

No studies on sodium bisulfite were located.

Dermal

No studies on sodium bisulfite were located.

G. Genotoxicity

In Vitro Studies

No *in vitro* genotoxicity studies were located for sodium bisulfite. Table 2 presents the findings from *in vitro* genotoxicity studies conducted on structural analogues of sodium bisulfite.

Table 2: *In Vitro* Genotoxicity Studies on Structural Analogues to Sodium Bisulfite

Test System	Test Substance	Results*		Klimisch Score	Reference
		-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* strains)	Sodium metabisulfite	-	-	2	ECHA
Bacterial reverse mutation (*S. typhimurium* strains)	Potassium metabisulfite	-	-	2	ECHA
Bacterial reverse mutation (*S. typhimurium* strains)	Potassium metabisulfite	-	-	2	ECHA
Bacterial reverse mutation (*S. typhimurium* and *E. coli* strains)	Sodium metabisulfite	-	-	2	ECHA
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	Sodium metabisulfite	-	-	2	ECHA
Chromosomal aberration (human lymphocytes)	Sodium metabisulfite	-	-	1	ECHA

*+, positive; -, negative

In Vivo Studies

Sodium bisulfite did not show a mutagenic response in a rat dominant lethal assay when given in feed at doses of 0, 4.5, 15, or 45 mg/kg-day (ECHA). [Kl. score = 2]

Sodium sulfite was not genotoxic in a bone marrow micronucleus test in rats. Male NMRI rats were given a single subcutaneous injection of 0, 250, 500, or 1,000 mg/kg sodium sulfite (ECHA). [Kl. score = 1]

H. Carcinogenicity

No studies are available on sodium bisulfite.

Male and female Wistar rats were fed in their diet 0, 0.125, 0.25, 0.5, 1.0, or 2.0% sodium metabisulfite for up to two years and over three generations. There was no

increased incidence of tumors in the treated groups compared to the controls (Til et al., 1972). [Kl. score = 2]

Male and female ICR/JCL mice were given in their drinking water 0, 1, or 2% potassium metabisulfite for two years. There was no increased incidence of tumors in the treated groups compared to the controls (Tanaka et al., 1979). [Kl. score = 2]

No inhalation or dermal carcinogenicity studies were located.

I. Reproductive Toxicity

No studies are available on sodium bisulfite.

Male and female Wistar rats were fed in their diet 0, 0.125, 0.25, 0.5, 1.0, or 2.0% sodium metabisulfite for up to two years and over three generations. The diet was enriched with thiamine to prevent thiamine deficiency as a result of sulfite-induced destruction of this vitamin. During storage up to the time of consumption, the losses of sulfite from the feed containing sodium metabisulfite at levels of 0.125, 0.25, 0.5, 1.0, and 2.0% averaged 22, 14,12, 8, and 4.5%, respectively, while the decrease in thiamine was 2.7, 1.7, 8.3, 14.5, and 15.4%, respectively. Addition of thiamine to the diet prevented thiamine deficiency in rats at all dose levels based on measurements of thiamine levels in the urine and liver. The effects other than reproductive and developmental toxicity are discussed above in the Repeated Dose Toxicity section. There were no treatment-related effects on female fertility, the number of young per litter, or birth weight or mortality of the offspring. The number of F_{2a} pups was significantly reduced in the $\geq$0.5% groups during the first breeding cycle, but there was no dose-response and the reduction did not occur during the second breeding cycle. Slight growth retardation was observed in the F_1 and F_2 generation rats both before and after weaning. The NOAEL for reproductive toxicity is 1.91% in the diet. This was estimated to be 955 mg/kg-day based on a rat body weight of 400 g and a daily feed intake of 20 g (Til et al., 1972; ECHA). [Kl. score = 2]

Male and female rats were given sodum metabisulfite in their drinking water for up to 2.5 years and in three successive generations. The doses were 375 and 750 ppm as sulfur dioxide (SO_2). There was no evidence of systemic toxicity in either dose group. The number of offspring of either the F_1 and F_2 generation and the proportion surviving to the end of lactation were similar between treated and control groups. The NOAEL for reproductive toxicity is 750 ppm (as SO_2) in drinking water. Assuming an average rat body weight of 400 g and a daily water intake of 28 mL, 750 ppm (as SO_2) corresponds to 53 mg/kg-day sodium metabisulfite (Lockett and Natoff, 1960; ECHA). [Kl. score = 2]

J. Developmental Toxicity

Pregnant female Wistar rats were dosed by oral gavage with up to 110 mg/kg-day sodium bisulfite during GD 6-15. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity for this study is 110 mg/kg-day (ECHA). [Kl. score = 2]

Pregnant female CD-1 mice were dosed by oral gavage with up to 150 mg/kg-day sodium bisulfite during GD 6-15. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity for this study is 150 mg/kg-day (ECHA). [Kl. score = 2]

Pregnant female Dutch-belted were dosed by oral gavage with up to 100 mg/kg-day sodium bisulfite during GD 6-18. There was no maternal or developmental toxicity. The NOAEL for maternal and developmental toxicity for this study is 100 mg/kg-day (ECHA). [Kl. score = 2]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for sodium metabisulfite follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

Oral

No repeated dose toxicity studies have been conducted on sodium bisulfite. In a study conducted on sodium metabisulfite, there was no evidence of systemic toxicity in rats fed up to 2% for two years (Til et al., 1972). The NOAEL for this study is 2% or 955 mg/kg-day.

Using the molecular weights of sodium metabisulfite (190.1 g/mol) and sodium bisulfite (104.1 g/mol), the NOAEL of 955 mg/kg-day for sodium metabisulfite is converted to 523 mg/kg-day for sodium bisulfite. The NOAEL of 523 mg/kg-day will be used for determining the oral reference dose (RfD) and the drinking water guidance value for sodium bisulfite.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10

UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 523/(10 x 10 x 1 x 1 x 1) = 523/100 = 5 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (5 x 70 x 0.1)/2 = 18 mg/L

The Australian drinking water guidance value for sodium is 180 mg/L based on aesthetics (ADWG, 2011).

B. Cancer

There are no carcinogenicity studies on sodium bisulfite. No carcinogenic effects were reported for sodium metabisulfite in rat and mouse chronic studies. Thus, a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Sodium bisulfite does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

No aquatic toxicity studies have been conducted on sodium bisulfite. Other inorganic sulfite compounds show low to moderate toxicity concern to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

No acute aquatic studies are available on sodium bisulfite; however, studies are available on other inorganic sulfite compounds. The studies on these inorganic sulfite compounds can used to read-across to sodium bisulfite since sulfite ions are formed in water upon dissociation of sodium bisulfite. Table 3 lists the results of acute aquatic toxicity studies on the structural analogues of sodium bisulfite.

Table 2: Acute Aquatic Toxicity Studies on the Structural Analogues of Sodium Bisulfite

Test Species	Test Substance	Endpoint	Results (mg/L)	Klimisch score	Reference
Leuciscus idus	Potassium sulfite	96-hr LC_{50}	316	2	ECHA
Salmo gairdneri	Sodium pyrosulfite	96-hr LC_{50}	147-215 (177.8*)	2	ECHA
Brachydanio rerio	Potassium metabisulfite	96-hr LC_{50}	464-1,000 (681.2*)	1	ECHA
Daphnia magna	Sodium disulfite	48-hr EC_{50}	88.8	2	ECHA
S. subspicatus	Sodium disulfite	96-hr EC_{50} 72-hr EC_{10}	43.9 33.3	2	ECHA

*Geometric mean.

Chronic Studies

No chronic studies are available on sodium bisulfite; however, studies are available on sodium sulfite. Table 4 lists the results of chronic aquatic toxicity studies conducted on sodium sulfite.

Table 4: Chronic Aquatic Toxicity Studies on Sodium Sulfite (CAS No. 7757-83-7)

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Danio rerio	34-d NOEC	>316	1	ECHA
Daphnia magna	21-d NOEC	>10	2	ECHA

B. Terrestrial Toxicity

No studies were located.

C. Calculation of PNEC

The PNEC calculations for sodium bisulfite follow the methodology discussed in DEWHA (2009).

PNEC water

No studies have been conducted on sodium bisulfite; however, the results from studies conducted on other inorganic sulphite compounds can be used to read-across to sodium bisulfite. Hence, experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (177.8 mg/L for sodium pyrosulfite), invertebrates (88.8 mg/L for sodium sulfite), and algae (43.9 mg/L for sodium disulfite).

Results from chronic studies on sodium sulfite are also available for all three trophic levels, with the lowest NOEC being 10 mg/L for invertebrates. Using the molecular weights of sodium sulfite (126 g/mol) and sodium bisulfite (104.1 g/mol, the NOEC of 10 mg/L for sodium sulfite is converted to 8.3 mg/L. On the basis that the data consist of short-term and long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported NOEC of 8.3 mg/L for invertebrates. The $PNEC_{water}$ is 0.8 mg/L.

PNEC sediment

No experimental toxicity data on sediment organisms are available. Sodium bisulfite dissociates completely in water with its environmental distribution is dominated by its high water solubility. K_{ow} and K_{oc} parameters do not readily apply to inorganics, such as sodium bisulfite. Thus, the equilibrium partitioning method cannot be used to calculate

the $PNEC_{sed}$. Based on its properties, no adsorption of sodium bisulfite to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

PNEC soil

No experimental toxicity data on soil organisms are available. Sodium bisulfite dissociates completely in water with its environmental distribution is dominated by its high water solubility. K_{ow} and K_{oc} parameters do not readily apply to inorganics, such as sodium bisulfite. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on its properties, no adsorption of sodium bisulfite to soil is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Sodium bisulfite is an inorganic compound that dissociates completely to ionic species and sulfur dioxide gas. Biodegradation is not applicable to these compounds. For the purposes of this PBT assessment, the persistent criterion is not considered applicable to sodium bisulfite or its dissociated compounds.

Sodium bisulfite is not expected to bioaccumulate because its dissociated species are inorganic ions and a gas.

There are no aquatic toxicity data on sodium bisulfite. The lowest NOEC from chronic aquatic toxicity studies on sodium sulfite, a structural analogue of sodium bisulfite, is >0.1 mg/L. Thus, sodium bisulfite is not expected to meet the criteria for toxicity.

The overall conclusion is that sodium bisulfite is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Aquatic Acute Category 3

B. Labelling

No signal word.

C. Pictogram

None

X. SAFETY AND HANDLING [for a solution of sodium bisulfite]

A. FIRST AID

Eye Contact
In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. If symptoms persist, seek medical advice.

Skin Contact
Wash thoroughly with soap and water.

Inhalation
If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Ingestion
Rinse mouth with water and then drink plenty of water. Never give anything by mouth to an unconscious person. If symptoms develop, seek medical advice.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
When contacted by water, sodium bisulfite releases sulfur dioxide (SO_2), a poisonous gas. In the case of fire, the following may be liberated: Sulfur oxides and sulfur dioxide.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Use appropriate protective equipment.

Environmental Precautions
Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled
Pick up with absorbent material. Dispose of contaminated material as prescribed.

D. STORAGE AND HANDLING

General Handling
No special measures necessary provided product is used correctly.

Other Handling Precautions
Avoid eye and skin contact.

Storage
Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards

The workplace exposure standard for sodium bisulfite in Australia is 5 mg/m^3 as an 8-hr TWA.

Engineering Controls
None

Personal Protection Equipment

Respiratory Protection:
Respiratory protection is not required.

Hand Protection:
Chemical resistant protective gloves.

Skin *Protection*:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Safety glasses with side-shields.

Other Precautions:

Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible.

F. TRANSPORT INFORMATION

Sodium bisulfite is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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SODIUM CARBONATE

This dossier on sodium carbonate does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of sodium carbonate in its use in drilling muds and hydraulic fracturing fluids. The information presented in this dossier was obtained primarily from the OECD-SIDS documents on sodium carbonate (OECD, 2002a, b) and the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch et al., 1997).

I. SUBSTANCE IDENTIFICATION

Chemical Name (IUPAC): disodium carbonate

CAS RN: 497-19-8

Molecular formula: $CH_2O_3.2Na$

Molecular weight: 106

Synonyms: sodium carbonate; disodium carbonate; carbonic acid, disodium salt; bisodium carbonate; soda ash, calcined soda

SMILES: C(=O)([O-])[O-].[Na+].[Na+]

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-Chemical Properties of Sodium Carbonate

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Solid; white powder	1	ECHA
Melting Point	851°C	2	ECHA
Boiling Point	No data	-	-
Density	>2.52 and <2.53 (20°C)	1	ECHA
Vapour Pressure	No data	-	-
Partition Coefficient (log K_{ow})	Not applicable	-	-
Water Solubility	404 g/L* [soluble]	2	ECHA
pH	ca 11.5**	2	ECHA
Flammability	No	1	ECHA

*GLP-compliant study. The water solubility was overestimated, possibly due to the high temperature (during dissolution) or due to gel formation.

**pH value from water solubility test.

Aqueous solutions are strongly alkaline. At 25°C, the pH of 1, 5 and 10 wt% sodium carbonate solutions are 11.37, 11.58, and 11.70, respectively (Eggeman, 2001).

III. ENVIRONMENTAL FATE PROPERTIES

Due to its high water solubility and low vapour pressure, sodium carbonate will be found predominantly in the aquatic environment where it dissociates completely to sodium (Na^+) and carbonate (CO_3^{2-}) ions. Both ions are ubiquitous in the environment (UNEP, 1995).

Addition of sodium carbonate to an aquatic ecosystem will result in an increase in alkalinity and a tendency to increase the pH. The carbonate ions will react with water, forming bicarbonate (HCO_3^-) and hydroxide (OH^-) ions until an equilibrium is reached. A re-equilibration takes place when carbonate (CO_3^{2-}) is dissolved in water according to the following equations:

$HCO_3^- \leftrightarrow CO_3^{2-} + H^+$ pKa=10.33

$CO_2 + H_2O \leftrightarrow HCO_3^- + H^+$ pKa = 6.35

Only a small fraction of the dissolved CO_2 is present as H_2CO_3 (carbonic acid), the major part is present as CO_2. The amount of CO_2 in water is in equilibrium with the partial pressure of CO_2 in the atmosphere. The CO_2/ HCO_3^-/ CO_3^{2-} equilibria are the major buffer of the pH of freshwater.

Based on the above equations, CO_2 is the predominant species at a pH smaller than 6.35, while HCO_3^- is the predominant species at a pH in the range of 6.35-10.33 and CO_3^{2-} is the predominant species at a pH higher than 10.33.

A release of sodium carbonate into the aquatic environment from the use of sodium carbonate could potentially increase the sodium concentration and the pH in the aquatic environment. Table 2 shows the concentration of sodium carbonate needed to increase the pH to values of 9.0, 10.0, and 11.0.

Table 2: Sodium Carbonate Concentration (mg/L) Needed to Increase pH (DeGroot et al., 2002; taken from OECD, 2002b).

Buffer capacity*	Final pH**		
	9.0	10.0	11.0
0 mg/L HCO_3^- (distilled water)	11.1 (0.6)	16 (6.1)	603 (61)
20 mg/L HCO_3^- (10^{th} percentile of 77 rivers)	2.7 (21)	32 (26)	766 (81)
106 mg/L HCO_3^- (mean value of 77 rivers)	9.7 (107)	102 (112)	1467 (167)
195 mg/L HCO_3^- (90^{th} percentile of 77 rivers)	17 (196)	175 (201)	2192 (256)

*The initial pH of a bicarbonate solution with a concentration of 20-195 mg/L is 8.3 (calculated).

**The final concentration of bicarbonate is given in parentheses.

Na^+ and CO_3^{2-} ions will not adsorb on particulate matter or surfaces and will not accumulate in living tissues (OECD 2002b).

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

There are limited toxicity data on sodium carbonate. It has a low order of acute toxicity by the oral, dermal, and inhalation routes. It is not a skin irritant, but it is an eye irritant. Sodium carbonate is not expected to be systemically available in the body from oral exposure due to its dissociation in bodily fluids and the neutralisation of the carbonate ion in the stomach. No developmental toxicity was seen in studies with rats, mice, or rabbits.

B. Toxicokinetics and Metabolism

Sodium carbonate will dissociate in bodily fluids into sodium (Na^+) and carbonate (CO_3^{2-}) ions. The oral uptake of sodium carbonate would lead to neutralisation of carbonate in the stomach by the gastric acids which would lead to bicarbonate and/or carbon dioxide (CO_2) formation. It is unlikely that an oral uptake of sodium carbonate would disrupt the acid-base balance of the body because CO_2 formation in the stomach would alleviate the high amounts of carbonate that would be present in the stomach from an acute exposure. The equation that describes this reaction is:

$HCO_3^- + H^+ \leftrightarrow \square H_2CO_3 \leftrightarrow CO_2 + H_2O$

C. Acute Toxicity

An acute oral LD_{50} of sodium carbonate monohydrate in rats is 2,800 mg/kg, and the acute dermal LD_{50} in rabbits is >2,000 mg/kg (OECD, 2002a,b; ECHA). [Kl. scores = 1]

An acute inhalation toxicity study was conducted on an aerosol of sodium combustion products, which contain predominantly sodium carbonate. The 2-hour inhalation LC_{50} values for this aerosol to guinea pigs, mice and rats were 800, 1,200 and 2,300 mg/m^3, respectively. The median aerodynamic diameter of the aerosol was 0.77 $\pm$ 2.1µm (OECD, 2002a, b; ECHA). [Kl. score = 1]

D. Irritation

As reviewed in the OECD-SIDS documents (OECD, 2002a,b), skin irritation studies in laboratory animals and human volunteers with sodium carbonate either as a 50% solution or as a solid showed slight to no skin irritation.

Sodium carbonate is an eye irritant (OECD, 2002a,b; ECHA). A dose of 0.1 ml sodium carbonate monohydrate was irritating to the eyes of rabbits and, in another study, 0.1 ml of sodium carbonate (anhydrous) was highly irritating to rabbit eyes. However, 0.1 g sodium carbonate (anhydrous) was found not to be an eye irritant. [Kl scores of 1, 2, 1, respectively]

E. Sensitisation

No studies were identified.

F. Repeated Dose Toxicity

No studies were identified by the oral, inhalation or dermal routes.

G. Genotoxicity

In Vitro Studies

Sodium carbonate did not induce primary DNA damage in an *E. coli* chromotest (Olivier and Marzin, 1987; OECD, 2002a, b). [Kl. score = 3]

In Vivo Studies

No studies were identified.

H. Carcinogenicity

No studies were identified.

I. Reproductive Toxicity

No studies were identified.

J. Developmental Toxicity

Pregnant rats were dosed by oral gavage with 0, 2.45, 11.4, 52.9 or 245 mg/kg sodium carbonate on gestational days 6 to 15. No maternal or developmental toxicity was observed. The NOAEL for maternal and developmental toxicity is 245 mg/kg-day, the highest dose tested (OECD, 2002a, b). [Kl. score = 2]

Pregnant mice were given doses of sodium carbonate (3.4 to 340 mg/kg) by oral gavage on gestational days 6 to 15. No maternal or developmental toxicity was observed. The NOAEL for maternal and developmental toxicity is 340 mg/kg-day, the highest dose tested (OECD, 2002a, b). [Kl. score = 2]

Pregnant rabbits were dosed by oral gavage with 0, 1.79, 8.31, or 179 mg/kg sodium carbonate on gestational days 6 to 15. No maternal or developmental toxicity was observed. The NOAEL for maternal and developmental toxicity is 179 mg/kg-day, the highest dose tested (OECD, 2002a, b). [Kl. score = 2]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

There are no repeated dose toxicity studies conducted on sodium carbonate by any route of exposure. Developmental toxicity studies conducted by the oral route in three animal species showed no developmental effects at the highest doses tested. Sodium carbonate dissociates to sodium and carbonate ions in bodily fluids, and significant amount of these ions are already ingested in foods. Furthermore, both ions are present in the body and are highly regulated by homeostatic mechanisms.

Sodium carbonate is used in many countries (e.g., U.S. and EU) as a food additive. It is regarded as a Generally Recognized as Safe (GRAS) substance in food with no limitation other than current good manufacturing practice (OECD, 2002a, b).

Therefore, a toxicological reference value was not derived for sodium carbonate.

The Australian drinking water guideline values for sodium (180 ppm, aesthetic) and pH may be applicable (ADWG, 2011).

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Sodium carbonate does not exhibit the following physico-chemical properties:

- Flammability
- Explosivity
- Oxidising potential.

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Sodium carbonate is of low toxicity concern to aquatic and terrestrial organisms.

B. Aquatic Toxicity

Acute Studies

The results of the aquatic toxicity studies conducted on sodium carbonate are presented in Table 3.

Table 3: Aquatic Toxicity Studies on Sodium Carbonate (OECD, 2002a,b)

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Bluegill sunfish	96-h LC_{50}	300	2	OECD, 2002a, b
Mosquitofish	96-h LC_{50}	740	2	OECD, 2002a, b
Bluefill sunfish	24-h LC_{50}	385	4	OECD, 2002a, b
Molly	50-h LC_{50}	297	4	OECD, 2002a, b
Ceriodaphnia dubia	48-h EC_{50}	200 - 227	2	OECD, 2002a, b

There are other studies conducted on invertebrates, but the results of these studies were not included in Table 3 because of the low reliability of the data (OECD, 2002a, b). No studies on algae were identified (OECD, 2002a, b).

C. Terrestrial Toxicity

No studies were identified.

D. Calculation of PNEC

The OECD-SIDS SIAR on sodium carbonate states the following regarding the aquatic toxicity studies on sodium carbonate (OECD, 2002b):

> "In general, the available toxicity studies with sodium carbonate were not conducted according to current standard guidelines. In many cases pH, buffer capacity and/or medium composition were not discussed in the publications, although this is essential information for toxicity tests with sodium carbonate. In general, mortality of the test organisms was found at concentrations higher than 100 mg/l but for *Amphipoda*, salmon and trout lethal effects were already observed at 67-80 mg/l although these studies had a low reliability. The main factor explaining the acute aquatic toxicity of sodium carbonate is most likely the increase of the pH."

> "Because the natural pH, bicarbonate and also the sodium concentration (and their fluctuations in time) varies significantly between aquatic ecosystems, it is not considered useful to derive a generic PNEC or $PNEC_{added}$."

Based on the information above, PNEC values for freshwater, sediment, and soil were not derived for sodium carbonate.

VIII. PBT ASSESSMENT

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Sodium carbonate is an organic salt that dissociates completely to sodium and carbonate ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both sodium and

carbonate ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria are not considered applicable to this inorganic salt.

Sodium and carbonate ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, sodium carbonate is not expected to bioaccumulate.

No chronic aquatic toxicity data exist on sodium carbonate; however, the acute $EC(L)_{50}$s are >1 mg/L in fish, invertebrates and algae. Therefor, sodium carbonate does not meet the screening criteria for toxicity.

The overall conclusion is that sodium carbonate is not a PBT substance.

IX. CLASSIFICATION AND LABELLING

A. Classification

Eye Irritant Category 2

B. Labelling

Warning

C. Pictograms



X. SAFETY AND HANDLING

A. First Aid

Eye Contact

Immediately flush eyes with plenty of water for at least 15 minutes. Remove contacts, if present and easy to do. If symptoms persist, seek medical attention.

Skin Contact

Wash with soap and water.

Inhalation

If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Ingestion

Do not induce vomiting. Rinse mouth with water. Never give anything by mouth to an unconscious person. If symptoms persist, get medical attention.

B. Firefighting Information

Extinguishing Media

Water fog, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards

Decomposition in fire may produce toxic gases.

Special Protective Equipment for Fire fighters

Full protective clothing and approved self-contained breathing apparatus.

C. Accidental Release Measures

Personal Precautions

Use appropriate protective equipment. Avoid creating and breathing dust.

Environmental Precautions

Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled

Scoop up and remove.

D. Storage and Handling

General Handling

Avoid contact with eyes and skin. Avoid creating or inhaling dust.

Storage

Store away from acids. Store in a cool, dry location.

E. Exposure Controls/Personal Protection

Occupational Exposure Standards

Workplace Australia has not established an occupational exposure limit for sodium carbonate.

Engineering Controls

Use in a well ventilated area. Localised ventilation should be used to control dust levels.

Personal Protection Equipment

Respiratory Protection: In case of insufficient ventilation, wear suitable respiratory equipment. Dust/mist respirator.

Hand Protection: Chemical resistant protective gloves.

Skin Protection: Body protection must be chosen depending on activity and possible exposure

Eye protection: Safety glasses with side-shields.

Other Precautions: Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible.

F. Transport Information

Sodium Carbonate is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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XIV. ACRONYMS AND GLOSSARY

C	Centigrade
ECHA	European Chemicals Agency
EU	European Union
GD	gestational day
GHS	Globally Harmonised System of Classification and Labelling of Chemicals
GRAS	Generally Recognized as Safe
IUPAC	International Union of Pure and Applied Chemistry
kg	kilogram
kPa	kilopascal
L	litre
LOAEL	lowest observed adverse effect level
m	metre
mg/m3	milligrams per cubic meter
mm	millimetre
µg	microgram
mg	milligram
mL	millilitre
NOAEL	no observed adverse effect level
OECD	Organisation for Economic Co-operation and Development
Kl	Klimisch scoring system
Pow	octanol/water partition coefficient
PNEC	Predicted No Effect Concentration
ppm	parts per million

REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RfD	Reference Dose
SDS	Safety Data Sheet
SIDS	Screening Information Data Set
SMILES	simplified molecular-input line-entry system

SODIUM HYDROXIDE

This dossier on sodium hydroxide does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of sodium hydroxide in its use in drilling muds and hydraulic fracturing fluids. The information presented in this dossier was obtained from the OECD-SIDS documents on sodium hydroxide (OECD, 2002a, b) and the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch et al., 1997).

I. SUBSTANCE IDENTIFICATION

Chemical Name (IUPAC): Sodium hydroxide

CAS RN: 1310-73-2

Molecular formula: HNaO

Molecular weight: 40 g/mol

Synonyms: Caustic soda, soda lye, NaOH

SMILES: O[Na]

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Physico-Chemical Properties of Sodium Hydroxide

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Solid	2	Lide, 2009; ECHA
Melting Point	318°C (solid, 100%); 52°C (60% solution)	2	ECHA
Boiling Point	1,388°C @ 101.325 kPa	2	Lide, 2009; ECHA
Density	2.13 g/cm^2, 20°C (100%) 1.43 g/cm^2, 20°C (40%)	2	Lide, 2009; ECHA
Vapour Pressure	1 Pa @ 513°C	2	Lide, 2009; ECHA
Partition Coefficient (log Kow)	Not applicable	-	-
Water Solubility	Very soluble	2	Lide, 2009; ECHA
Dissociation Constant (pKa)	14.8 @ 25°C	2	Lide, 2009; ECHA
pH of 5% NaOH solution	14	2	O'Neil, 2006

Sodium hydroxide (NaOH) is a strong alkaline substance that dissociates completely in water to sodium (Na^+) and hydroxyl (OH^-) ions.

III. ENVIRONMENTAL FATE PROPERTIES

Due to its high water solubility and low vapour pressure, sodium hydroxide will be found predominantly in the aquatic environment where it dissociates completely to sodium (Na^+) and hydroxyl (OH^-) ions. Both ions are ubiquitous in the environment (UNEP, 1995).

The addition of sodium hydroxide to an aquatic ecosystem may increase the pH depending on the buffer capacity of the receiving water. In general, the buffer capacity is regulated by the equilibria between CO_2, HCO_3^- and CO_3^{2-}:

$CO_2 + H_2O \leftrightarrow HCO_3^- + H^+$ ($pKa_1 = 6.35$)
$HCO_3^- \leftrightarrow CO_3^{2-} + H^+$ ($pKa_2 = 10.33$)

A release of sodium hydroxide into the aquatic environment from the use of NaOH could potentially increase the sodium concentration and the pH in the aquatic environment. Table 2 shows the concentration of sodium hydroxide needed to increase the pH to values of 9.0, 10.0, 11.0, and 12.0.

Table 2: Sodium Hydroxide Concentration (mg/L) Needed to Increase pH (DeGroot et al., 2002; taken from OECD, 2002b).

Buffer capacity*	Final pH			
	9.0	10.0	11.0	12.0
0 mg/L HCO_3 (distilled water)	0.4	4.0	40	400
20 mg/L HCO_3 (10^{th} percentile of 77 rivers)	1.0	8.2	51	413
106 mg/L HCO_3^- (mean value of 77 rivers)	3.5	26	97	468
195 mg/L HCO_3^- (90^{th} percentile of 77 rivers)	6.1	45	145	525

*The initial pH of a bicarbonate solution with a concentration of 20-195 mg/L was 8.25 to 8.35.

Na^+ and OH^- ions will not adsorb on the particulate matter or surfaces and will not accumulate in living tissues (OECD, 2002b).

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Limited toxicity data exist for sodium hydroxide (NaOH). Depending on the concentration, solutions of NaOH are corrosive, irritating, or non-irritating. These solutions cause direct effects to the skin, eyes, respiratory tract, and gastrointestinal tract. Vapors from aqueous solutions of KOH can cause respiratory irritation. NaOH is not a skin sensitiser. There are no repeated dose, reproductive, and developmental toxicity studies on potassium hydroxide.

B. Toxicokinetics/Metabolism

Sodium hydroxide dissociates completely in aqueous solutions to sodium (Na^+) and hydroxyl (OH^-) ions. Sodium is an essential nutrient involved in fluid and electrolyte balance and is required for normal cellular function (Ganong, 1995). Sodium is the major extracellular cation in the body; the total body content is tightly regulated (Ganong, 1995).

C. Acute Toxicity

There are no oral toxicity guideline studies on sodium hydroxide. An oral LD_{50} of a 1 to 10% solution of NaOH in rabbits was reported to be 325 mg/kg (expressed as 100% NaOH) (OECD, 2002a,b). Mortality was also observed when a 1% NaOH solution was dosed, but in this case, the applied volume was relatively high (24 mL per kg body weight) (OECD, 2002a,b).

Acute toxicity studies were not identified for the inhalation and dermal route.

D. Irritation

Animal studies have shown that an 8% NaOH solution is corrosive to the skin. In humans, 0.5 to 4% NaOH concentrations produced skin irritation; and, based on the results of two different human patch tests, a NaOH solution that is slightly less than 0.5% would be non-irritating to human skin (OECD, 2002a,b).

Results from animal eye irritation studies indicate that a 0.2-1.0% NaOH solution would be non-irritating, while 1.2 or >2% NaOH solutions would be corrosive (OECD, 2002a,b).

E. Sensitisation

Male volunteers were exposed on the skin of their back to solutions of 0.063 to 1.0% NaOH in the induction phase of a human patch test. After 7 days the volunteers were challenged to a concentration of 0.125% NaOH. The irritant response correlated well with the concentration of NaOH, but an increased response was not observed when the previously patch tested sites were re-challenged. Based on this study, sodium hydroxide is not a skin sensitiser (OECD, 2002a, b; ECHA). [Kl. score = 2]

F. Repeated Dose Toxicity

No studies were identified for the oral and dermal route. An inhalation study was conducted in rats exposed to aerosols of solutions of NaOH ranging from 5% to 40%. Exposures were twice weekly (hours/day and total exposure days unspecified). All animals in the 40% solution group died within a month mostly from bronchopneumonia. At the lower concentrations, respiratory tract lesions were observed; an NOAEL was not identified (NIOSH, 1975).

G. Genotoxicity

In Vitro Studies

Several *in vitro* studies have been conducted on NaOH (OECD, 2002a, b; ECHA). Although these studies reported negative results, they are considered unreliable (Kl. score = 3) due to methodological or reporting deficiencies.

In Vivo Studies

Several *in vivo* studies have been conducted on NaOH (OECD, 2002a,b; ECHA). Although these studies reported negative results, they are considered unreliable (Kl. score = 3) due to methodological or reporting deficiencies.

H. Carcinogenicity

No studies were identified.

I. Reproductive Toxicity

No valid studies were identified regarding toxicity to reproduction in animals after oral, dermal or inhalation exposure to NaOH.

J. Developmental Toxicity

No valid studies were identified regarding developmental toxicity in animals after oral, dermal or inhalation exposure to NaOH (OECD, 2002a, b; ECHA).

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

Oral and dermal repeated dose, reproductive, and developmental toxicity studies have not been conducted on NaOH. A repeated dose toxicity study was conducted by the inhalation route, but the methodology and documentation preclude its use for deriving a toxicological reference value. These toxicity studies would have questionable usefulness because of the corrosive/irritating nature of NaOH, which would limit the amount absorbed. NaOH dissociates to sodium and hydroxyl ions in bodily fluids, and a significant amount of these ions are already ingested in foods. Furthermore, both ions are present in the body and are highly regulated by homeostatic mechanisms. Thus, a toxicological reference value was not derived for NaOH.

The Australian drinking water guideline values for sodium (180 ppm, aesthetic) and pH may be applicable (ADWG, 2011).

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Sodium hydroxide does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidising potential.

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Aquatic Toxicity

The OECD-SIDS SIAR on NaOH states the following regarding the aquatic toxicity studies on NaOH (OECD, 2002b):

> "At concentrations reported in publications and study reports, the toxicity has been assumed to be due to hydroxide only, because at these effect concentrations the concentration of sodium is too low to explain the effects. However, it should be realised that the results of toxicity tests with NaOH depend on the buffer capacity of the test medium. In a highly buffered test medium, the hydroxyl ion will be neutralised, and the observed toxicity will be low, while in a poorly buffered test medium the pH will increase rapidly and therefore the observed toxicity will be relatively high. Besides the direct effects (pH change) NaOH could also have indirect effects. The pH change could influence the speciation of other chemicals and therefore increase and/or decrease the toxicity, e.g.; NH_3 is more toxic than NH_4^+."

There are no guideline studies on NaOH; the studies summarised below have Klimisch scores of 3 or 4.

Acute Fish

The 24-hour LC_{50} to *Carassius auratus* (goldfish) is 160 mg/L. At 100 mg/L, which was equivalent to a pH of 9.8, no mortality was observed. The 48-hour LC_{50} to *Leuciscus idus melanotus*, is 189 mg/L. The 96-hour LC_{50} of *Gambusia affinis* (mosquitofish) is 125 mg/L. At 84 mg/L, no effects on the fish were observed. The pH was 9 at 100 mg/L.

Acute Invertebrate

The 48-hour LC_{50} is 40 mg/L for *Ceriodaphnia cf. dubia*. The toxicity threshold concentration of NaOH for *Daphnia magna* was reported to range from 40 to 240 mg/L.

Acute Algae

No studies were identified.

B. Terrestrial Toxicity

No studies were identified.

C. Calculation of PNEC

The OECD-SIDS SIAR on NaOH states the following regarding the aquatic toxicity studies on NaOH (OECD, 2002b):

> "In many cases pH, buffer capacity and/or medium composition were not discussed in the publications, although this is essential information for toxicity tests with NaOH. This is the most important reason why most of the studies, mentioned above were considered invalid. Although valid acute ecotoxicity tests and chronic ecotoxicity tests with NaOH are not available, there is no need for additional testing with NaOH. A significant number of acute toxicity tests are available, and the results of the tests are more or less consistent. Altogether they give a sufficient indication of acute toxicity levels of sodium hydroxide."
>
> "Furthermore, acute toxicity data cannot be used to derive a PNEC or a PNEC added for sodium hydroxide. Aquatic ecosystems are characterised by an alkalinity/pH, and the organisms of the ecosystem are adapted to these specific natural conditions. Based on the natural alkalinity of waters, organisms will have different optimum pH conditions, ranging from poorly buffered waters with a pH of 6 or less to very hard waters with pH values up to 9. A lot of information is available about the relationship between pH and ecosystem structure and also natural variations in pH of aquatic ecosystems have been quantified and reported extensively in ecological publications and handbooks."
>
> "Normally a PNEC or a PNEC added has to be derived from the available ecotoxicity data. A PNEC added is a PNEC which is based on added concentrations of a chemical (added risk approach). Based on the available data it is not considered useful to derive a PNEC or a PNEC added for NaOH because:
> - The natural pH of aquatic ecosystems can vary significantly between aquatic ecosystems,
> - Also, the sensitivity of the aquatic ecosystems to a change of the pH can vary significantly between aquatic ecosystems and
> - The change in pH due to an anthropogenic NaOH addition is influenced significantly by the buffer capacity of the receiving water."
>
> "Although a PNEC or a PNEC added was not calculated for NaOH, there is a need to assess the environmental effect of a NaOH (alkaline) discharge. Based on the pH and buffer capacity of effluent and receiving water and the dilution factor of the effluent, the pH of the receiving water after the discharge can be calculated. Of course, the pH change can also be measured very easily via a laboratory experiment or by conducting field measurements. The change in pH should be compared with the natural variation in pH of the receiving water and based on this comparison it should be assessed if the pH change is acceptable."

Based on the information above, PNEC values for freshwater, sediment, and soil were not derived for sodium hydroxide.

VIII. PBT ASSESSMENT

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Sodium hydroxide is an inorganic salt that dissociates completely to sodium and hydroxide ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both sodium and hydroxide ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria are not considered applicable to this inorganic salt.

Sodium and hydroxide ions are essential to all living organisms, and their intracellular, and extracellular concentrations are actively regulated. Thus, sodium hydroxide is not expected to bioaccumulate.

No chronic toxicity data exist on sodium hydroxide; however, the acute $E(L)C_{50}$ values are >1 mg/L in fish, invertebrates and algae. Thus, sodium hydroxide does not meet the screening criteria for toxicity.

The overall conclusion is that sodium hydroxide is not a PBT substance.

IX. CLASSIFICATION AND LABELLING

A. Classification

Metal Corrosive Category 1
Skin Corrosive, Category 1A
Eye Damage, Category 1

EU Concentration Limits:

≥5%: Skin Corrosive 1A

≥2 to <5%: Skin Corrosive 1B

≥0.5%to <2%: Skin Irritant Category 2

≥0.5% to <2%: Eye Irritant Category 2

In addition to the hazard statements corresponding the GHS classification for corrosive, the following non-GHS hazard statement is to be added to the SDS: AUH071: Corrosive to the Respiratory Tract.

B. Labelling

Danger

C. Pictograms



X. SAFETY AND HANDLING

A. First Aid

Eye Contact

Flush with plenty of fresh water for 15 minutes holding eyelids open, lifting eyelids occasionally to ensure complete removal of the product. Remove contacts, if present and easy to do. DO NOT allow rubbing of eyes or keeping eyes closed. Seek medical attention.

Skin Contact

Rinse with soap and plenty of water for several minutes. Remove contaminated clothing. Seek medical attention immediately.

Inhalation

Remove person to fresh air. Apply artificial respiration if not breathing. Seek medical attention.

Ingestion

Rinse mouth with water (only if the person is conscious), but do not administer fluids. Do NOT induce vomiting. Seek medical attention immediately.

B. Fire Fighting Information

Extinguishing Media

Carbon dioxide, water spray, foam, dry chemical.

Specific Exposure Hazards

Containers may explode when heated. May form explosive mixtures with strong acids. Hazardous combustion products may include the following materials: halogenated compounds, metal oxides/oxides, sodium monoxide.

Special Protective Equipment for Firefighters

Full protective clothing and approved self-contained breathing apparatus required for firefighting personnel.

C. Accidental Release Measures

Personal Precautions

Use appropriate protective equipment and avoid direct contact. Do not touch damaged containers or spilt material unless wearing appropriate protective clothing. Ventilate the area before entry.

Environmental Precautions

Prevent spills from entering storm drains or sewers and contact with soil.

Steps to be Taken if Material is Released or Spilt

Use an absorbent material to recover as much product as possible, then, rinse the affected area with water to dilute the residue. Disposal of leftover product and used containers should be carried out in accordance with all local, state and federal regulations.

D. Storage and Handling

General Handling

Wear appropriate personal protective equipment. Avoid contact with eyes, skin or clothing. Avoid breathing mist, vapours or spray. Use only with adequate ventilation. Wash hands after use. Launder contaminated clothing.

Storage

Store away from acids. Keep container closed when not in use. Store in a cool well-ventilated area.

E. Exposure Controls / Personal Protection

Occupational Exposure Standards

The workplace exposure standard for sodium hydroxide in Australia is 2 mg/m^3 as a peak limitation, with a sensitisation notation. A peak limitation is defined by Safe Work Australia as a maximum or peak airborne concentration of a substance determined over the shortest analytically practicable period of time which does not exceed 15 minutes.

Engineering Controls

Good general ventilation should be used. If applicable, use process enclosures, local exhaust ventilation, or other engineering controls to maintain airborne levels below recommended exposure limits.

Personal Protection Equipment

Respiratory Protection: Use a mask or approved air-purifying respirator with appropriate cartridge or canister in spray applications or in confined spaces.

Hand Protection: Wear impervious gloves to prevent skin contact and absorption of this material. Rubber or Neoprene gloves may afford adequate skin protection.

Skin Protection: Wear appropriate clothes (i.e., coveralls). Use non-slip footwear.

Eye protection: Wear eye protection in situations where splash or thick mists are possible.

Other Precautions: Avoid contact with skin, eyes and clothing. When using, do not eat or drink. Wash hands thoroughly with soap and water before eating or drinking. Remove contaminated clothing and launder before reuse.

F. Transport Information

For sodium hydroxide solutions of >5%:
Australian Dangerous Goods
UN1824, Corrosive liquid, (Sodium hydroxide solution)
Class 8
Packing Group: II

Lower concentrations of sodium hydroxide may require a different packing group or may not require any hazard code if the concentration of NaOH is low enough not to be considered a corrosive material.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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XIV. ACRONYMS AND GLOSSARY

°C	degrees Celsius
ADWG	Australian Drinking Water Guidelines
DEWHA	Department of the Environment, Water, Heritage and the Arts
ECHA	European Chemicals Agency
EU	European Union
GHS	Globally Harmonised System of Classification and Labelling of Chemicals
HHRA	enHealth Human Risk Assessment
IUPAC	International Union of Pure and Applied Chemistry
LOAEL	lowest observed adverse effect level
mg/kg	milligrams per kilogram
mg/L	milligrammes per litre
mg/m^3	milligrammes per cubic metre
NOAEL	no observed adverse effect level
NOEC	no observed effective concentration
OECD	Organisation for Economic Co-operation and Development
PBT	Persistent, Bioaccumulative and Toxic
ppm	parts per million
RfD	oral Reference Dose
SDS	Safety Data Sheet
SIDS	Screening Information Data Set
SMILES	simplified molecular-input line-entry system

SODIUM PERSULFATE

This dossier on sodium persulfate does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of sodium persulfate in its use in drilling muds and hydraulic fracturing fluids. Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBSTANCE IDENTIFICATION

Chemical Name (IUPAC): Disodium [(sulfonatoperoxy)sulfonyl]oxidanide

CAS RN: 7775-27-1

Molecular formula: $O_8S_2.2Na$

Molecular weight: 238.1

Synonyms: Sodium persulfate; disodium persulfate; sodium peroxodisulfate; disodium [(sulfonatoperoxy)sulfonyl]oxidanide

SMILES: [O-]S(=O)(=O)OOS(=O)(=O)[O-].[Na+].[Na+]

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Sodium Persulfate

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	White, crystalline, odorless solid	1	ECHA
Melting Point	Decomposes at 180°C before melting point is reached.	1	ECHA
Density	1.68 g/cm^3	1	ECHA
Vapor Pressure	Negligible	2	ECHA
Partition Coefficient (log K_{ow})	Not applicable	-	-
Water Solubility	Very soluble	2	ECHA
Oxidizing Properties	Strong oxidizer	4	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

Sodium persulfate dissociates in aqueous media to the sodium cation (Na^+) and persulfate anion ($S_2O_8^{2-}$) (OECD 2005a; ECHA). The persulfate anion will readily hydrolyze (decompose) into sulfate ions.

The rates of hydrolysis are expected to be similar for sodium persulfate, potassium persulfate, and ammonium persulfate. The rates of decomposition (hydrolysis) was measured at 50°C at various pHs. The half-lives increased from 20 hours at pH 1 to 210 hours at pH 10 (Koltoff and Miller, 1951).

Biodegradation is not applicable to inorganic compounds. Sodium persulfate is not expected to bioaccumulate; it will dissociate (and decompose) to ions that are ubiquitous in the environment. Sodium persulfate is not expected to absorb to soil or sediment because of its dissociation properties, instability (hydrolysis), and high-water solubility.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Sodium persulfate exhibits moderate acute toxicity by the oral route, and low acute toxicity by the inhalation and dermal routes. In humans, sodium persulfate has the potential for skin irritation; it is also a skin sensitizer to guinea pigs and humans. Human exposure to persulfates (including sodium persulfate) have been linked to a variety of skin and respiratory complaints indicative of sensitization. The complaints consist of immediate and delayed contact hypersensitivity, contact urticarial, rhinitis, bronchitis, and asthma. Repeated oral exposure to sodium persulfate resulted in irritation to the gastrointestinal tract; and respiratory irritation was seen in rats repeatedly exposed by inhalation to ammonium persulfate. Sodium persulfate is not genotoxic. A dermal carcinogenicity study showed no carcinogenic effects in mice. In a screening study, there was no reproductive or developmental toxicity in rats given oral gavage doses of ammonium persulfate.

B. Acute Toxicity

The oral LD_{50} in male rats is 895 mg/kg (ECHA) [Kl. score = 2].

The 4-hour inhalation LC_{50} of sodium persulfate dust is >5.1 mg/L. The mass median aerodynamic diameter (MMAD) ranged from 4.28 to 5.35 μm. The fraction of particles ≤1 μm in MMAD ranged from 0 to 5.6%. The fraction of particles ≤10 μm in MMAD ranged from 76.5 to 81.2% (ECHA) [Kl. score = 1].

The dermal LD_{50} in rabbits is >2,000 mg/kg (ECHA) [Kl. score = 1].

C. Irritation

Application of 0.5 mL of sodium persulfate (aqueous solution) to the skin of rabbits for 4 hours under occlusive conditions was not irritating (ECHA) [Kl. score = 1]. In another study, application of sodium persulfate to the skin of rabbits was not irritating (ECHA) [Kl. score = 2].

Instillation of sodium persulfate into the eyes of rabbits was slightly irritating. Slight conjunctival effects were noted in five of six animals; all observed effects were completely reversible within 24 hours (ECHA) [Kl. score = 2].

Studies in humans indicate that persulfates have the potential for skin irritation (NICNAS, 2001). Calnan and Schuster (1963) reported skin irritation in a human patch test with 5% ammonium persulfate. Jordan (1998) reported that a mixture with 17.5% persulfates (ammonium, potassium, and sodium) induced skin irritation in human subjects from patches applied under occlusive conditions.

D. Sensitization

Sodium persulfate was a skin sensitizer when tested in a guinea pig maximization test. The concentration of sodium persulfate used in the induction and challenge phases was 0.1% in physiological saline (ECHA) [Kl. score = 1]. Sodium persulfate was not a skin sensitizer to guinea pigs in a Buehler test (dermal application only). The concentration of sodium persulfate used for the induction and challenge phase was 0.3 g (ECHA) [Kl. score = 1].

Sodium persulfate was considered a strong skin sensitizer in a mouse local lymph node assay (ECHA) [Kl. score = 1].

Human exposure to persulfates have been linked to a variety of skin and respiratory complaints indicative of sensitization. The complaints consist of immediate and delayed contact hypersensitivity, contact urticarial, rhinitis, bronchitis, and asthma (NICNAS, 2001).

E. Repeated Dose Toxicity

Oral

Male and female CR strain rats were fed in their diet 0, 300, 1,000 or 3,000 ppm sodium persulfate for 90-days. On day 48 of the study, the dietary concentration of the group receiving 1,000 ppm was increased to 5,000 ppm for the remainder of the study. Body

weights was decreased in the two highest dose groups during the last six weeks of treatment. There were no treatment-related effects on urinalysis, clinical chemistry or hematology parameters. Histopathological findings were limited to the 3,000 ppm group only and consisted of necrosis and atrophy of the gastrointestinal tract epithelial lining. The absence of the gastrointestinal lesions in the group receiving 1,000 ppm for 8 weeks, followed by 5000 ppm for 5 weeks, indicates that the lesions are related both to concentration in diet (dose) and length of exposure. A clear NOAEL for this study is 300 ppm, which is estimated to be 22 mg/kg-day. Another NOAEL may be the 1,000 ppm dietary group for an 8-week exposure period. (ECHA; OECD, 2005a,b). [Kl. score = 2]

Inhalation

No studies are available on sodium persulfate.

Male and female SD rats were exposed (whole-body) by inhalation to 0, 5, 10.3, or 25 mg/m^3 ammonium persulfate dust, 6 hours/day, 5 days/week for 13 weeks. Additional groups of animals were exposed for 13 weeks, followed by either a 4- or 13-week recovery period. The MMAD was 2.5, 2.7, and 2.5 μm for the 5, 10, and 25 mg/m^3 groups, respectively. No deaths occurred during the study that were considered to be exposure-related. The 25 mg/m^3 animals showed increased respiration rates, as well as a few of the 25 mg/m^3 animals. This clinical sign disappeared during the first few weeks of the recovery period. Body weights of the 25 mg/m^3 animals were significantly lower during most of the exposure period; by the end of the recovery period the body weights were comparable to the controls. Lung weights were increased in the 25 mg/m^3 animals at the end of the 13-week exposure period, but were similar to controls after 6 weeks in the recovery period. Histopathologic changes indicative of irritation was seen in the trachea and bronchi/bronchioles in the 25 mg/m^3 animals; these lesions were not seen after 6 weeks in the recovery period. The NOAEL for this study is 10.3 mg/m^3 (ECHA). [Kl. score = 1]

Dermal

No studies are available.

F. Genotoxicity

In Vitro Studies

The *in vitro* genotoxicity studies on sodium persulfate are presented below in Table 2.

Table 2: *In vitro* Genotoxicity Studies on Sodium Persulfate

Test System	**Results***		**Klimisch Score**	**Reference**
	-S9	**+S9**		

Bacterial reverse mutation (*S. typhimurium* strains)	-	-	1	ECHA
Unscheduled DNA synthesis (rat hepatocytes)	NA	-	1	ECHA

*+, positive; -, negative; NA, not applicable

In vivo Studies

Sodium persulfate did not induce micronuclei in the bone marrow cells of male and female mice given a single intraperitoneal injection of 0, 85, 169, or 338 mg/kg sodium persulfate (ECHA) [Kl. score = 2].

G. Carcinogenicity

No studies are available on sodium persulfate.

A 51-week dermal study in female SENCAR mice exposed to 0.2 ml of a 200 mg/mL solution of ammonium persulfate showed that ammonium persulfate is neither a tumor promoter nor a complete carcinogen when applied to the skin (OECD, 2005a,b; ECHA). [Kl. score = 2]

H. Reproductive and Developmental Toxicity

No studies are available on sodium persulfate.

A reproductive and developmental toxicity screening study (OECD 421) has been conducted on ammonium persulfate. Male and female Crl:CD (SD)GS BR rats were fed in their diet 0, 40, 100, or 250 mg/kg ammonium persulfate. In the parental animals, there was no treatment-related mortality, clinical signs, body or organ weight changes, or effects seen in gross necropsy. There were no effects on reproductive performance, fertility, fetal anomalies, fetal viability, spermatogenesis, spermatogenic cycle. The NOAEL for reproductive and developmental toxicity and parental toxicity is 250 mg/kg-day, the highest dose tested (ECHA). [Kl. score = 1]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

Toxicological reference values were not derived. Sodium persulfate dissociates in water to sodium and persulfate ions. The persulfate ions will further hydrolyze to sulfate ions.

The Australian drinking water guideline value for sodium is 180 mg/L based on aesthetics (ADWG, 2011).

The Australian drinking water guideline value for sulfate is 500 mg/L based on health. Concentrations of >500 mg/L can have purgative effects. There is also an Australian drinking water guideline value for sulfate of 250 mg/L based on aesthetics; it is the taste threshold (ADWG, 2011).

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Sodium persulfate is an oxidizing solid.

Sodium persulfate does not exhibit the following physico-chemical properties:
- Explosivity
- Flammability

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Sodium persulfate has a low toxicity concern to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies on sodium persulfate.

Table 3: Acute Aquatic Toxicity Studies on Sodium Persulfate

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Oncorhynchus mykiss	96-h LC_{50}	163	1	ECHA
Daphnia magna	48-h EC_{50}	133	1	ECHA
Selenastrum capricornutum	72-h EC_{50}	116	1	ECHA

Chronic Studies

No data are available.

C. Terrestrial Toxicity

No data are available.

D. Calculation of PNEC

The PNEC calculations for sodium persulfate follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (163 mg/L), *Daphnia* (133 mg/L), and algae (116 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 116 mg/L for algae. The $PNEC_{water}$ is 0.12 mg/L.

PNEC sediment

No experimental toxicity data on sediment organisms are available. Sodium persulfate dissociates completely in water with its environmental distribution is dominated by its high water solubility. K_{ow} and K_{oc} parameters do not readily apply to inorganics, such as sodium persulfate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of sodium persulfate to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

PNEC soil

No experimental toxicity data on terrestrial organisms are available. The environmental distribution of sodium persulfate is dominated by its water solubility. Sorption of sodium persulfate should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. K_{oc} and K_{ow} parameters do not readily apply to inorganics, such as sodium persulfate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, sodium persulfate is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Sodium persulfate is an inorganic compound that dissociates completely to sodium and persulfate ions in aqueous solutions. Persulfate ions are further hydrolysed to sulphate ions. Biodegradation is not applicable to these compounds. For the purposes of this PBT assessment, the persistent criteria are not considered applicable to sodium persulfate or its dissociated compounds.

Sodium persulfate is an inorganic compound that dissociates completely in water to ionic compounds that are ubiquitous in the environment. Thus, sodium persulfate is not expected to bioaccumulate.

There are no chronic aquatic toxicity data on sodium persulfate. The acute $E(L)C_{50}$ values for fish, invertebrates, and algae are >1 mg/L. Thus, sodium persulfate does not meet the criteria for toxicity.

The overall conclusion is that sodium persulfate is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Oxidizing Solid Category 3
Acute Toxicity Category 4 [Oral]
Skin Irritant Category 2
Eye Irritant Category 2
Skin Sensitizer Category 1
Respiratory Sensitization Category 1
STOT SE Category 3 [Respiratory Irritation]

B. Labelling

Danger

C. Pictogram



X. SAFETY AND HANDLING

A. First Aid

Eye Contact
Immediately flush open eyes with plenty of water for at least 15 minutes. Remove contacts, if present and easy to do. Get medical attention.

Skin Contact
Wash thoroughly with soap and water.

Inhalation
If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Ingestion
Rinse mouth with water and then drink plenty of water. Get medical attention. Never give anything by mouth to an unconscious person.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: sulfur oxides.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus and chemical-protective clothing.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Use personal protective clothing. Avoid dust formation. Ensure adequate ventilation. Do not breathe dust. Wear respiratory protection if ventilation is inadequate. Avoid contact with skin, eye, and clothing.

Environmental Precautions
Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled
Scoop up and remove.

D. STORAGE AND HANDLING

General Handling
Good general ventilation should be used. Ventilation rates should be matched to conditions. If applicable, use process enclosures, local exhaust ventilation, or other engineering controls to maintain airborne levels below recommended exposure limits.

Other Handling Precautions
Avoid eye and skin contact. Avoid creating or inhaling dust.

Storage
Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place. Do not store with alkalis, acids, or reducing agents.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
The workplace exposure standard for sodium persulfate in Australia is 0.01 mg/m^3 as a peak exposure. A peak limitation is defined by Safe Work Australia as a maximum or peak airborne concentration of a substance determined over the shortest analytically practicable period of time which does not exceed 15 minutes.

Engineering Controls

Ensure adequate ventilation. Localized ventilation should be used to control dust levels below permissible exposure limits.

Personal Protection Equipment

Respiratory Protection:
Use respiratory protection when airborne concentrations are expected to be high.

Hand Protection:
Chemical resistant protective gloves.

Skin *Protection*:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Safety glasses with side-shields.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible. Remove and wash contaminated clothing before re-use. Contaminated work clothing should not be allowed out of the workplace.

F. TRANSPORT INFORMATION

UN1505 SODIUM PERSULPHATE
Class: 5.1
Packing Group: III

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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XIV. ACRONYMS AND GLOSSARY

°C	degrees Celsius
ADI	acceptable daily intake
ADWG	Australian Drinking Water Guidelines
BCF	bioconcentration factor
BMD	benchmark dose

BOD	biological oxygen demand
CAS	Chemical Abstracts Service
CERHR	Centre for Evaluation of Risks to Human Reproduction
CHO	Chinese Hamster Ovary
CNS	central nervous system
DEWHA	Department of the Environment, Water, Heritage and the Arts
ECHA	European Chemicals Agency
EU	European Union
FAO	Food and Agriculture Organization
FOB	functional observation battery
GD	gestational days
GHS	Globally Harmonised System of Classification and Labelling of Chemicals
HHRA	enHealth Human Risk Assessment
HRIPT	Human Repeated Insult Patch Test
IOM	Institute of Medicine
IRIS	Integrated Risk Information System
IUPAC	International Union of Pure and Applied Chemistry
JECFA	Joint FAO/WHO Expert Committee on Food Additives
LOAEL	lowest observed adverse effect level
MCI	molecular connectivity index
mg/kg	milligrams per kilogram
mg/L	milligrams per litre
mg/m^3	milligrams per cubic metre
MOA	mode-of-action
NICNAS	The National Industrial Chemicals Notification and Assessment Scheme
NIOSH	National Institute for Occupational Safety and Health
NOAEC	no observed adverse effect concentration
NOAEL	no observed adverse effect level
NOEC	no observed effective concentration
OECD	Organisation for Economic Cooperation and Development
PBPK	physiologically-based pharmacokinetic
PBT	Persistent, Bioaccumulative and Toxic
PND	postnatal day
PNEC	predicted no effect concentration
ppm	parts per million

QAC	quaternary ammonium compound
QSAR	quantitative structure activity relationship
RACB	Reproductive Assessment by Continuous Breeding
REACH	Registration, Evaluation, Authorisation and Restriction of Chemical Substances
RfD	Reference Dose (oral)
SCBA	self-contained breathing apparatus
SCE	sister chromatid exchange
SDS	Safety Data Sheet
SIAR	SIDS Initial Assessment Report
SIDS	Screening Information Data Set
SMILES	simplified molecular-input line-entry system
STEL	short-term exposure limit
ThOD	theoretical oxygen demand
TWA	time-weighted average
WHO	World Health Organization

SODIUM POLYACRYLATE

This dossier on sodium polyacrylate do not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of sodium polyacrylate in its use in drilling muds and hydraulic fracturing fluids. The majority of information presented in this dossier was obtained from the HERA document on polyacrylic acid homopolymers and their sodium salts (CAS 9003-04-7) (HERA, 2014). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch et al., 1997).

I. SUBSTANCE IDENTIFICATION

Chemical Name (IUPAC): 1-Propenoic acid, homopolymer, sodium salt

CAS RN: 9003-04-7

Molecular formula: $(C_3H_4O_2)x$-.x-Na

Molecular weight: Variable

Synonyms: 2-Propenoic acid, homopolymer, sodium salt; polyacrylic acid, sodium salt, sodium polyacrylate; acrylic acid, polymers, sodium salt; poly(acrylic acid), sodium salt; polyacrylate sodium salt

II. PHYSICO-CHEMICAL PROPERTIES

Sodium polyacrylates are polymers that range in molecular weight (MW) from 1,000 to 78,000 (HERA, 2014). The sodium polyacrylates mostly used in detergents have a typical molecular weight of approximately 4,500 (HERA, 2014). For sodium polyacrylate (MW 4,500), the melting point is >150^{o}C, where is decomposes; and the water solubility is >400 g/L (HERA, 2014).

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Sodium polyacrylates are not readily biodegradable. Due to their high molecular weights, sodium polyacrylates are not expected to bioaccumulate. In addition, these water-soluble polymers can form insoluble calcium salts in natural waters, suggesting that bioaccumulation is unlikely.

B. Abiotic Degradation

Abiotic degradation mechanisms, such as photolytic and hydrolytic processes, do not significantly influence the environmental fate of sodium polyacrylates (HERA, 2014).

C. Biodegradation

Sodium polyacrylates are not readily biodegradable, but are partly accessible to ultimate biodegradation particularly under long incubation conditions. Sodium polyacrylates with MW of <2,000 are partly biodegradable under the conditions of soil and sediment inoculation. Test results with activated sludge inoculum indicate different elimination degrees, apparently due to adsorption and precipitation processes. The removal degrees of different sodium polyacrylates show no clear relationship between elimination extent and molecular weight (HERA, 2014).

D. Bioaccumulation

No experimental studies are available on sodium polyacrylates. Estimated bioconcentration factors based on octanol-water coefficients are not appropriate since the molecular weights of these polymers are higher than the molecular weight range for the QSAR models. Due to their high molecular weights, sodium polyacrylates are not expected to bioaccumulate. In addition, these water-soluble polymers can form insoluble calcium salts in natural waters, suggesting that bioaccumulation is unlikely.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

The acute toxicity of sodium polyacrylates are very low by the oral and dermal routes. These polymers are not irritating to the skin and eyes; nor are they skin sensitizers. No systemic toxicity was observed in rats given high oral doses of a sodium polyacrylate for four weeks; pulmonary irritation was seen in rats that inhaled an aerosol or dust of a sodium polyacrylate for 13 weeks, but there was no systemic toxicity. No developmental toxicity was seen in rats when given high oral doses of sodium polyacrylates. Sodium polyacrylates are not genotoxic.

B. Acute Toxicity

Acute oral toxicity studies have been conducted in rats on sodium polyacrylates with molecular weights (MW) of 1,000 to 78,000. The oral LD_{50} values are >5,000 or >10,000 mg/kg (the highest doses tested), with the exception of one study on a 3,500 MW sodium polyacrylate, which was reported to be >1,000 mg/kg (the attainable limit dose of a 10% aqueous solution) (HERA, 2014). [Kl. scores = 2]

The dermal LD_{50} values in rabbits for sodium polyacrylates with MW of 1,000 or 4,500 are >5,000 mg/kg (HERA, 2014). [Kl. scores = 2]

No acute inhalation studies are available.

C. Irritation

The sodium polyacrylates with MW of 1,000 to 78,000 are not irritating to the skin or eyes (HERA, 2014). [Kl. scores = 2]

D. Sensitisation

Sodium polyacrylates with MW of 4,500 or 78,000 were not dermal sensitizers in the guinea pig maximization test (HERA, 2014). [Kl. scores = 2 and 4, respectively]

E. Repeated Dose Toxicity

Oral

Male rats were fed diets containing 0 or 2.5% sodium polyacrylate (MW 2,500) for four weeks. Body weight, body weight gain, and appearance of the animals were similar between treated and control animals. In the fourth week of the study, a small, but significant, decrease in total weight of bone minerals was detected and confirmed by radiographic and histological examination. There was a significant reduction in the concentration of magnesium in the bones and plasma of the treated animals. Calcium loss was slight and not statistically significant. Urinary excretion of sodium and phosphorus was markedly increased; calcium only slightly increased. The authors of the study

interpreted the finding as a metabolic imbalance rather than systemic toxicity. Sodium excretion could have been increased by the high intake of the sodium-neutralized test substance. The NOAEL for the study was considered to be 2.5% sodium polyacrylate in the diet, which was estimated to be 1,136 mg/kg-day (HERA, 2014). [Kl. score = 2]

Inhalation

Male and female rats were exposed by inhalation to 0, 0.2, 1.0, or 5.0 mg/m^3 sodium polyacrylate (MW 4,500) as an aerosol for 6 hours/day, 5 days/week for 13 weeks. Additional groups of animals were exposed for 13 weeks followed by a 91-day recovery period. There were no treatment-related effects on body weights, organ weights, feed and water consumption, clinical observations, and blood chemistry. In the histopathologic examination, the lungs of the mid- and high-dose animals showed signs of mild pulmonary irritation: increases in polymorphonuclear granulocytes or alveolar macrophages, pneumocyte hyperplasia, alveolar wall thickening and focal alveolitis. The lung effects were reversible and were not seen in the recovery group animals. The NOEC for systemic effects in this study was considered to be 5 mg/m^3, and the NOEC for localized irritation is 0.2 mg/m^3 (HERA, 2014). [Kl. score = 2]

Dermal

No studies are available.

F. Genotoxicity

In Vitro Studies

The results of the *in vitro* studies on sodium polyacrylates are presented below in Table 1. All of the studies show that sodium polyacrylates are not mutagenic or genotoxic.

Table 1: In Vitro Genotoxicity Studies on Sodium Polyacrylates (HERA, 2014)

Mean MW	Test System	Results*	Klimisch Score	Reference
2,000	Bacterial reverse mutation	-	2	HERA (2014)
2,000	Mouse lymphoma	-	2	HERA (2014)
2,000	Unscheduled DNA synthesis	-	2	HERA (2014)
4,500	Bacterial reverse mutation	-	2	HERA (2014)
4,500	Mouse lymphoma	-	2	HERA (2014)
4,500	Unscheduled DNA synthesis	-	2	HERA (2014)
4,500	Cytogenetic (CHO cells)	-	2	HERA (2014)
4,500	Bacterial reverse mutation	-	2	HERA (2014)
4,500	Mammalian cell gene mutation	-	2	HERA (2014)
4,500	Unscheduled DNA synthesis	-	2	HERA (2014)

*+, positive; -, negative

In Vivo Studies

There was no increase in micronuclei in polychromatic erythrocytes from the bone marrow of mice given a single oral gavage dose of 13,850 mg/kg sodium polyacrylate with a MW of 2,000 (HERA, 2014).

G. Carcinogenicity

No studies are available.

H. Reproductive Toxicity

No studies are available

I. Developmental Toxicity

Pregnant female rats were dosed by oral gavage with 0, 500, 1,000, or 3,000 mg/kg sodium polyacrylate (MW 4,500) on GD 6 to 15. At 3,000 mg/kg, the dams had soft or liquid stools during the treatment period. There was no maternal or developmental toxicity observed in this study. The NOAEL for maternal and developmental toxicity is 3,000 mg/kg-day (HERA, 2014). [Kl. score = 2]

Pregnant female rats were dosed by oral gavage with 0, 125, 375, or 1,125 mg/kg sodium polyacrylate (MW 90,000 as a 77.5% aq. solution) during GD 6 to 13. Some of the dams were sacrificed on GD 13 and the remaining on GD 19. One mid-dose dam and 6 high-dose dams died during the study; of these, three of the high-dose deaths were treatment-related and the remaining were considered the result of gavage errors. There was a transient decrease in feed consumption in the high-dose dams during GD 7-9, but not other indications of maternal toxicity. There was no developmental toxicity. The NOAELs for maternal and developmental toxicity are 375 and 1,125 mg/kg-day (HERA, 2014). [Kl. score = 2]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

NICNAS has assessed sodium polyacrylates in an IMAP Tier 1 assessment and considers it “a chemical identified as low concern to human health by application of expert validated rules”.[1]

The toxicological reference values developed for sodium polyacrylates follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

<u>Oral</u>

A 4-week dietary study showed no systemic toxicity in rats given 2.5% sodium polyacrylate (MW 2,500) in their feed. The estimated dose is 1,136 mg/kg-day. Two pre-natal developmental toxicity studies showed no effects at the highest dose tested: 3,000 and 1,125 mg/kg-day for sodium polyacrylates with MW of 4,500 and 90,000, respectively. The NOAEL of 1,136 mg/kg-day from the 4-week dietary study will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10

[1] https://www.nicnas.gov.au/chemical-information/imap-assessments/imap-assessments/tier-i-human-health-assessments#cas-A_9003-04-7

UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subacute to chronic) = 10
UF_D (database uncertainty) = 1

Oral RfD = 1,136 (10 x 10 x 1 x 10 x 1) = 1,136/1,000 = 1.0 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD:

Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (1 x 70 x 0.1)/2 = 3.5 mg/L

B. Cancer

No carcinogenicity studies have been conducted on sodium polyacrylates. Therefore, a cancer reference value was not derived.

VI. Human Health Hazard Assessment of Physico-Chemical Properties

Sodium polyacrylates do not exhibit the following physico-chemical properties:

- Flammability
- Explosivity
- Oxidising potential.

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Sodium polyacrylates are a low toxicity concern for aquatic organisms, terrestrial invertebrates, and plants.

B. Aquatic Toxicity

Acute Studies

Table 2 lists the results of acute aquatic toxicity studies on sodium polyacrylates.

Table 2: Acute Aquatic Toxicity Studies on Sodium Polyacrylates

Mean MW	Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
1,000	*Brachydanio rerio*	96-hr LC_{50}	>200	1	HERA, 2014

Mean MW	Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
1,000	*Salmo gairdneri*	96-hr LC_{50}	>1,000	1	HERA, 2014
1,200	*Leuciscus idus*	96-hr LC_{50}	>500	1	HERA, 2014
2,000	*Brachydanio rerio*	96-hr LC_{50}	>200	1	HERA, 2014
2,500	*Leuciscus idus*	96-hr LC_{50}	>500	1	HERA, 2014
4,500	*Lepomis macrochirus*	96-hr LC_{50}	>1,000	1	HERA, 2014
4,500	*Lepomis macrochirus*	96-hr LC_{50}	>1,000	1	HERA, 2014
8,000	*Leuciscus idus*	96-hr LC_{50}	>500	1	HERA, 2014
10,000	*Lepomis macrochirus*	96-hr LC_{50}	>1,000	1	HERA, 2014
15,000	*Leuciscus idus*	96-hr LC_{50}	>10,000	1	HERA, 2014
78,000	*Brachydanio rerio*	96-hr LC_{50}	>400	2	HERA, 2014
1,000	*Daphnia magna*	48-hr EC_{50}	>200	1	HERA, 2014
1,000	*Daphnia magna*	48-hr EC_{50}	>1,000	1	HERA, 2014
2,000	*Daphnia magna*	48-hr EC_{50}	>200	1	HERA, 2014
4,500	*Daphnia magna*	48-hr EC_{50}	>200	1	HERA, 2014
4,500	*Daphnia magna*	48-hr EC_{50}	>1,000	1	HERA, 2014
78,000	*Daphnia magna*	24-hr EC_{50}	276	2	HERA, 2014
8,000	*Selenastrum capricornutum*	72-hr EC_{50}	40	1	HERA, 2014
78,000	*Scenedesmus subspicatus*	96-hr EC_{50}	44	2	HERA, 2014

Chronic Studies

Table 3 lists the results of chronic aquatic toxicity studies on sodium polyacrylates.

Table 3: Chronic Aquatic Toxicity Studies on Sodium Polyacrylates (HERA, 2014)

Mean MW	Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
4,500	*Pimephales promelas*	32-d NOEC	56	2	HERA, 2014
4,500	*Brachydanio rerio*	28-d NOEC	>450	1	HERA, 2014
78,000	*Brachydanio rerio*	14-d NOEC	>400	2	HERA, 2014
4,500	*Daphnia magna*	21-d NOEC	450	1	HERA, 2014
4,500	*Daphnia magna*	21-d NOEC	58	1	HERA, 2014
4,500	*Daphnia magna*	21-d NOEC	12	2	HERA, 2014
78,000	*Daphnia magna*	21-d NOEC	100	2	HERA, 2014
4,500	*Scenedesmus subspicatus*	96-hr NOEC	180	2	HERA, 2014
78,000	*Scenedesmus subspicatus*	96-hr NOEC	32.8	2	HERA, 2014

There is considerable variability in the chronic aquatic toxicity results for *Daphnia magna* for sodium polyacrylates with the same molecular weight of 4,500. This was discussed in HERA (2014) and was explained by the solubility of sodium polyacrylates in water. In distilled water, the solubility of sodium polyacrylates with the molecular weight of 4,500 is >400 mg/L; however, under test conditions water solubility will decrease due to the presence of Ca^{++} and Mg^{++} (as measured by water hardness). In a study by BASF (reviewed in HERA, 2014), the water solubility of sodium polyacrylate (MW 4,500) was determined with radiolabelled compounds in a test system with a calcium concentration of 70 mg/L, which corresponds to the mean water hardness to the media used in an OECD TG 202 test. Under these conditions, the water solubility of sodium polyacrylate was 1.3 mg/L after 24 hours. So, one explanation for the variability of the chronic *Daphnia* studies may be due to differences in water hardness.

C. Toxicity to Sediment Organisms

The 96-hr EC_0 to *Chironomus riparius* (larvae) is >4,500 mg/kg sediment dry weight (HERA, 2014).

D. Terrestrial Toxicity

The results of terrestrial toxicity studies on sodium polyacrylate polymers are listed below.

Table 3: Terrestrial Toxicity Studies on Sodium Polyacrylates (HERA, 2014)

Mean MW	Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
4,500	*Eisenia foetida foetida*	14-d EC_0	1,000	1	HERA, 2014
78,000	*Eisenia foetida andrei*	14-d EC_0	1,000	2	HERA, 2014
78,000	*Brassica rapa*	21-d NOEC	1,000	2	HERA, 2014
4,500	Nitrogen transformation*	28-d EC_{10}	>2,500	1	HERA, 2014
4,500	Carbon transformation*	28-d EC_{10}	>2,500	1	HERA, 2014

*Soil organisms

E. Calculation of PNEC

The PNEC calculations for sodium polyacrylates follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute E(L)C_{50} values are available for fish (>200 mg/L), invertebrates (>200 mg/L), and plants (40 mg/L). Results from chronic studies are also available for all three trophic levels, with the lowest NOEC being 12 mg/L for invertebrates. On the basis that the data consists of short-term and long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported NOEC of 12 mg/L for invertebrates. The $PNEC_{water}$ is 1.2 mg/L.

PNEC sediment

Experimental results are available for one trophic level. There were no visual signs of toxicity to *Chironomus riparius* (larvae) at the highest concentration tested (>4,500 mg/kg sediment dry weight) (HERA) 2014). The EC_0 is considered to be above 4,500 mg/kg and an assessment factor cannot apply. Thus, the equilibrium partitioning method will be used to determine the $PNEC_{sed}$. The HERA (2014) risk assessment calculated a $PNEC_{sed}$ of 130 mg/kg sediment wet weight using the default of

0.05 as the weight fraction of organic carbon in sediment according to the EU Technical Guidance Document (TGD) (EU 2003).

PNEC soil

Experimental results are available for three trophic levels. An acute LC_{50} value is available for earthworms (1,000 mg/kg soil dry weight). A 21-day NOEC for *Brassica rapa* was reported to be 1,000 mg/kg soil dry weight. Results from two long-term studies are available for soil microorganisms, with the NOECs for nitrogen and carbon transformation being >2,500 mg/kg soil dry weight. On the basis that the data consists of short-term tests, as well as one long-term test from one trophic level, an assessment factor of 100 has been applied to the lowest reported long-term NOEC of >2,500 mg/kg soil dry weight. The $PNEC_{soil}$ is 25 mg/kg soil dry weight.

VIII. PBT ASSESSMENT

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009, ECHA, 2008).

The sodium polyacrylates are not readily biodegradable; thus they meet the screening criteria for persistence.

The sodium polyacrylates are expected to have high molecular weights and are not expected to be bioavailable. Thus these polymers do not meet the criteria for bioaccumulation.

Chronic NOECs for fish, daphnia and algae are available for sodium polyacrylates, and the NOEC values are >0.1 mg/L. Thus sodium polyacrylates do not meet the screening criteria for toxicity.

The overall conclusion is that sodium polyacrylates are not PBT substances.

IX. CLASSIFICATION AND LABELLING

A. Classification

Aquatic Acute Toxicity Category 3

B. Labelling

No signal word.

C. Pictograms

None.

X. SAFETY AND HANDLING

A. First Aid

Eye Contact

In case of contact, immediately flush eyes with plenty of water for at least 5 minutes. If symptoms persist, seek medical advice.

Skin Contact

Wash thoroughly with soap and water..

Inhalation

If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Ingestion

Rinse mouth with water and then drink plenty of water. Never give anything by mouth to an unconscious person. If symptoms develop, seek medical advice.

B. Firefighting Information

Extinguishing Media

Water fog, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards

Burning produces harmful and toxic fumes. Heat from fire may melt, decompose polymer, and generate flammable vapors. Combustion products may include: Carbon monoxide, carbon dioxide, and unburned hydrocarbons (smoke). Dust can accumulate static charges which can cause an incendiary electrical discharge. Fine dust dispersed in air in sufficient concentrations, and in the presence of an ignition source, is a potential dust explosion hazard.

Special Protective Equipment for Firefighters

Wear a self-contained breathing apparatus.

C. Accidental Release Measures

Personal Precautions

Use appropriate protective equipment. Potential combustible dust hazard. Avoid generating dust. Creates dangerous slipping hazard on any hard smooth surface.

Environmental Precautions

Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilt

Scoop up and remove.

D. Storage and Handling

General Handling

Avoid dust accumulation in enclosed space. Avoid generating dust; fine dust dispersed in air in sufficient concentrations, and in the presence of an ignition source is a potential dust explosion

hazard. Electrostatic charge may build up during handling. Equipment, container and metal containers should be grounded and bonded.

Storage

Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place. Use adequate ventilation to avoid excessive dust accumulation. Store away from excessive heat and away from strong oxidizing agents. Take measures to prevent the build up of electrostatic charge.

E. Exposure Controls/Personal Protection

Occupational Exposure Standards

Workplace Australia has not established an occupational exposure limit for sodium polyacrylates.

Engineering Controls

Use in a well ventilated area. Avoid creating dust. Take precautionary measures against static charge.

Personal Protection Equipment

Respiratory Protection: Not normally needed. But if significant exposures are possible then the following respirator is recommended: Dust/mist respirator.

Hand Protection: Normal work gloves.

Skin Protection: Normal work coveralls.

Eye protection: Wear safety glasses or goggles to protect against exposure.

Other Precautions: Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible.

F. Transport Information

Sodium polyacrylates are not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

Department of the Environment, Water, Heritage and the Arts (DEWHA). (2009). Environmental risk assessment guidance manual for industrial chemicals, Department of the Environment, Water, Heritage and the Arts, Commonwealth of Australia.

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XIV. ACRONYMS AND GLOSSARY

°C	degrees Celsius
ADWG	Australian Drinking Water Guidelines
DEWHA	Department of the Environment, Water, Heritage and the Arts
ECHA	European Chemicals Agency
EU	European Union
GHS	Globally Harmonised System of Classification and Labelling of Chemicals
HHRA	enHealth Human Risk Assessment
IUPAC	International Union of Pure and Applied Chemistry
LOAEL	lowest observed adverse effect level
mg/kg	milligrams per kilogram
mg/L	milligrams per litre
mg/m^3	milligrams per cubic metre
MW	molecular weight
NICNAS	The National Industrial Chemicals Notification and Assessment Scheme
NIOSH	National Institute for Occupational Safety and Health
NOAEL	no observed adverse effect level
NOEC	no observed effective concentration
OECD	Organisation for Economic Co-operation and Development
PBT	Persistent, Bioaccumulative and Toxic
ppm	parts per million
QSAR	quantitative structure–activity relationship
RfD	oral Reference dose

SDS	Safety Data Sheet
SMILES	simplified molecular-input line-entry system
TGD	Technical Guidance Document

SODIUM SULFATE

This dossier on sodium sulfate does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of sulfate in its use in drilling muds and hydraulic fracturing fluids. The majority of information presented in this dossier was obtained the OECD-SIDS documents on sodium sulfate (OECD, 2005a,b), and from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBSTANCE IDENTIFICATION

Chemical Name (IUPAC): Disodium sulfate

CAS RN: 7757-82-6

Molecular formula: Na_2SO_4

Molecular weight: 142.04

Synonyms: Sodium sulfate; disodium sulfate; sodium bisulfate; sulfuric acid, disodium salt

SMILES: [O-]S(=O)(=O)[O-].[Na+].[Na+]

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Sodium Sulfate

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	White crystalline solid,	2	ECHA
Melting Point	ca. 884°C	2	ECHA
Density	2.7 g/cm^3 @ 20°C	2	ECHA
Water Solubility	445.5 g/L @ 20°C	1	ECHA
Auto flammability	Not auto-flammable	1	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

Sodium sulfate dissociates in aqueous media to sodium (Na^+) and sulfate (SO_4^{2-}) ions in water.

Biodegradation is not applicable to inorganic compounds. Sodium sulfate is not expected to bioaccumulate; it will dissociate to ions that are ubiquitous in the environment. Sodium sulfate is not expected to absorb to soil or sediment because of its dissociation properties and high water solubility.

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

Sodium sulfate exhibits low acute toxicity by the oral and inhalation routes. It is not irritating to the skin and eyes; and it is not a skin sensitizer. In a reproductive and developmental toxicity screening study, there was no indication of any toxicity in rats given oral doses as high as 1,000 mg/kg-day. Sodium sulfate is not genotoxic.

B. Acute Toxicity

The oral LD_{50} in rats is >2,000 mg/kg (ECHA) [Kl. score = 1]. The 4-hour inhalation LC_{50} for an aerosol of sodium sulfate is >2.4 mg/L, which was the highest technically feasible aerosol concentration. The mas median aerodynamic diameters (MMAD) were 2.65 to 2.71 μm (ECHA) [Kl. score = 1]. There are no data on acute dermal toxicity.

Human data indicate a very low acute toxicity of sodium sulfate. High oral doses of sodium sulfate, from 300 mg/kg up to 20 grams for an adult, are well tolerated, except from (intentionally) causing severe diarrhea (OECD, 2005a,b).

C. Irritation

Application of 0.5 g sodium sulfate (in PEG 400) to the skin of rabbits for 4 hours was not irritating (ECHA) [Kl. score = 1].

Instillation of 90 mg sodium sulfate to the eyes of rabbits was not irritating (ECHA) [Kl. score = 1].

D. Sensitization

Sodium sulfate was not considered a skin sensitizer in a mouse local lymph node assay (ECHA). [Kl. score = 1]

E. Repeated Dose Toxicity

Oral

In a reproductive and developmental toxicity screening (OECD 421) study, male and female Wistar rats were dosed by oral gavage with 0, 100, 300, or 1,000 mg/kg sodium sulfate for a total of 4 weeks for males and 7 weeks for females. There was no evidence of toxicity at any dose level. The NOAEL for systemic toxicity is 1,000 mg/kg-day, the highest dose tested.

Inhalation

No studies are available.

Dermal

No studies are available.

F. Genotoxicity

In Vitro Studies

The *in vitro* genotoxicity studies on sodium sulfate are presented in Table 2.

Table 2: *In vitro* Genotoxicity Studies on Sodium Sulfate

Test System	Results*		Klimisch Score	Reference
	-S9	+S9		
Bacterial reverse mutation (*S. typhimurium* and E. coli strains)	-	-	1	ECHA
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	-	-	1	ECHA
Chromosomal aberration (Chinese hamster lung fibroblasts)	-	-	1	ECHA

*+, positive; -, negative

In Vivo Studies

No studies are available.

G. Carcinogenicity

No valid studies are available.

H. Reproductive/Developmental Toxicity

A reproductive and developmental toxicity screening (OECD 421) study has been conducted on sodium sulfate. Male and female Wistar rats were dosed by oral gavage with 0, 100, 300, or 1,000 mg/kg sodium sulfate. There were no deaths during the study and no clinical signs. Body weights, body weight gain, and feed consumption were similar across all groups. There was no reproductive or developmental toxicity at any dose level. The NOAEL for systemic, reproductive, and developmental toxicity is 1,000 mg/kg-day, the highest dose tested (ECHA) [Kl. score = 1].

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

Toxicological reference values were not derived. Sodium sulfate dissociates in water to sodium andsulfate ions.

The Australian drinking water guideline value for sodium is 180 mg/L based on aesthetics (ADWG, 2011).

The Australian drinking water guideline value for sulfate is 500 mg/L based on health. Concentrations of >500 mg/L can have purgative effects. There is also an Australian drinking water guideline value for sulfate of 250 mg/L based on aesthetics; it is the taste threshold (ADWG, 2011).

B. Cancer

There are no valid carcinogenicity studies on sodium sulfate. Thus, a cancer reference value was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Sodium sulfate does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Sodium sulfate is of low acute concern to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies conducted on sodium sulfate.

Table 3: Acute Aquatic Toxicity Studies on Sodium Sulfate

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Pimephales promelas	96-h LC_{50}	7,960	2	Mount *et al.* (1997)
Daphnia magna	48-h EC_{50}	4,736*	2	Davies and Hall (2007)

* Standard test conditions: 100 mg $CaCO_3$/L and Ca:Mg ratio of 0.7.

Chronic Studies

The lowest 7-day NOEC from a *Ceriodapnia dubia* reproduction study, in which the test media contained varying degrees of water hardness, was 1,109 mg/L (Soucek, 2007).

C. Sediment Toxicity

The lowest 96-hour LC_{50} value to *Hyalella azteca* in series of studies involving different hardness of water was 757 mg/L (Soucek and Kennedy, 2005). In another study with *Hyalella Azteca*, the lowest 96-hour LC_{50} value (in water with the lowest hardness) was 841 mg/L (Davies and Hall, 2007). The lowest 96-hour LC_{50} value to *Chironomus tentans* in series of studies involving different hardness of water was 20,899 mg/L (Soucek and Kennedy, 2005).

D. Terrestrial Toxicity

No adequate studies were located.

E. Calculation of PNEC

The PNEC calculations for sodium sulfate follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for two trophic levels. Acute $E(L)C_{50}$ values are available for fish (7,960 mg/L) and *Daphnia* (4,736 mg/L). A chronic toxicity study has also been conducted on *Ceriodapnia dubia*, but this study is considered inadequate for deriving a PNEC value. On the basis that the data consists of short-term results from two trophic levels, an assessment factor of 1,000 has been applied to the lowest reported $E(L)C_{50}$ value of 4,736 mg/L for *Daphnia*. The $PNEC_{water}$ is 4.7 mg/L.

PNEC sediment

No reliable experimental toxicity data on sediment organisms are available. Sodium sulfate dissociates completely in water with its environmental distribution is dominated by its high water solubility. K_{ow} and K_{oc} parameters do not readily apply to inorganics, such as sodium sulfate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of sodium sulfate to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

PNEC soil

No reliable experimental toxicity data on terrestrial organisms are available. The environmental distribution of sodium sulfate is dominated by its water solubility. Sorption of sodium sulfate should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. K_{ow} and K_{oc} parameters do not readily apply to inorganics, such as sodium sulfate. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, sodium sulfate is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Sodium sulfate is an organic salt that dissociates completely to sodium and sulfate ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both sodium and sulfate ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria is not considered applicable to sodium sulfate or its dissociated ions.

Sodium and sulfate ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus sodium sulfate is not expected to bioaccumulate.

The NOEC from a chronic toxicity study in *Ceriodaphnoa rerio* is >0.1 mg/L, and the acute E(L)C_{50} values for fish and *Daphnia* are >1 mg/L. Thus sodium sulfate does not meet the screening criteria for toxicity.

The overall conclusion is that sodium sulfate is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Not classified.

B. Labelling

No signal words.

C. Pictogram

None

X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact

Immediately flush eyes with plenty of water for at least 15 minutes. Remove contacts, if present and easy to do. If symptoms persist, seek medical attention.

Skin Contact

Wash with soap and water.

Inhalation

If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Ingestion

Do not induce vomiting. Rinse mouth with water and then drink a small amount of water. Get medical attention. Never give anything by mouth to an unconscious person.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: sodium and sulfur oxides.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus and chemical-protective clothing.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions

Use appropriate protective equipment. Avoid creating and breathing dust.

Environmental Precautions

Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled

Scoop and remove.

D. STORAGE AND HANDLING

General Handling

Avoid creating or inhaling dust.

Storage

Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
Workplace Australia has not established an occupational standard for sodium sulfate.

Engineering Controls

Use in a well-ventilated area.

Personal Protection Equipment

Respiratory Protection: Respiratory protection is not required.

Hand Protection: Chemical resistant protective gloves.

Skin Protection: Body protection must be chosen depending on activity and possible exposure.

Eye Protection: Safety glasses with side-shields.

Other Precautions: Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible.

F. TRANSPORT INFORMATION

Sodium sulfate is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods Code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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XIV. ACRONYMS AND GLOSSARY

°C	degrees Celsius
ADI	acceptable daily intake
ADWG	Australian Drinking Water Guidelines

BCF	bioconcentration factor
BMD	benchmark dose
BOD	biological oxygen demand
CAS	Chemical Abstracts Service
CERHR	Centre for Evaluation of Risks to Human Reproduction
CHO	Chinese Hamster Ovary
CNS	central nervous system
DEWHA	Department of the Environment, Water, Heritage and the Arts
ECHA	European Chemicals Agency
EU	European Union
FAO	Food and Agriculture Organization
FOB	functional observation battery
GD	gestational days
GHS	Globally Harmonised System of Classification and Labelling of Chemicals
HHRA	enHealth Human Risk Assessment
HRIPT	Human Repeated Insult Patch Test
IOM	Institute of Medicine
IRIS	Integrated Risk Information System
IUPAC	International Union of Pure and Applied Chemistry
JECFA	Joint FAO/WHO Expert Committee on Food Additives
LOAEL	lowest observed adverse effect level
MCI	molecular connectivity index
mg/kg	milligrams per kilogram
mg/L	milligrams per litre
mg/m^3	milligrams per cubic metre
MOA	mode-of-action
NICNAS	The National Industrial Chemicals Notification and Assessment Scheme
NIOSH	National Institute for Occupational Safety and Health
NOAEC	no observed adverse effect concentration
NOAEL	no observed adverse effect level
NOEC	no observed effective concentration
OECD	Organisation for Economic Cooperation and Development
PBPK	physiologically-based pharmacokinetic
PBT	Persistent, Bioaccumulative and Toxic
PND	postnatal day

PNEC	predicted no effect concentration
ppm	parts per million
QAC	quaternary ammonium compound
QSAR	quantitative structure activity relationship
RACB	Reproductive Assessment by Continuous Breeding
REACH	Registration, Evaluation, Authorisation and Restriction of Chemical Substances
RfD	Reference Dose (oral)
SCBA	self-contained breathing apparatus
SCE	sister chromatid exchange
SDS	Safety Data Sheet
SIAR	SIDS Initial Assessment Report
SIDS	Screening Information Data Set
SMILES	simplified molecular-input line-entry system
STEL	short-term exposure limit
ThOD	theoretical oxygen demand
TWA	time-weighted average
WHO	World Health Organization

TRIETHANOLAMINE

This dossier on triethanolamine does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of triethanolamine in its use in drilling muds and hydraulic fracturing fluids. The majority of information presented in this dossier was obtained from the ECHA database that provides information on chemicals that have been registered under the EU REACH (ECHA). Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC): 2-[bis(2-hydroxyethyl)amino]ethan-1-ol

CAS RN: 102-71-6

Molecular formula: $C_6H_{15}NO_3$ or $(CH_2OHCH_2)_3N$

Molecular weight: 149.19

Synonyms: Triethanolamine; 2,2',2"-nitrilotriethanol; 2,2',2"-nitrilotris[ethanol]; ethanol, 2,2',2"-nitrilotri- (8Cl); ethanol, 2,2',2"-nitrilotris- (9Cl); nitrilotriethanol; TEA; tris(beta-hydroxyethyl)amine; tris(2-hydroxyethyl)amine

SMILES: C(CO)N(CCO)CCO

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Triethanolamine

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Colorless to pale-yellow liquid with an amine-like odor.	2	ECHA
Melting Point	20.5°C	2	ECHA
Boiling Point	336.1°C	2	ECHA
Density	1.12 g/cm^3 @ 20°C	2	ECHA
Vapor Pressure	Negligible	2	ECHA
Partition Coefficient (log K_{ow})	-1.9 @ 25°C [Experimental]	2	ECHA

Water Solubility	>1,000 g/L @ 20°C	2	ECHA
Flash Point	179°C	2	ECHA
Auto flammability	324°C	2	ECHA
Viscosity	830.2 mm^2/s @ 20°C 181.5 mm^2/s @ 40°C	2	ECHA

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

Triethanolamine is readily biodegradable, and it has a low potential to bioaccumulate. Triethanolamine will not adsorb significantly to suspended solids and sediments in water and would be highly mobile in soil.

B. Biodegradation

Triethanolamine is readily biodegradable. In an OECD 301E test, there was 96% degradation after 19 days (ECHA). [Kl. score = 2]

Triethanolamine was completely degraded after incubation in municipal activated sludge for 1 or 5 days (West and Gonsior, 1996). The rate constants in all test batches for degradation and mineralization were reported to be >0.359. Thus, triethanolamine can be considered to be readily biodegradable. [Kl. score = 2]

C. Environmental Distribution

Adsorption/desorption

No experimental data are available for triethanolamine. Using KOCWIN in EPISUITE™ (EPA, 2017), the estimated K_{oc} value from log K_{ow} is 0.3046 L/kg. The estimated K_{oc} value from the molecular connectivity index (MCI) is 10 L/kg.

E. Bioaccumulation

Triethanolamine has been tested in a bioconcentration flow-through fish (OECD 305) test using *Cyprinus carpio*. The BCF was determined to be <0.4 and <3.9 at triethanolamine concentrations of 2.5 and 0.25 mg/L, respectively (ECHA). [Kl. score = 2]

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

The acute toxicity of triethanolamine by the oral, dermal, and inhalation routes is very low. Triethanolamine is not a skin or eye irritant; it is not a skin sensitizer to guinea pigs, but it may cause an allergic skin reaction in a small proportion of individuals. Repeated exposure by the oral route in rats showed no adverse effects. Repeated exposure by the inhalation caused effects to the respiratory tract and skin, respectively, in rats as a result of chronic irritation; but no target organs were identified from systemic exposure. Triethanolamine is not genotoxic, and lifetime oral and dermal studies in rats showed no clear carcinogenic effects. Developmental toxicity was seen in rats at oral doses that caused maternal toxicity.

B. Acute Toxicity

The oral LD_{50} in rats is 6,400 mg/kg (ECHA) [Kl. score = 2], and the dermal LD_{50} in rabbits is >2,000 mg/kg (ECHA) [Kl. score = 2]. No deaths seen in rats following an 8-hour exposure to a saturated vapor atmosphere [approximately 1.8 mg/m^3] (ECHA) [Kl. score = 2].

C. Irritation

Application of 0.5 mL to the skin of rabbits for 4 hours under occlusive conditions was not irritating. The mean of the 24, 48, and 72 hours erythema and edema scores were zero (ECHA). [Kl. score = 1]

Instillation of 0.1 mL into the eyes of rabbits were minimally irritating (Griffith *et al.*, 1980). [Kl. score = 2]

D. Sensitization

Triethanolamine was not considered a skin sensitizer when tested in a guinea pig maximization test (ECHA). [Kl. score = 1]

Patch test results with triethanolamine on patients from 1992 to 2007 were collected and evaluated. There were 85,098 patients that were tested with triethanolamine; of these, 323 (0.35%) patients tested positively to triethanolamine. The positive reactions that were interpreted as allergic seem to be caused by exposure to triethanolamine in cosmetics and/or topical therapeutic preparations possibly on damaged skin (Lessmann *et al.*, 2009).

E. Repeated Dose Toxicity

<u>Oral</u>

Male and female Cox CD rats were fed diets containing 0, 250, 500 or 1,000 mg/kg triethanolamine for 91 days. There were no effects that were considered treatment-related. The NOAEL for this study is 1,000 mg/kg-day (ECHA). [Kl. score = 2]

Inhalation

Male and female Wistar rats were exposed (nose-only) by inhalation to 0, 0.02, 0.1, or 0.5 mg/L triethanolamine aerosol 6 hours/day, 5 days/week for 28 days. There was no mortality; the only clinical signs were reddish crusts on the nasal edges in the 0.5 mg/L animals during the second half of the exposure period. Body weights and body weight gain were similar across all groups. There was no treatment-related changes in the hematology parameters, clinical chemistry, and neurobehavioral endpoints. Local inflammatory changes were observed in the submucosa of the larynx region. In both sexes, there was a tendency for a concentration-dependent increase in incidence and severity of the inflammatory lesions, with the effects greater in males than females. The NOAEC for systemic effects is 0.5 mg/L; the NOAEC for localized effects is 0.02 mg/L (ECHA) [Kl. score = 1].

Dermal

Male and female F344 rats were given dermal applications of 0, 125, 250, 500, 1,000, and 2,000 mg/kg triethanolamine 5 days/week for 90 days. There was deaths during the study. Body weight gain was significantly reduced (-33%) in the 2,000 mg/kg males compared to controls. Body weight gain was also significantly reduced (-13% to 36%) for the ≥125 mg/kg females. The mean final body weights of the 2,000 mg/kg males and females were significantly reduced. The only treatment-related clinical signs occurred at the site of dermal application. Brain weights relative to body weights were significantly elevated in the 2,000 mg/kg animals; because absolute brain weights were unaffected, the changes in brain weights is likely due to reduced body weights in these animals. Absolute kidney weights were increased in the ≥1,000 mg/kg animals; relative kidney weights were elevated in the ≥250 mg/kg males and ≥1,000 mg/kg females. Absolute and relative spleen weights were lower in the 2,000 mg/kg females; relative spleen weights were elevated in the ≥1,000 mg/kg males. Absolute and relative thymus weights were increased in the 2,000 mg/kg males. Relative liver weights were increased in the 500 and 1,000 mg/kg males. Absolute and relative lung weights were lower in the 2,000 mg/kg males. Relative testes weights were increased in the 2,000 mg/kg males. Hematological changes were seen in the 2,000 mg/kg animals and were considered to be due to an inflammatory response from dermal irritation at the application site. Elevated SGOT levels were noted in the 250 and 2,000 mg/kg males; and mean SGPT levels were significantly increased in the 2,000 mg/kg males. Elevated serum urea nitrogen, albumin, SGOT, and SGPR levels were noted in the 2,000 mg/kg females. At study termination, the specific gravity of urine was elevated in the 2,000 mg/kg males; urine protein levels for the ≥500 mg/kg males were significantly lower. The specific gravity of urine was elevated in the ≥1,000 mg/kg females; urine

glucose concentrations were also increased in these two dose groups. Apart for skin lesions at the site of application, there were no treatment-related histopathologic changes. The NOAEL for localized effects is 125 mg/kg-day based on chronic-active inflammation and acanthosis at the site of application in males. The NOAEL for systemic toxicity is 125 mg/kg-day based on increased relative kidney weights in males (ECHA) [Kl. score = 2].

F. Genotoxicity

In Vitro Studies

The findings from the *in vitr*o genotoxicity studies on triethanolamine are presented below in Table 2.

Table 2: *In vitro* Genotoxicity Studies on Triethanolamine

Test System	**Results***		**Klimisch Score**	**Reference**
	-S9	**+S9**		
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	2	Mortelsman *et al.* (1986); ECHA
Mammalian cell gene mutation (mouse lymphoma L5178Y cells)	-	-	1	ECHA
Chromosomal aberration (CHO cells)	-	-	2	Galloway *et al.* (1987); ECHA
Sister chromatid exchange (CHO cells)	-	-	2	Galloway *et al.* (1987); ECHA

*+, positive; -, negative

In Vivo Studies

Male and female $B6C3F_1$ mice were given dermal applications of triethanolamine, 5 days/week for 13 weeks. There were no increase in the frequency of micronucleated erythrocytes in the peripheral blood (NTP, 2004).

Triethanolamine did not induce sex-linked recessive lethal mutations in germ cells of adult male *Drosophila melanogaster* exposed by feeding or injection (Yoon *et al.*, 1985).

G. Carcinogenicity

Oral

Male and female F344 were given triethanolamine in their drinking water for two years. The doses were 0, 1, and 2%; but starting on week 69, the doses for females were 0.5 and 1%. The estimated daily intakes for 1 and 2% dose groups were approximately 667 and 1,333 mg/kg-day; and the estimated daily intakes for the 0.5% and 1% in females were approximately 333 and 667 mg/kg-day. There were no statistically significant increases in the incidence of tumors between treated and control groups when analyzed by Chi-square test. However, there was an increase in nephrotoxicity which appeared to have an adverse effect on the life expectancy of the treated animals, especially the females. So, an age-adjusted statistical analysis was conducted. There was a positive trend ($p<0.05$) in the occurrence of liver tumors in males and of uterine endometrial sarcomas and renal-cell adenomas in females. These tumors have been observed spontaneously in this strain of rats, and their incidences in the controls were lower than historical controls for other laboratories. The results may indicate that a positive trend in the occurrence of these tumors is not attributable to triethanolamine exposure. Increased incidence of kidney tumors in the high-dose females may have been connected with kidney damage. Histopathologic examination of the kidney effects observed in the treated groups, especially the high-dose females, showed acceleration of chronic nephropathy. Also, mineralization of the renal papilla, nodular hyperplasia of the pelvic mucosa, and pyelonephritis with or without papillary necrosis were also observed (Maekawa *et al.*, 1986; ECHA) [Kl. score = 2]

Male and female B6C3F$_1$ mice were given in their drinking water 0, 1 or 2% triethanolamine (0 and approximately 1,600 and 3,200 mg/kg-day) for 82 weeks. Mortality, organ weights and tumor incidences were similar between treated and control animals (Konishi *et al.*, 1992; ECHA). [Kl. score = 2]

Inhalation

No studies are available.

Dermal

Male and female F344 rats were given dermal applications of triethanolamine, 5 days/week for two years. The doses were: 0, 32, 63 or 125 mg/kg-day for males, and 0, 63, 125 or 250 mg/kg-day for females. There were no treatment-related carcinogenic effects in either sexes (NTP, 1999). [Kl. score = 1]

Male and female B6C3F$_1$ mice were given dermal applications of triethanolamine, 5 days/week for two years. The doses were: 0, 200, 630 and 2,000 mg/kg-day for males, and 0, 100, 300 and 1,000 mg/kg-day for females. In females, there was some evidence of carcinogenicity activity based on increased incidences of hepatocellular adenomas. In males, there was equivocal evidence of carcinogenicity activity based on the incidence of liver hemangiosarcomas (NTP, 2004). [Kl. score = 1]

H. Reproductive/Developmental Toxicity

In a reproductive and developmental toxicity screening (OECD 421) study, male and female Wistar rats were dosed by oral gavage with 0, 100, 300 or 1,000 mg/kg-day triethanolamine. Most of the 1,000 mg/kg-day animals and one 100 mg/kg-day animals showed transient salivation for a few minutes immediately after each treatment. This effect was considered to be induced by the unpalatability of the test substance or from local irritation of the upper digestive tract. Body weight gain was slightly lower in the 1,000 mg/kg-day females during gestation and was considered to be caused by the increased postimplantation loss rather than by a systemic effect of the test substance. In the 1,000 mg/kg-day group, there were lower mean number of implantation sites, increased postimplantation loss, and lower average litter size. There were no treatment-related effects in the F_1 pups. The NOAEL for systemic toxicity is 1,000 mg/kg-day. The NOAEL for reproductive toxicity is 1,000 mg/kg-day. The NOAEL for developmental toxicity is 300 mg/kg-day (ECHA). [Kl. score = 1]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for triethanolamine follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

There were no effects seen in a 91-day dietary study in rats, with a NOAEL of 1,000 mg/kg-day (ECHA). This NOAEL will be used for determining the oral Reference dose (RfD) and the drinking water guidance value.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 10
UF_D (database uncertainty) = 1

Oral RfD = 1,000/(10 x 10 x 1 x 10 x 1) = 1,000/1,000 = <u>1.0 mg/kg-day</u>

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (1.0 x 70 x 0.1)/2 = 3.5 mg/L

B. Cancer

There were no carcinogenic effects in male and female mice given triethanolamine in their drinking water for 82 weeks (Konishi et al., 1992). In a two-year drinking water study, age-adjust tumor incidence showed increased liver tumors in males, and uterine endometrial sarcomas and renal tubule adenomas in females. These tumors were not attributed to triethanolamine exposure because, in comparison with historical control incidences, the tumors reflected low incidences in the control groups rather than increased incidences in the exposed groups.

In dermal carcinogenicity studies, there was no evidence of carcinogenicity in male and female rats (NTP, 1999). In female mice, there was some evidence of carcinogenicity activity based on increased incidences of hepatocellular adenomas. In male mice, there was equivocal evidence of carcinogenicity activity based on the incidence of liver hemangiosarcomas (NTP, 2004).

A cancer reference value for triethanolamine was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Triethanolamine does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

Triethanolamine has low acute toxicity concern to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

Table 3 lists the results of acute aquatic toxicity studies conducted on triethanolamine.

Table 3: Acute Aquatic Toxicity Studies on Triethanolamine

Test Species	Endpoint	Results (mg/L)	Klimisch score	Reference
Pimephales promelas	96-h LC_{50}	11,800	2	ECHA
Ceriodaphnia dubia	48-h EC_{50}	610	2	Warne and Schifko, 1999
Desmodesmus subspicatus	72-h EC_{50} EC_{10}	512 (neutralized) 216 (un-neutralized) 26 (neutralized)	2	ECHA

Chronic Studies

In a 21-day *Daphnia* reproduction test, the NOEC for mortality is 16 mg/L, the NOEC for reproduction rate was 125 mg/L, and the NOEC for reproduction on the appearance of first offspring was 250 mg/L (Kuehn *et al.*, 1989). [Kl. score = 2]

C. Terrestrial Toxicity

No studies are available.

D. Calculation of PNEC

The PNEC calculations for triethanolamine follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (11,800 mg/L), invertebrates (610 mg/L), and plants (512 mg/L). Results

from chronic studies are available for invertebrates (NOEC = 16 mg/L) and algae (EC_{10} = 26 mg/L). On the basis that the data consists of chronic studies for two trophic levels, an assessment factor of 50 has been applied to the lowest reported EC_{10} of 16 mg/L for *Daphnia*. The $PNEC_{aquatic}$ is 0.32 mg/L.

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 0.25 mg/kg sediment wet weight.

The calculations are as follows:

$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$
$= (0.99/1280) \times 1000 \times 0.32$
$= 0.25$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$K_{sed\text{-}water} = 0.8 + [0.2 \times Kp_{sed})/1000 \times BD_{solid}]$
$= 0.8 + [0.2 \times 0.4/1000 \times 2400]$
$= 0.99$

Where:
Kp_{sed} = solid-water partition coefficient (L/kg).
BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$Kp_{sed} = K_{oc} \times f_{oc}$
$= 10 \times 0.04$
$= 0.4$

Where:
K_{oc} = organic carbon normalized distribution coefficient (L/kg). The K_{oc} for triethanolamine calculated from EPISUITE™ using MCI is 10 L/kg .
F_{oc} = fraction of organic carbon in sediment = 0.04 [default].

PNEC soil

There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is 0.04 mg/kg soil dry weight.

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
$= (0.2/1500) \times 1000 \times 0.32$
$= 0.04$

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
$= 10 \times 0.02$
$= 0.2$

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for triethanolamine calculated from EPISUITE™ using the MCI is 10 L/kg .
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Triethanolamine is readily biodegradable; thus it does not meet the screening criteria for persistence.

The BCF values for triethanolamine in fish was <3.9; thus it does not meet the criteria for bioaccumulation.

The NOEC or EC_{10} values from chronic aquatic toxicity studies on triethanolamine is >0.1 mg/L. Thus triethanolamine does not meet the criteria for toxicity.

The overall conclusion is that triethanolamine is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Not classified.

B. Labelling

No signal word.

C. Pictogram

None.

X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
Immediately flush open eyes with plenty of water for at least 15 minutes. Remove contacts, if present and easy to do. If effects occur, get medical attention immediately, preferably a physician for an ophthalmologic examination.

Skin Contact
Remove contaminated clothing. Wash thoroughly with soap and water. Seek medical attention if irritation persists.

Inhalation
If inhaled, remove from area to fresh air. Give artificial respiration if victim is not breathing. Get medical attention.

Ingestion
Rinse mouth with water and then drink plenty of water. Get medical attention. Never give anything by mouth to an unconscious person.

B. FIRE FIGHTING INFORMATION

Extinguishing Media
Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
Keep product and empty container away from heat and sources of ignition. May emit toxic fumes under fire conditions. Depending on conditions, decomposition products may include the following: nitrogen oxides, carbon monoxide, carbon dioxide.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus and chemical-protective clothing.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Use appropriate protective equipment. Handle in accordance with good industrial hygiene and safety practice. Avoid contact with skin, eyes, and clothing.

Environmental Precautions
Prevent from entering sewers, waterways, or low areas.

Steps to be Taken if Material is Released or Spilled
For large amounts: dike spillage and pump off product. For residues: pick up with suitable absorbent material. Dispose of contaminated material as prescribed.

D. STORAGE AND HANDLING

General Handling
Keep product and empty container away from heat and sources of ignition. Ensure adequate ventilation, especially in confined areas.

Storage
Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
The workplace exposure standard for triethanolamine in Australia is 5 mg/m^3 as an 8-hour TWA, with a sensitization notation.

Engineering Controls
Good general ventilation should be used. Use local exhaust ventilation, or other engineering controls to maintain airborne levels below exposure limit guidelines.

Personal Protection Equipment

Respiratory Protection:
Use respiratory protection in case of vapor or aerosol release.

Hand Protection:
Chemical resistant protective gloves.

Skin *Protection*:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Safety glasses with side-shields.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Wearing of closed work clothing is recommended. Ensure that eyewash stations and safety showers are close to the workstation location.

F. TRANSPORT INFORMATION

Triethanolamine is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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TRIBUTYL TETRADECYL PHOSPHONIUM CHLORIDE

This dossier on tributyl tetradecyl phosphonium chloride (TTPC) does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of TTPC in its use in drilling muds and hydraulic fracturing fluids. Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name (IUPAC): Tributyl(tetradecyl)phosphonium;chloride

CAS RN: 81741-28-8

Molecular formula: $C_{26}H_{56}PCl$

Molecular weight: 435.15

Synonyms: Tributyl tetradecyl phosphonium chloride; TTPC; tri-n-butyltetradecylphosphonium chloride; Bellacide 350; Bellacide 355

SMILES: CCCCCCCCCCCCCC[P+](CCCC)(CCCC)CCCC.[Cl-]

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of TTPC

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	Clear, colorless liquid	4	BWA Additives (2016)
Boiling Point	100°C*	4	BWA Additives (2016)
Specific Gravity	0.98 – 1.00 @ 20°C	4	BWA Additives (2016)
Partition Coefficient (log K_{ow})	2.45	4	BuruEnergy
Viscosity	55-65 mm^2/s @ 25°C	4	BWA Additives (2016)

*5% aqueous solution of TTPC

TTPC is a non-oxidizing biocide. Information on TTPC in this dossier has been obtained from BWA™ Water Additives, a producer of TTPC. BWA™ Water Additives produces a 5% or 50% aqueous solution of TTPC, which is sold under the product names Bellacide® 355 and Bellacide® 350, respectively.

III. ENVIRONMENTAL FATE PROPERTIES

A. Summary

TTPC is stable over a wide pH range and is not susceptible to photodegradation. TTPC is biodegradable, but not readily biodegradable. It will strongly adsorb to soil and sediment. TTPC is not expected to bioaccumulate.

B. Abiotic Degradation

Hydrolysis

TTPC is stable over a wide pH range (BuruEnergy). [Kl. score = 4]

Photolysis

TTPC is not susceptible to photodegradation. (BuruEnergy). [Kl. score = 4]

C. Biodegradation

TTPC was not readily biodegradable in an OECD 301 test (BuruEnergy). [Kl. score = 4]

A die-away [simulation] test was conducted with radiolabelled TTPC for 168 hours at concentration of 0.31 mg/L. The first-order rate constant was 0.69/hour and the half-life was 6.6 hours. After 24 and 168 hours, degradation was >81% and >98%, respectively (BuruEnergy). [Kl. score = 4]

TTPC was evaluation in a simulation test over a 40-day period using double ^{14}C labeled TTPC. In activated sludge, there was >40% degradation after 30 days with 50 ppb TTPC and >30% degradation after 7 days with 5 ppb TTPC. In river water, there was >20% after 35 days with 5 ppb TTPC. In sea water, there was >30% degradation after 35 days with 5 ppb TTPC (BuruEnergy). [Kl. score = 4]

D. Environmental Distribution

Adsorption/desorption

TTPC strongly adsorbs to soil. In a study involving three different soil types (sand, silt, and clay), 93 to 96% of TTPC adsorbed to soil (BuruEnergy). [Kl. score = 4]

No experimental studies are available for determining the K_{oc} of TTPC. Using KOCWIN in EPISUITE™ (EPA, 2017), the estimated K_{oc} value for TTPC using the MCI method is 4.555×10^7 L/kg.

E. Bioaccumulation

No bioaccumulation studies are available on TTPC. TTPC is not expected to bioaccumulate based on the experimental log K_{ow} of 2.45 (BuruEnergy). [Kl. score = 4]

IV. HUMAN HEALTH HAZARD ASSESSMENT

A. Summary

TTPC exhibits moderate acute toxicity by the oral route, but is very highly toxic by the inhalation route. It is corrosive to the skin and eyes, but it is not a skin sensitizer. No target organ effects were noted in a 90-day rat drinking water study. TTPC was not mutagenic in a bacterial reverse mutation (Ames) test. There are no carcinogenicity studies on TTPC. In rats, developmental toxicity was shown to occur at oral dose levels that were not maternally toxic; whereas, in rabbits, developmental toxicity occurred only at maternally toxic doses.

B. Acute Toxicity

An oral LD_{50} in rats for Bellacide 350 (50% aq. solution of TTPC) was reported to be >1,002 mg/kg (BWA Additives, 2011) [Kl. score = 4]. An oral LD_{50} in rats for Bellacide 355 (5% aqueous solution of TTPC) was reported to be >4,000 mg/kg (BWA Additives, 2009) [Kl. score = 4].

The 4-hour inhalation LC_{50} in male and female rats for a 50% aq. solution of TTPC was <0.05 mg/L (aerosol). The mass median aerodynamic diameter for the aerosol was 1.93 μm (Cytec, 2012) [Kl. score = 1]. The 1-hour inhalation LC_{50} in male and female rats for a 50% aq. solution of TTPC is 0.227 mg/L (aerosol). The mass median aerodynamic diameter for the aerosol was 1.92 μm (Cytec, 2013) [Kl. score = 1].

C. Irritation

Both Bellacide 350 (50% aq. solution TTPC) and Bellacide 355 (5% aq. solution TTPC) are considered to be corrosive to the skin and eyes (BWA Additives, 2011; 2015). [Kl. score = 4]

D. Sensitization

TTPC is not considered to be a skin sensitizer (BWA Additives, 2011; 2015). [Kl. score = 4]

E. Repeated Dose Toxicity

Oral

A 90-day rat drinking water study has been conducted on a product containing TTPC. The LOAEL for the active ingredient (TTPC) is 27.2 and 32.3 mg/kg-day in males and females, respectively, based on various clinical signs and significantly reduced body weights, feed and water consumption. The NOAEL for this study is 8.66 mg/kg-day (EPA, 2006). [Kl. score = 2]

Inhalation

No data are available.

Dermal

No data are available.

F. Genotoxicity

In Vitro Studies

TTPC was not mutagenic in a reverse mutation bacterial (Ames) test (BWA Additives, 2015). [Kl. score = 4]

In vivo Studies

No studies are available.

G. Carcinogenicity

No studies are available.

H. Reproductive Toxicity

No studies are available.

I. Developmental Toxicity

Female Tif:RAIf(SPF) rats were dosed by oral gavage with 0, 20, 60, or 120 mg/kg Belclene® [50% active ingredient: TTPC] during gestational days (GD) 6 through 15. In the high-dose group, there were two possible treatment-related spontaneous deaths (GD 9 and 14) and another death on GD 15 due to an intubation error. Clinical signs included dyspnea in one mid-dose and 4 high-dose animals, and vaginal bleeding in one mid-dose female on GD 15. In the high-dose group, maternal body weight gain was significantly lower during the treatment period (GD 6-15) and throughout the gestational period (GD 0-20). Mean food consumption was significantly reduced during GD 6-11 for both the mid- and high-dose animals. The number of females with implantations and the number of implantations/females were similar across all groups. Embryonic and fetal deaths were similar between treated and control groups. There were no soft tissue changes. There was an increased incidence of incomplete ossification of the 5th sternebra in the mid- and high-dose groups. The NOAELs for maternal and developmental toxicity for the active ingredient TTPC in this study is 30 and 10 mg/kg-day, respectively (EPA, 2006). [Kl. score = 2]

Female chinchilla rabbits were dosed by oral gavage with 0, 7.5, 22.5, or 45 mg/kg Belclene® [50% active ingredient: TTPC] during gestational days (GD) 6 through 18. In the mid- and high-dose groups, body weight gain was significantly reduced during GD 6-18 and feed consumption was reduced during GD 6-11. Fetal body weights were significantly reduced in the mid-(males only) and high-dose dose groups. There was also an increased incidence of delayed ossification of the hindlimb phalangeal nuclei in the mid- and high-dose groups. The NOAEL for maternal and developmental toxicity for the active ingredient TTPC in this study is 3.75 mg/kg-day (EPA 2006). [Kl. score = 2]

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

The toxicological reference values developed for TTPC follow the methodology discussed in enHealth (2012). The approach used to develop drinking water guidance values is described in the Australian Drinking Water Guidelines (ADWG, 2011).

A. Non-Cancer

<u>Oral</u>

The NOAEL from a rat 90-day drinking water study based on various clinical signs and significantly reduced body weight and reduced feed and water consumption is 8.66 mg a.i./kg-day (EPA, 2006). This NOAEL will be used to derive the oral Reference Dose.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 10
UF_D (database uncertainty) = 1

Oral RfD = 8.66/(10 x 10 x 1 x 10 x 1) = 8.66/1000 = 0.009 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (0.009 x 70 x 0.1)/2 = 0.03 mg/L

B. Cancer

No carcinogenicity studies are available on TTPC. Thus, a cancer reference dose was not derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

TTPC does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

A. Summary

TTPC has a very high acute toxicity concern to aquatic organisms.

B. Aquatic Toxicity

Acute Studies

Table 2 lists the results of acute aquatic toxicity studies conducted on TTPC.

Table 2: Acute Aquatic Toxicity Studies on TTPC

Test Species	Endpoint	Results (µg/L)	Klimisch score	Reference
Bluegill sunfish	96-h LC_{50}	58.6	2	ECOTOX
Common Carp	96-h LC_{50}	87	2	ECOTOX
Rainbow trout	96-h LC_{50}	490	2	ECOTOX
Rainbow trout	96-h LC_{50}	200	2	ECOTOX
Daphnia magna	48-h EC_{50}	25.2	2	ECOTOX
Selenastrum capricornutum	72-h EC_{50}	19	4	BuruEnergy

Chronic Studies
No studies are available.

C. Terrestrial Toxicity

Table 3 lists the avian toxicity studies conducted on TTPC.

Table 3: Avian Toxicity Studies on TTPC

Test Species	Endpoint	Results	Kl. score	Reference
Bobwhite Quail	8-d dietary	LC_{50}: 4,215 ppm NOEL: 1,980 ppm	2	ECOTOX

Mallard Duck	8-d dietary	LC_{50}: 3,663 ppm NOEL: 1,780 ppm	2	ECOTOX
Mallard Duck	14-d oral gavage	LD_{50}: 232 mg/kg NOEL: <178 mg/kg	2	ECOTOX

D. Calculation of PNEC

The PNEC calculations for TTPC follow the methodology discussed in DEWHA (2009).

PNEC water

Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (58.6 µg/L), *Daphnia* (25 µg/L), and algae (19 µg/L). No chronic toxicity studies are available on TTPC. On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the effect concentration of 19 µg/L for algae. The $PNEC_{aquatic}$ is calculated to be 0.019 µg/L (1.9×10^{-5} mg/L).

PNEC sediment

There are no toxicity data for sediment-dwelling organisms. Therefore, the $PNEC_{sed}$ was calculated using the equilibrium partitioning method. The $PNEC_{sed}$ is 12,982 µg/kg (13.0 mg/kg) sediment wet weight.

The calculations are as follows:

$$PNEC_{sed} = (K_{sed\text{-}water}/BD_{sed}) \times 1000 \times PNEC_{water}$$
$$= (874{,}561/1280) \times 1000 \times 0.019$$
$$= 12{,}982$$

Where:
$K_{sed\text{-}water}$ = suspended matter-water partition coefficient (m^3/m^3)
BD_{sed} = bulk density of sediment (kg/m^3) = 1,280 [default]

$$K_{sed\text{-}water} = 0.8 + [0.2 \times Kp_{sed}/1000 \times BD_{solid}]$$
$$= 0.8 + [0.2 \times 1{,}822{,}000/1000 \times 2400]$$
$$= 874{,}561$$

Where:
Kp_{sed} = solid-water partition coefficient (L/kg).

BD_{solid} = bulk density of the solid phase (kg/m^3) = 2,400 [default]

$Kp_{sed} = K_{oc} \times f_{oc}$
= 45,550,000 x 0.04
= 1,822,000

Where:
K_{oc} = organic carbon normalized distribution coefficient (L/kg). The K_{oc} for TTPC calculated from EPISUITE™ using the MCI method is 4.555×10^7 L/kg.
F_{oc} = fraction of organic carbon in sediment = 0.04 [default].

PNEC soil
There are no toxicity data for terrestrial or soil organisms. Therefore, the $PNEC_{soil}$ was calculated using the equilibrium partitioning method. The $PNEC_{soil}$ is 11,539 µg/kg (11.5 mg/kg) soil dry weight.

The calculations are as follows:

$PNEC_{soil} = (Kp_{soil}/BD_{soil}) \times 1000 \times PNEC_{water}$
= (911,000/1500) x 1000 x 0.019
= 11,539

Where:
Kp_{soil} = soil-water partition coefficient (m^3/m^3)
BD_{soil} = bulk density of soil (kg/m^3) = 1,500 [default]

$Kp_{soil} = K_{oc} \times f_{oc}$
= 45,550,000 x 0.02
= 911,000

Where:
K_{oc} = organic carbon normalised distribution coefficient (L/kg). The K_{oc} for TTPC calculated from EPISUITE™ using the MCI method is 4.555×10^7 L/kg.
F_{oc} = fraction of organic carbon in soil = 0.02 [default].

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

In a simulation test using river water, there was >20% after 35 days; however, no information is available on longer time points. TTPC is not readily biodegradable; thus it meets the screening criteria for persistence.

The log K_{ow} for TTPC is 2.45. Thus, TTPC does not meet the screening criteria for bioaccumulation.

There are no chronic aquatic toxicity studies available on TTPC. The lowest acute $E(L)C_{50}$ value for TTPC is <1 mg/L in algae. Thus TTPC meet the criteria for toxicity.

The overall conclusion is that TTPC is not a PBT substance.

IX. CLASSIFICATION AND LABELING (Australia GHS)

A. Classification

Acute Toxicity Category 4 [Oral]
Acute Toxicity Category 1 [Inhalation]
Skin Corrosion Category 1
Eye Damage Category 1
STOT RE Category 2
Aquatic Acute Category 1
Aquatic Chronic Category1

B. Labelling

Danger

C. Pictogram



In addition to the hazard statements corresponding the GHS classifications, the following non-GHS hazard statement is to be added to the SDS: AUH071: Corrosive to the Respiratory Tract.

X. SAFETY AND HANDLING

A. First Aid

<u>Eye Contact</u>

Flush with plenty of fresh water for 15 minutes holding eyelids open, lifting eyelids occasionally to ensure complete removal of the product. DO NOT allow rubbing of eyes or keeping eyes closed. Remove contact lenses. Seek medical advice.

Skin Contact

Rinse with soap and plenty of water for several minutes. Remove contaminated clothing. Seek medical attention immediately.

Inhalation

Remove person to fresh air. Apply artificial respiration if not breathing. Seek medical attention.

Ingestion

Rinse mouth with water (only if the person is conscious). Do NOT induce vomiting. Seek medical advice immediately.

B. FIRE FIGHTING INFORMATION

Extinguishing Media

Suitable Extinguishing Media: carbon dioxide, water spray, foam, dry chemical.

Specific Exposure Hazards

Containers may explode when heated. May form explosive mixtures with strong acids. Hazardous combustion products may include the following materials: carbon monoxide, carbon dioxide, phosphorus oxides, chlorine.

Special Protective Equipment for Firefighters

Full protective clothing and approved self-contained breathing apparatus required for firefighting personnel.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions

Use appropriate protective equipment and avoid direct contact. Do not touch damaged containers or spilled material unless wearing appropriate protective clothing. Ventilate the area before entry.

Environmental Precautions

Prevent spills from entering storm drains or sewers and contact with soil.

Steps to be Taken if Material is Released or Spilled

Use an absorbent material to recover as much product as possible, then, rinse the affected area with water to dilute the residue. Disposal of leftover product and used containers should be carried out in accordance with all local, state and federal regulations.

D. STORAGE AND HANDLING

General Handling

Wear appropriate personal protective equipment. Avoid contact with eyes, skin or clothing. Avoid breathing mist, vapours or spray. Use only with adequate ventilation. Wash hands after use. Launder contaminated clothing.

Storage

Keep container closed when not in use. Store in a cool well ventilated area.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
Workplace Australia has not established an occupational exposure standard for TTPC.

Engineering Controls

Good general ventilation should be used. Ventilation rates should be matched to conditions. If applicable, use process enclosures, local exhaust ventilation, or other engineering controls to maintain airborne levels below recommended exposure limits. If exposure limits have not been established, maintain airborne levels to an acceptable level.

Personal Protection Equipment

Respiratory Protection: Use a mask or approved air-purifying respirator with appropriate cartridge or canister in spray applications or in confined spaces.

Hand Protection: Wear impervious gloves to prevent skin contact and absorption of this material. Rubber or Neoprene gloves may afford adequate skin protection.

Skin Protection: Wear appropriate clothes (*i.e*., coveralls). Use non-slip footwear.

Eye protection: Wear eye protection in situations where splash or thick mists are possible.

Other Precautions: Avoid contact with skin, eyes and clothing. When using, do not eat or drink. Wash hands thoroughly with soap and water before eating or drinking. Remove contaminated clothing and launder before reuse.

F. TRANSPORT INFORMATION

UN2922 CORROSIVE LIQUID, TOXIC N.O.S. (contains tributyltetradecyl phosphonium chloride)
Class 8 and 6.1
Packing Group: II

Environmentally Hazardous Substance

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

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U.S. Environmental Protection Agency [EPA] (2017). EPISuite™ v. 4.11, United States Environmental Protection Agency, Office of Pollution Prevention and Toxics and Syracuse Research Corporation. Available at: https://www.epa.gov/tsca-screening-tools/epi-suitetm-estimation-program-interface.

ULEXITE

This dossier on ulexite does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies pertinent to the risk assessment of ulexite in its use in drilling muds and hydraulic fracturing fluids. Where possible, study quality was evaluated using the Klimisch scoring system (Klimisch *et al.*, 1997).

I. SUBTANCE IDENTIFICATION

Chemical Name: Sodium-calcium pentaborate octahydrate

CAS RN: 1319-33-1

Molecular formula: $(NaCaB_5O_6(OH)_6 \bullet 5H_2O)$

Molecular weight: Not applicable

Synonyms: Ulexite; sodium-calcium pentaborate octahydrate

II. PHYSICO-CHEMICAL PROPERTIES

Table 1: Overview of the Physico-chemical Properties of Commercially Available Ulexite

Property	Value	Klimisch score	Reference
Physical state at 20°C and 101.3 kPa	White, granular, ground, or powder form	4	Etimine USA, Inc. (2016)
Melting Point	870°C	4	Etimine USA, Inc. (2016)
Bulk Density	1,410 to 1,500 kg/m^3	4	Etimine USA, Inc. (2016)
Water solubility	26.67% as dissolved Ulexite @ 25°C by weight of solution	4	American Borate Company (2016)

Ulexite is a naturally-occurring mineral that is slightly soluble in water.

In a study investigating the relative rates of boron from soluble and controlled-release boron fertilizers, ulexite showed releases of boron of 20% in just under 10 weeks; 40% in approximately 25 weeks; 60% by 40 weeks; and 80% by 60 weeks (Broschat, 2008).

III. ENVIRONMENTAL FATE PROPERTIES

No information is available. Ulexite is a naturally-occurring mineral and is not expected to biodegrade or bioaccumulate.

IV. HUMAN HEALTH HAZARD ASSESSMENT

No information is available.

V. DERIVATION OF TOXICOLOGICAL REFERENCE AND DRINKING WATER GUIDANCE VALUES

No values were derived.

VI. HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES

Ulexite does not exhibit the following physico-chemical properties:

- Explosivity
- Flammability
- Oxidizing potential

VII. ENVIRONMENTAL HAZARD ASSESSMENT

No information is available.

VIII. PBT Assessment

The methodology for the Persistent, Bioaccumulative and Toxic (PBT) substances assessment is based on the Australian and EU Reach Criteria methodology (DEWHA, 2009; ECHA, 2008).

Ulexite is a naturally-occurring mineral. For the purposes of this PBT assessment, the persistence criteria is not considered applicable to this inorganic substance.

Bioaccumulation is not applicable to naturally-occuring minerals, such as ulexite. Although boron is slowly released from ulexite, limited data indicate that bioaccumulation is not significant in aquatic and terrestrial food chains. Thus, it does not meet the criteria for bioaccumulation.

There are no mammalian or aquatic toxicity studies on ulexite. Ulexite, being a slightly water-soluble mineral, is not expected to be bioavailable. Thus, it does not meet the criteria for toxicity.

The overall conclusion is that ulexite is not a PBT substance.

IX. CLASSIFICATION AND LABELING

A. Classification

Not classified.

B. Labelling

No signal word.

C. Pictogram

None

X. SAFETY AND HANDLING

A. FIRST AID

Eye Contact
In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. If symptoms persist, seek medical advice.

Skin Contact
Wash thoroughly with soap and water.

Inhalation
If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Ingestion
Rinse mouth with water and then drink plenty of water. Never give anything by mouth to an unconscious person. If symptoms develop, seek medical advice.

B. FIRE FIGHTING INFORMATION

Extinguishing Media

Water spray, carbon dioxide, foam, dry chemical.

Specific Exposure Hazards
Ulexite is non-flammable, combustible, or explosive. It is a flame retardant.

Special Protective Equipment for Firefighters
Wear self-contained breathing apparatus and protective clothing.

C. ACCIDENTAL RELEASE MEASURES

Personal Precautions
Use appropriate protective equipment.

Environmental Precautions
Ulexite is slightly water-soluble; at high concentrations it may cause damage to trees or vegetation by root absorption. Do not flush to drains.

Steps to be Taken if Material is Released or Spilled
Scoop up and remove.

D. STORAGE AND HANDLING

General Handling
No special measures necessary provided product is used correctly.

Other Handling Precautions
Avoid eye and skin contact. Avoid creating or inhaling dust.

Storage
Keep container tightly closed and in a dry and well-ventilated place. Keep in a cool place.

E. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Standards
Workplace Australia has not established an occupational exposure standard for ulexite.

Engineering Controls
None

Personal Protection Equipment

Respiratory Protection:
Respiratory protection is not required.

Hand Protection:
Chemical resistant protective gloves.

Skin *Protection*:
Body protection must be chosen depending on activity and possible exposure.

Eye protection*:*
Safety glasses with side-shields.

Other Precautions:
Handle in accordance with good industrial hygiene and safety practice. Eyewash fountains and safety showers must be easily accessible.

F. TRANSPORT INFORMATION

Ulexite is not considered hazardous for purposes of transportation by road or rail. An Australian Dangerous Goods code is not required.

XI. DISPOSAL

Disposal should be in accordance with all local, state, and federal regulations.

XII. REGULATORY INFORMATION

Australian AICS Inventory: Listed.

XIII. REFERENCES

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

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APPENDIX H OTHER ASSESSED HYDRAULIC FRACTURING FLUID AGENTS

APPENDIX H.1 ENVIRONMENTAL HAZARD ASSESSMENT OF POTASSIUM CHLORIDE

TECHNICAL MEMORANDUM

DATE 13 December 2011

PROJECT No. 117636002-7000-008-TM-Rev0

TO Paul Wybrew

CC Carolyn Brumley, Len Turczynowicz

FROM Lange Jorstad

ENVIRONMENTAL HAZARD ASSESSMENT OF POTASSIUM CHLORIDE

1.0 INTRODUCTION

Santos Ltd (Santos) has requested that Golder Associates Pty Ltd (Golder) undertake a review of the chemical potassium chloride in regard to its toxicity to human health and toxicity to both aquatic and terrestrial environments.

The human health toxicity profile attached presents an overview of the toxicity of potassium chloride to human receptors. The chemical information sheet attached presents the available chemical and aquatic ecotoxicological data for potassium chloride.

1.1 Chemical Information

Potassium chloride is a metal halide salt composed of potassium and chlorine. Potassium chloride is highly water soluble, and readily undergoes dissociation (SIDS, 2001). Potassium chloride can be used as a shale stabiliser when drilling through hydro sensitive clays and shales. The potassium ion enters between individual clay platelets in the shale so that they are held together; thus eliminating entry of water from the drilling fluid (AMC, 2011).

Potassium is an essential element for animals and plants. Potassium is a neurotransmitter and is ubiquitous in living cells. Proteins called potassium channels located on cell membranes regulate the uptake and removal of ions in cells. Consequently potassium is actively regulated in organisms and is unlikely to be readily taken up by organisms exposed to high concentrations.

Chloride ions are similarly regulated in plant and animal cell membranes. Marine animals and plants regulate uptake and removal of chloride ions from their surrounding environment. Groundwaters are saline environments to which the native flora and fauna are well adapted.

2.0 POTASSIUM CHLORIDE HEALTH HAZARD ASSESSMENT

The assessment of human health toxicity represents an assessment of hazard and an intrinsic potential based on toxicological properties rather than risk. The aim of the hazard assessment is to provide a semi-quantitative hierarchy or hazard ranking of chemicals based on human health toxicity including both physical and chemical hazards to identify contaminants of potential concern (COPC). Further evaluation of the risk posed by such COPCs in terms of exposure pathways and fate and transport modelling has been presented in Section 7 of the previous Golder CSHF Risk assessment, dated 12 July 2011 (Ref No 117636002-7000-004-R). While this has not focussed on potassium chloride, other inorganic COPCs would reflect similar physico-chemical properties to potassium chloride and hence fate and transport characteristics.

Section 6 (pp130-143) of the CSHF Risk assessment, (Golder (2011), Ref No 117636002-7000-004-R) provides a detailed basis to the human health hazard ranking and is not reproduced here. The methodology in general terms is based on range of toxicological and fate and transport properties with associated ranking thresholds consistent with OECD and UN Global Harmonisation Systems. The use of these thresholds

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allows a qualification and scoring across these parameters with an averaging of the scoring across data sets. No weighting is placed on the various parameters examined.

Preliminary examination of potassium chloride based on the NOHSC (2004) "*Approved Criteria for Classifying Hazardous Substances, 3rd Edition*" in terms of its notification indicates it is not listed as a hazardous substance on the Safework Australia, Hazardous Substances Information System. While this provides some confidence in terms of its toxicity, a review was undertaken as a precautionary measure. The summary of the hazard ranking is provided in Table 1 below. The overall toxicity score reports a low to moderate level of concern (Score 1.67). This reflects the dissociative nature of this inorganic substance when introduced to water and its ability to introduce potassium ions into the environment.

Table 1: Potassium chloride human health toxicity score

Chemical Name	Hazard Classification NOHSC (2004)	Carcinogenicity	Mutagenicity/ genotoxicity	Developmental toxicity	Acute toxicity	Systemic toxicity/ Organ effects	Overall Toxicity Score
Potassium chloride	**Review**	**1**	**1**	**1**	**2**	**3**	**1.67**

The concluding summary comments from the toxicity profile put the hazard score in perspective:

"Potassium is an essential element in the body and the main intracellular cation with 98% of total body potassium located within the cells. Potassium chloride also occurs widely in the environment, including natural and drinking water as a consequence of the use of water treatment chemicals. Potassium chloride is used for the prevention and treatment of potassium deficiency, e.g. when thiazide diuretics or corticosteroids are used in case of excessive vomiting or diarrhoea, or diets poor in potassium or in the treatment of cumulative digitalis poisoning.

The most common form of ingestion is through drinking water. It is not considered necessary to establish a health-based guideline value for potassium in drinking water due to its lack of toxicity. Occupational exposure to potassium chloride may occur through inhalation of dust and dermal contact of this compound at workplaces where potassium chloride is produced or used. Specific occupational exposure limits (OELs) and actual exposure levels in the mining, refining, fertilizer and other industries are not available.

Acute effects are rare in humans although under particular circumstances severe effects may occur. Lethal effects were observed in a 2 month old baby fed 15,000 mg potassium chloride for 2 days and in another case report where an adult woman had ingested slow released potassium chloride tablets (35, 000 mg).Potassium chloride has not been evaluated and is not listed by the IARC as a carcinogen. In a long-term study performed with KCl, no carcinogenic effects were observed in male rats and it is a slight skin and eye irritant.

In the environment and in contact with water, potassium chloride dissociates readily into its component ions. No further degradation subsequently results. In soil, transport and leaching of potassium and chloride ions in solution is affected by surrounding conditions".

2.1 Conclusion : health hazard assessment

Taken collectively the potassium chloride toxicity and hazard ranking is of a low to moderate concern. Ingestion of high levels of dissolved potassium chloride in water at levels producing severe health effects is unlikely due to the rapid dilution of potassium chloride following environmental introduction into sub-surface waters, however, this requires qualification in terms of the masses of potassium chloride introduced.

Occupational exposures and short-term environmental spills may lead to short-term irritant effects depending on the nature of the exposure and are the main areas warranting consideration.

3.0 ECOLOGICALTOXICITY ASSESSMENT

3.1 Aquatic toxicity assessment

An environmental hazard assessment was undertaken of potassium chloride, used as a fracturing chemical, based on persistence (P), bioaccumulation (B) and toxic (T) potential (hereafter referred to as PBT). The methodology used to assess potassium chloride is outlined in Chapter 4 of report 117636002-7000-004-Rev0. The environmental hazard assessment categorizes a chemical as having a high, moderate or low risk to the environment.

The Chemical Information Sheet presents the available ecotoxicological data for freshwater organisms. The concentrations of potassium chloride required to illicit toxic effect are consistent with the expectation that this substance is inherently non-toxic and will only result in adverse effects in excess concentrations and when cellular mechanisms of active regulation are impaired.

An overall score (the environmental hazard score) for potassium chloride was calculated based on the toxicity scores. Potassium chloride is inorganic so it has not been assessed for bioaccumulation potential. Potassium chloride is also highly water soluble, and readily dissociates into naturally occurring ions in aquatic systems (SIDS, 2001). As such, potassium chloride was not scored for persistence. Table 2 below summarises the overall hazard score for potassium chloride.

Table 2: Toxicity score for potassium chloride

Chemical	Bioaccumulation Score	Persistence Score	Toxicity Score	Overall Hazard Score
Potassium Chloride	NA	NA	**2**	**2**

Based on the PBT ranking, potassium chloride has been given an overall hazard score of 2 and is considered to pose a moderate hazard to the aquatic environment. To obtain a moderate hazard score the PBT score must be between 1.65 and 2.34. The moderate hazard ranking was based on acute toxicological effects in a freshwater mussel. These effects relate to the exposure of a freshwater organism to a salty medium.

Terrestrial toxicity assessment

The lowest terrestrial toxicity data for modelled (QSAR earthworm) and measured (mammalian LD50) is presented in Table 3 below.

Table 3: Terrestrial toxicity data for potassium chloride

		QSAR earthworm LC50	Mammalian LD50
		mg/L	**mg/kg bw/d**
Potassium chloride	7447-40-7	2.33	383

NEPC (2010) provides only limited discussion on how the environmental fate and persistence of inorganic substances should be assessed. Further assessment of the hazards of the inorganic chemicals to terrestrial receptors has not been undertaken.

Potassium chloride and salinity

Increased concentrations of cations and anions such as potassium and chloride in groundwater amount to changes in salinity. Increased salinity can impact adversely on aquatic and terrestrial ecosystems.

Groundwater dependent ecosystems include surface water bodies such as wetlands, rivers and lakes, and also some terrestrial ecosystems.

Available data suggest that aquatic biota may be adversely affected as salinity exceeds 1,000 mg/L but there is limited information on how increasing salinity will affect the various life stages of the biota. Salinisation can lead to changes in the physical environment that will affect ecosystem processes (Hart *et al*., 2003). However, the tolerances of freshwater fish, aquatic plants and invertebrates to increased salinity vary, with invertebrates possibly the most sensitive organisms (adverse effects noted at 1,000 mg/L) and fish the least (generally tolerant up to 10,000 mg/L).

Conclusions: ecological toxicity

Based on the information considered, potassium chloride is considered to pose a moderate hazard to the freshwater environment. The moderate hazard evaluation is considered to be conservative given the active regulation of potassium and chloride in living cells. However, it is possible that adverse effects may occur in organisms where potassium and / or chloride are present in excess.

On this basis, potassium chloride is not considered a COPC for the purposes of either a human health or ecological risk assessment. Further, the operational controls established at well pads during and following hydraulic stimulation events should substantially reduce the potential for complete exposure pathways to occur.

References

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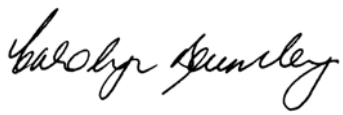
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Name	Potassium Chloride
Synonyms	Sylvite, Muriate of potash
CAS number	7447-40-7
Molecular formula	KCl
Molecular structure	K^+-- --Cl^-

Overview	References
Potassium is an essential element in the body. It is the main intracellular cation with 98% of total body potassium located within the cells. It is mainly used in fertilisers, medicine, lethal injections, scientific applications, feedstock, food processing and as a sodium substitute in table salt.	6
Potassium chloride is an essential element with homeostatic physiological processes regulating levels in the body. In cases of increased exposure to high levels of potassium significant health effects in people with kidney disease or other conditions, such as heart disease may result.	1
Potassium chloride as an inorganic salt is not subjected to further degradation processes in the environment once it dissociates into its respective ions. In water, potassium chloride is highly water soluble, and readily undergoes dissociation. In soil, transport and leaching of potassium and chloride ions is affected by the clay minerals (type and content), pH, and organic matter.	6

Human Health Toxicity Summary	Reference
Inhalation Occupational exposure to potassium chloride may occur through inhalation of dust at workplaces where potassium chloride is produced or used.	2
Carcinogenicity Potassium chloride has not been evaluated and is not listed by the IARC as a carcinogen. In a long-term study, male rats (50 per group) were fed potassium chloride in the diet at levels of 110, 450 or 1820 mg/kg bw/day for 2 years. No carcinogenic effects were observed in male rats.	3 6
Dermal Slight skin and eye irritant. A threshold concentration for skin irritancy of 60% was seen when potassium chloride in aqueous solution was in contact with skin of human volunteers. The threshold concentration when applied to broken skin was 5%.	2 4 6
Developmental A developmental study revealed no foetotoxic or teratogenic effects of potassium chloridel in doses up to 235 mg/kg/day (mice) and 310 mg/kg/day (rats). No fertility study has been located. Further human and ecological assessment was not recommended by the OECD SIDS.	6
Mutagenicity/genotoxicity No gene mutations were reported in bacterial tests, with and without metabolic activation. However, high concentrations of potassium chloride showed positive results in a range of genotoxic screening assays using mammalian cells in culture. The action of potassium chloride in culture seems to be an indirect effect therefore further *in vivo* studies were not considered necessary (OECD SIDS).	6
Therapeutic dosage Adult: In case of potassium deficiency, the dose should be adjusted to the needs of the patient. For the prevention of hypokalaemia the usual dose is 20-30 mEq of potassium per day; and 40- 100 mEq or more per day (approximately 40-100 mg/kg bw per day) for the treatment of potassium	5

depletion. Children: The dose usually indicated in children is 2 mmol/kg/day of potassium (approximately 15 mg/kg bw/d for a child with a body weight of 10 kg)	

Toxicity Values	Value	Reference
Animal Studies	**Oral, LD50**	
Guinea pig	2500 mg/kg bw	2
Mouse	383 mg/kg bw	2
Rat	2600-3020 mg/kg bw	2
Human Toxicity Values		
Acute oral toxicity	Rare	6

Human Health Toxicity Ranking		
	Hazard Category	**Number**
Carcinogenicity	L	1
Mutagenicity/genotoxicity	L	1
Reproductive toxicity	NA	-
Developmental toxicity	L	1
Endocrine disruption	NA	-
Neurotoxicity	NA	-
Acute toxicity (oral, dermal or inhalation)	M	2
Corrosion/irritation of the skin or eye	M	2
Sensitisation of the skin or respiratory system	NA	-
Immune system effects	NA	-
Systemic toxicity/Organ effects (Cardiovascular toxicity at very high oral doses)	H	3
Explosive potential	NA	-
Flammable potential	NA	-
Sum		**10**
Number of points		**6**
Toxicity Score		**1.67**

Concluding Summary Comments

Potassium is an essential element in the body and the main intracellular cation with 98% of total body potassium located within the cells. Potassium chloride also occurs widely in the environment, including natural and drinking water as a consequence of the use of water treatment chemicals. Potassium chloride is used for the prevention and treatment of potassium deficiency, e.g. when thiazide diuretics or corticosteroids are used in case of excessive vomiting or diarrhoea, or diets poor in potassium or in the treatment of cumulative digitalis poisoning.

The most common form of ingestion is through drinking water. It is not considered necessary to establish a health-based guideline value for potassium in drinking water due to its lack of toxicity. Occupational exposure to potassium chloride may occur through inhalation of dust and dermal contact of this compound at workplaces where potassium chloride is produced or used. Specific occupational exposure limits (OELs) and actual exposure levels in the mining, refining, fertilizer and other industries are not available.

Acute effects are rare in humans although under particular circumstances severe effects may occur. Lethal effects were observed in a 2 month old baby fed 15,000 mg potassium chloride for 2 days and in another case report where an adult woman

had ingested slow released potassium chloride tablets (35, 000 mg).Potassium chloride has not been evaluated and is not listed by the IARC as a carcinogen. In a long-term study performed with KCl, no carcinogenic effects were observed in male rats and it is a slight skin and eye irritant.

In the environment and in contact with water, potassium chloride dissociates readily into its component ions. No further degradation subsequently results. In soil, transport and leaching of potassium and chloride ions in solution is affected by surrounding conditions.

Taken collectively the potassium chloride toxicity and hazard ranking is of a low to moderate concern. Ingestion of high levels of dissolved potassium chloride in water at levels producing severe health effects is unlikely due to the rapid dilution of potassium chloride following environmental introduction into sub-surface waters, however, this requires qualification in terms of the masses of potassium chloride introduced. Occupational exposure s and short-term environmental spills may lead to short-term irritant effects depending on the nature of the exposure and are the main areas warranting consideration.

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NA = Not available

LD50 = Lethal dose for 50% of experimental population

LDL_O = Lowest dose of a toxic material at which the death of the exposed test animal occurs.

LC50 = lethal concentration for 50% of experimental population

Name	Potassium Chloride
Synonyms	Chloride of potash, potassium monochloride, dipotassium dichloride
CAS number	7447-40-7
Molecular formula	Cl-K
Product name	Potassium Chloride M117

Physical Properties	Value	Reference
Phase/state	White crystals or crystalline powder	HSDB 2011
Molecular weight	74.55 g/mol	HSDB 2011
Melting point	771 ^{o}C	HSDB 2011
Boiling point	Sublimes 1500 ^{o}C	HSDB 2011
Solubility	34.2 g/100g at 20 ^{o}C	HSDB 2011

Persistence/ Bioaccumulation	Value	Reference
Reactivity	Violent reaction with bromine trifluoride	HSDB 2011
pH	pH of saturated aqueous solution at 15 ^{o}C = pH 7.	HSDB 2011

Notes: 1 HSDB, 2011. Accessed on 29/11/2011 at:http://toxnet.nlm.nih.gov/cgi-bin/sis/search/f?./temp/~Qo4yHz:1 EPI Suite™ v4.0, United States Environmental Protection Agency.

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	Not listed on IARC database.
ANZECC	2000	Stock water	NA	

Aquatic Ecotoxicological Data

Acute toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Lampsilis straminea ssp. claibornen	Southern Fatmucket	LC50	MOR	MORT	4	13500	ECOTOX
Diaphanosoma brachyurum	Water Flea	LC50	MOR	MORT	2	16500	ECOTOX
Ceriodaphnia rigaudi	Water Flea	LC50	MOR	MORT	2	21100	ECOTOX
Ceriodaphnia rigaudi	Water Flea	LC50	MOR	MORT	2	21110	ECOTOX
Villosa vibex	Southern Rainbow Mussel	LC50	MOR	MORT	4	26000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	4	29000	ECOTOX
Moinodaphnia macleayi	Water Flea	LC50	MOR	MORT	2	30100	ECOTOX
Dreissena polymorpha	Zebra Mussel	LC50	MOR	MORT	1	55000	ECOTOX
Dreissena polymorpha	Zebra Mussel	LC50	MOR	MORT	1	56000	ECOTOX
Nais variabilis	Oligochaete	LC50*	MOR	MORT	2	67000*	ECOTOX
Nais variabilis	Oligochaete	LC50*	MOR	MORT	2	75000*	ECOTOX
Anodonta imbecillis	Mussel	LC50	MOR	MORT	1	76000	ECOTOX
Dreissena polymorpha	Zebra Mussel	LC50	MOR	MORT	1	82000	ECOTOX
Daphnia magna	Water Flea	EC50*	ITX	IMBL	2	83000*	ECOTOX
Dreissena polymorpha	Zebra Mussel	LC50	MOR	MORT	1	86000	ECOTOX
Dreissena polymorpha	Zebra Mussel	LC50	MOR	MORT	1	87000	ECOTOX
Dreissena polymorpha	Zebra Mussel	LC50	MOR	MORT	1	88000	ECOTOX
Dreissena polymorpha	Zebra Mussel	LC50	MOR	MORT	1	88000	ECOTOX
Dreissena polymorpha	Zebra Mussel	LC50	MOR	MORT	1	90000	ECOTOX
Daphnia magna	Water Flea	EC50*	ITX	IMBL	2	93000	ECOTOX
Dreissena polymorpha	Zebra Mussel	LC50	MOR	MORT	1	98000	ECOTOX
Dreissena polymorpha	Zebra Mussel	LC50	MOR	MORT	1	102000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	4	115000*	ECOTOX
Dreissena polymorpha	Zebra Mussel	LC50	MOR	MORT	1	116000	ECOTOX
Daphnia magna	Water Flea	LC50	MOR	MORT	3	117000	ECOTOX
Dreissena polymorpha	Zebra Mussel	LC50	MOR	MORT	1	119000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	4	128000	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	134000	ECOTOX
Dreissena polymorpha	Zebra Mussel	LC50	MOR	MORT	1	138000	ECOTOX
Dreissena polymorpha	Zebra Mussel	LC50	MOR	MORT	1	138000	ECOTOX
Daphnia magna	Water Flea	EC50	ITX	IMBL	2	141460	ECOTOX
Hyalella azteca	Scud	LC50	MOR	MORT	4	141900	ECOTOX
Dreissena polymorpha	Zebra Mussel	LC50	MOR	MORT	2	147000	ECOTOX
Daphnia magna	Water Flea	EC50*	ITX	IMBL	2	149000*	ECOTOX
Dreissena polymorpha	Zebra Mussel	LC50	MOR	MORT	1	150000	ECOTOX
Dreissena polymorpha	Zebra Mussel	LC50	MOR	MORT	2	150000	ECOTOX

Acute toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	5	151000*	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	3	154000*	ECOTOX
Daphnia magna	Water Flea	EC50*	ITX	IMBL	2	166000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	4	166000*	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	5	168000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	5	168000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	3	172000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	10	180000*	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	13	180000*	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	4	185000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	4	185000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	8	190000*	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	10	200000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	10	200000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	13	200000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	13	200000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	6	205000*	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	8	212000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	8	212000	ECOTOX

298 lines of acute data. Data truncated at approx 50 lines.

Chronic toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Ceriodaphnia sp.	Water Flea	NOEC	REP	FCND	7	160000	ECOTOX
Ceriodaphnia sp.	Water Flea	NOEC	REP	PROG	7	190000	ECOTOX
Musculium transversum	Long Fingernail Clam	NOEC	MOR	MORT	42	195000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	GGRO	7	250000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	WGHT	7	300000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	GGRO	7	500000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	GGRO	7	500000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	GGRO	7	500000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	GGRO	7	500000	ECOTOX
Pimephales promelas	Fathead Minnow	NOEC	GRO	GGRO	7	500000	ECOTOX
Ceriodaphnia dubia	Water Flea	NOEL	GRO	LGTH	12	690000	ECOTOX
Biomphalaria alexandrina	Snail	NOEC	IMM	IFCT	98	1250000	ECOTOX
Schistosoma mansoni	Trematode Parasite	NOEC	REP	PROG	98	1250000	ECOTOX

Chronic toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Schistosoma mansoni	Trematode Parasite	NOEC	REP	PROG	98	1250000	ECOTOX
Salvelinus fontinalis	Brook Trout	NOEC	GRO	WGHT	7	2000000	ECOTOX
Daphnia magna	Water Flea	LOEC	REP	PROG	21	24000	ECOTOX
Daphnia magna	Water Flea	LOEC	REP	PROG	21	24000	ECOTOX
Musculium transversum	Long Fingernail Clam	LOEC	MOR	MORT	42	275000	ECOTOX
Pimephales promelas	Fathead Minnow	MATC	GRO	GGRO	7	353000	ECOTOX
Pimephales promelas	Fathead Minnow	LOEC	GRO	GGRO	7	500000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEL	REP	FCND	12	690000	ECOTOX
Pimephales promelas	Fathead Minnow	MATC	GRO	GGRO	7	707000	ECOTOX
Pimephales promelas	Fathead Minnow	MATC	POP	BMAS	7	707000	ECOTOX
Pimephales promelas	Fathead Minnow	MATC	POP	BMAS	7	707000	ECOTOX
Pimephales promelas	Fathead Minnow	MATC	POP	BMAS	7	707000	ECOTOX
Pimephales promelas	Fathead Minnow	MATC	POP	BMAS	7	707000	ECOTOX
Pimephales promelas	Fathead Minnow	MATC	POP	BMAS	7	707000	ECOTOX
Pimephales promelas	Fathead Minnow	MATC	POP	BMAS	7	707000	ECOTOX
Ceriodaphnia dubia	Water Flea	LOEL	GRO	LGTH	12	800000	ECOTOX
Ceriodaphnia sp.	Water Flea	LOEC	REP	FCND	7	960000	ECOTOX
Ceriodaphnia sp.	Water Flea	LOEC	REP	PROG	7	960000	ECOTOX
Pimephales promelas	Fathead Minnow	LOEC	GRO	WGHT	7	1000000	ECOTOX
Salvelinus fontinalis	Brook Trout	LOEC	GRO	WGHT	7	4000000	ECOTOX
Daphnia magna	Water Flea	EC50*	REP	GREP	21	61000*	ECOTOX
Daphnia magna	Water Flea	EC50*	REP	GREP	21	68000	ECOTOX
Daphnia magna	Water Flea	EC50*	ITX	IMBL	21	87000*	ECOTOX
Daphnia magna	Water Flea	EC50*	ITX	IMBL	21	97000	ECOTOX
Austropotamobius pallipes ssp. pall	Crayfish	LC50*	MOR	MORT	30	188000*	ECOTOX
Austropotamobius pallipes ssp. pall	Crayfish	LC50*	MOR	MORT	30	210000	ECOTOX
Austropotamobius pallipes ssp. pall	Crayfish	LC50*	MOR	MORT	30	251000*	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	16	269000*	ECOTOX
Austropotamobius pallipes ssp. pall	Crayfish	LC50*	MOR	MORT	30	280000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	25	287000*	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	29	287000*	ECOTOX
Orconectes limosus	Crayfish	LC50*	MOR	MORT	30	296000*	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	16	300000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	16	300000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	25	320000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	25	320000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	29	320000	ECOTOX

Chronic toxicity data							
Species name	**Common name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Conc (µg/L)**	**Reference**
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	29	320000	ECOTOX
Orconectes limosus	Crayfish	LC50*	MOR	MORT	30	330000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	27	348000*	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	23	359000*	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	27	388000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	27	388000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	19	395000*	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	23	400000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	23	400000	ECOTOX
Orconectes limosus	Crayfish	LC50*	MOR	MORT	30	404000*	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	22	407000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	22	430000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	19	431000*	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	19	440000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	19	440000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	16	444000*	ECOTOX
Orconectes limosus	Crayfish	LC50*	MOR	MORT	30	450000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	19	480000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	19	480000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	16	495000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	16	495000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	16	503000*	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	16	560000	ECOTOX
Musculium transversum	Long Fingernail Clam	LC50	MOR	MORT	16	560000	ECOTOX
Navicula seminulum	Diatom	EC50	POP	PGRT	4	1337000	ECOTOX

Media Type : Freshwater for toxicity data

MOR/ MORT: Mortality

ITX: Intoxication

IMBL: Immobile

POP : Population

IMBL: immobile

ABND: abundance

ITX : Intoxicated

MOR/MORT: Mortality

POP: Population

REP: Reproduction

PROG : Progeny Counts

WGHT: Weight

BMAS: Biomass

FCND: Fecundity

GREP: Reproduction, general,

LGTH: Length

PGRT : Population Growth Rate

The asterisk (*) denotes several meanings depending upon the field you are viewing. An asterisk can be used in these fields:

- *Concentration:* This means the reported concentration has been recalculated to meet database conformity. For example, the concentration unit was reported as Molar units, but the standard database unit is micrograms per liter. Anther example would be if the reported value was as a metal compound and it was recalculated to the ion level. Note: These recalculations are no longer performed.
- *Endpoint*: This denotes the reported endpoint acronym provided was modified to conform to the standard database acronym terminology. For example, if the author reported a TLM, the endpoint was coded as an LC50*.

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.
ECOSAR, US Environmental Protection Agency ECOSAR database , Ecological Structure Activity Relationships (ECOSAR) Class Program. Accessed at http://www.epa.gov/oppt/newchems/tools/21ecosar.htm.

APPENDIX H.2 ENVIRONMENTAL HAZARD ASSESSMENT OF CONSTITUENTS IN POLAR PROP

TECHNICAL MEMORANDUM

DATE 23 March 2012

PROJECT No. 117636002-7000-010-TM-Rev0

TO Paul Wybrew

CC Carolyn Brumley, Len Turczynowicz

FROM Lange Jorstad

ENVIRONMENTAL HAZARD ASSESSMENT OF CONSTITUENTS IN POLAR PROP

1.0 INTRODUCTION

Santos Ltd (Santos) has requested that Golder Associates Pty Ltd (Golder) undertake a review of Polar Prop in regard to its toxicity to human health and toxicity to both aquatic and terrestrial environments. Polar Prop is a proppant used in hydraulic stimulation activities; the product comprises crystalline silica with a surface coating of phenol-formaldehyde resin ('novolac'). According to a material safety data sheet (MSDS) provided by Schlumberger (Santrol MSDS, 2012), there are three compounds present within Polar Prop; crystalline silica (95%), novolac (3 – 5%) and hexamethylenetetramine (0.1%).

This Technical Memorandum discusses each constituent of Polar Prop with regard toxicity to human health and the environment. Golder has previously undertaken a risk assessment for Schlumberger hydraulic stimulation chemicals detailed in the following report:

- Golder Associates (2011). Coal Seam Hydraulic Fracturing Risk Assessment. Reference 117636002-7000-004-R, dated 12 July 2011.

Where possible the techniques for assessment that were employed in the Golder (2011) Risk Assessment have been utilised to assess the constituents of Polar Prop. However, there was insufficient chemical information to enable a quantitative risk assessment for novolac. As such, a qualitative assessment has been undertaken for novolac utilising available information.

This hazard assessment did not consider the combined effects of the constituents when present in a mixture (Polar Prop). Assessment of mixtures is considered beyond the scope of a screening level human health and ecological risk assessment. For more information on assessment of mixtures see Section 4.6.7 of the Golder (2011) Risk Assessment.

2.0 NOVOLAC

The human health toxicity profile discussed below presents an overview of the toxicity of phenol formaldehyde resins and their impurities. The description is generic to the class of resins known as phenol formaldehyde resins as the exact nature of the resin in Polar Prop is confidential and has not been disclosed to Golder.

2.1 Chemical Information

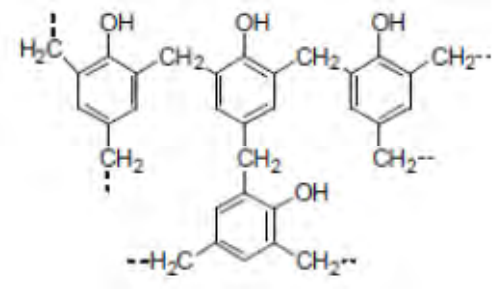
Phenol formaldehyde resins are a product of the polymeric reaction of phenol and formaldehyde crosslinked with an amine compound (hexamethylenetetramine). The polymer is categorised with the chemical abstract services number 9003-35-4 (Santrol MSDS, 2012). The resulting resin has a variable composition that can be described as a mixture of crosslinked 2-ring bisphenol F plus components with 3 or more rings. The number average molecular weight of a cured crosslinked novolac polymer is typically much greater than 1000 daltons (US EPA 1998). Polar Prop has a low residual hexamethylenetetramine content <0.01%)

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(Santrol MSDS, 2012). Although not specified, it is anticipated that the free formaldehyde content will also be very low (<0.1%)due to the catalytic and exothermic nature of the reaction. A typical structure is provided in Figure 1.

Figure 1: Typical structure of phenol formaldehyde resins (Danish EPA 2004).



Novolac resins are commonly used in a wide variety of industrial and also food contact applications. A similar polymer, epoxy phenolic novolac resins (Novolac Glycidyl Ether, NOGE) are used in the production of heavy duty coatings applied as clear coats in food packaging applications. The use of these coatings has been reviewed by the European Food Safety Authority (EFSA 2005).

2.2 Phenol-formaldehyde Resins Health Hazard Assessment

The assessment of human health toxicity represents an assessment of hazard (i.e. intrinsic toxicological properties rather than the probability of adverse human health effects during use). The aim of the hazard assessment is to provide a semi-quantitative hierarchy or hazard ranking of chemicals based on human health toxicity including both physical and chemical hazards to identify contaminants of potential concern (COPC). Further evaluation of the risk posed by such COPCs in terms of exposure pathways and fate and transport modelling has been presented in Section 7 of the previous Golder (2011) Risk assessment, dated 12 July 2011 (Ref No 117636002-7000-004-R).

Section 6 (pp130-143) of the Risk Assessment, (Golder, 2011), provides a detailed basis to the human health hazard ranking and has not been reproduced here. The methodology in general terms is based on the range of toxicological and fate and transport properties with associated ranking thresholds consistent with the Organisation for Economic Co-operation and Development (OECD) and United Nations (UN) Global Harmonisation Systems. The use of these thresholds allows a qualification and scoring across these parameters with an averaging of the scoring across data sets. No weighting is placed on the various parameters examined.

Novolac polymers are not classified as hazardous substances by the supplier (Santrol MSDS 2012). There is no reason to suspect that this classification is inaccurate based on the present assessment (according to the NOHSC (2004) "*Approved Criteria for Classifying Hazardous Substances, 3rd Edition*"). The crosslinked novolac polymer is likely to have a number average molecular weight of greater than 1000 (US EPA 1998) and as such is unlikely to cross biological membranes to cause toxicity. The European Food Safety Authority has evaluated the safety of low molecular weight (2250-900 daltons) epoxy phenolic novolac resins (Novolac Glycidyl Ether, NOGE). The NOGE is analogous substance to the non-crosslinked novolac polymer. The European Food Safety Authority (EFSA 2005) did not identify any safety concerns for the use of NOGE as a starting material in food contact applications. The summary of the hazard ranking is provided in Table 1 below. The overall toxicity score reports a low level of concern (Score 1.0). This reflects the low toxicity potential of cured novolac polymers.

Table 1: Novolac polymer in PolyProp human health toxicity score

Chemical Name	Hazard Classification NOHSC (2004)	Carcinogenicity	Mutagenicity/ genotoxicity	Developmental toxicity	Acute toxicity	Systemic toxicity/ Organ effects	Overall Toxicity Score
Novolac polymer in PolyProp	**Non hazardous**	**1**	**1**	**1**	**1**	**1**	**1**

2.3 Conclusion : Health Hazard Assessment

Taken collectively the cured novolac polymer in Poly Prop toxicity and hazard ranking is of a low concern from a human health perspective. Ingestion of trace levels of this polymer is unlikely to result in adverse health effects. Occupational exposures and short-term environmental spills are also unlikely to result in adverse human health effects.

2.4 Aquatic Toxicity Assessment

Chemical data for novolac was insufficient to be able to undertake the aquatic toxicity assessment based on persistence (P), bioaccumulation (B) and toxic (T) potential (hereafter referred to as PBT) as outlined in Chapter 4 of the Golder (2011) Risk Assessment. As such, a qualitative assessment has been undertaken for novolac utilising available information.

Ecotoxicological data and physic-chemical parameters were not found for novolac in the form used in Polar Prop. For polymeric substances both the molecular weight and their reactive functional groups are important in understanding their environmental hazard potential. Thus information on compounds with similar functional groups and a high molecular weight can inform the hazard assessment. A fatty acid modified epoxy Novolac acrylate (polymer CN-113) which is used as a binder in printing ink formulationshas been assessed in a full public report (NICNAS, 1996).

The NICNAS (1996) review on CN-113 states that no ecotoxicological data were provided, which is acceptable for polymers of number average molecular weight of greater than 1000, according to the Industrial Chemicals (Notification and Assessment) Act 1989. NICNAS considered that, due to its high number average molecular weight, the polymer is not expected to cross biological membranes. They note that the maximum percentage of low molecular weight species present in the mixture is <25% for molecular weight <1000 and <5% for molecular weights <500. NICNAS note that CN-113 is formulated into a printing ink, which is cured by UV light and used on paper/plastic bottles. Once cured, polymer is inextricably bound within the matrix of the printing ink.

The NICNAS (1996) review concludes that the low level of environmental exposure of the polymer as a result of normal use, together with its expected lack of biological activity, indicate that the overall environmental hazard of CN-113 should be negligible.

The crosslinked novolac polymer present in Polar Prop is also likely to have a number average molecular weight of greater than 1000 (US EPA 1998) and as such it is considered likely that novolac will exhibit the following characteristics:

- Very low water solubility;
- Non-volatile;
- Immisciblity with water;
- Low likelihood it will cross biological membranes to cause toxicity.

Hexamethylenetetramine is used as a cross-linker to contribute an element of hardness to the coating. As pure uncured novolac resin will not be introduced into the environment in this instance, and based on the

likelihood that the resin is not biologically active in this form, the conclusions regarding minimal hazard drawn from the NICNAS (1996) review of CN-113 may be considered applicable here.

While it should be noted that there is insufficient evidence to confirm that this compound will be stable under the pressures and temperatures that may be experienced during hydraulic stimulation, it is considered likely that this substance will be stable in the environment.

2.5 Terrestrial Toxicology

There was insufficient chemical information for novolac and its surrogate polymer CN-113 to be able to carry out a risk assessment for terrestrial toxicology.

2.6 Conclusions: Ecological Toxicity

There is limited information available relating to the ecological toxicity of the phenol-formaldehyde polymer novolac. Based on professional judgment of the likely physico-chemical parameters for this polymer, novolac in its current form is unlikely to pose a significant toxicological hazard to the freshwater environment.

On this basis, novolac is not considered a COPC for the purposes of either a human health or ecological risk assessment. Further, the operational controls established at well pads during and following hydraulic stimulation events should substantially reduce the potential for complete exposure pathways to occur.

3.0 HEXAMETHYLENETETRAMINE

Hexamethylenetetramine is used as a curing agent for phenolic resins and also as a urinary tract anti infective drug (Ymparisto, 2012). Hexamethylenetetramine is also used in eye make up preparations; as a preservative in lotions and creams; as a textile treating agent; a rubber accelerator and a chemical intermediate. Chemical information for hexamethylenetetramine is attached to this Technical Memorandum in the form of a chemical product sheet.

3.1 Human Health

A brief summary of human health effects of hexamethylenetetramine has been completed with information obtained from the hazardous substances data bank (HSDB).

Hexamethylenetetramine is used as a urinary tract anti infective drug (Swift et al., 2003). Adverse effects following administration have been reported in less than 3.5% of patients receiving hexamethylenetetramine and its salts. The most frequent adverse effects are gastro intestinal disturbances including nausea, vomiting, diarrhoea, abdominal cramps, and anorexia. Rarely, hypersensitivity reactions including rash, pruritus, urticaria, and stomatitis have occurred. Other adverse effects reported rarely are headache, dyspnea, generalised edema, tinnitus, muscle cramps, dysuria, and microscopic or, rarely, gross haematuria (HSDB, 2012).

Large oral doses of hexamethylenetetramine have been observed to causes irritation (vomiting and pain) with inflammatory lesions in renal tubules and renal pelvis causing impaired renal function. Hexamethylenetetramine is distributed into breast milk and has the potential for serious adverse effects in nursing infants. HSDB (2012) also states that a probable lethal dose for humans is approximately 0.5 kg for a 70 kg man.

Hexamethylenetetramine is a skin sensitiser and an irritant to the skin, eyes and mucous membranes. Inhalation may cause asthma-like reactions in previously sensitized individuals (HSDB, 2012).

3.2 Aquatic Toxicity

Sufficient chemical information is available for hexamethylenetetramine to be able to complete an aquatic toxicity assessment. The methodology used to assess hexamethylenetetramine is outlined in Chapter 4 of the Golder (2011) Risk Assessment.

Hexamethylenetetramine was scored based on its persistence (P), potential to bioaccumulate (B) and toxicity (T) to the aquatic environment. Possible overall scores range from a minimum of 1 (low hazard), to a maximum of 3 (high hazard). The use of averages ensures that where there are one or more data gaps, the score represents the average of available parameters. In the assessment of toxicity, the highest hazard score assigned to either acute or chronic data was adopted at the final hazard score for T.

An overall score (the environmental hazard score) for hexamethylenetetramine was calculated based on the average of the sum of the P, B and T scores. The overall score for hexamethylenetetramine is presented in Table 2 below.

Table 2: Environmental Hazard Score for Hexamethylenetetramine.

Fraccing Chemical	CASRN	Overall Environmental Hazard Score	Environmental Hazard Category
Hexamethylenetetramine	**100-97-0**	**1.4**	**Low**

Hexamethylenetetramine has been assigned an environmental hazard score of 1.4 and is ranked as a 'low hazard'. This score reflects a very low order of aquatic toxicity, a low potential for bioaccumulation and a moderate potential for persistence. As hexamethylenetetramine is not ranked as 'high hazard' it is not considered to be a COPC from an aquatic toxicology perspective.

3.3 Terrestrial Toxicity

Sufficient chemical information is available for hexamethylenetetramine to be able to complete a terrestrial toxicity assessment.

Terrestrial toxicity data and chemical data were used to rank hexamethylenetetramine using the following techniques:

- Mammalian LD50 data;
- Lettuce QSAR (Huzelbos *et al*. 1991); and
- Earthworm QSAR (Van Gestel 1992).

Full details of these techniques are provided in Section 5 of the Golder (2011) Risk Assessment. It was not possible to assess hexamethylenetetramine using the Earthworm QSAR (EPISUITE) as this data was not available.

Although an assessment of exposure concentrations and associated risks has not been made for the chemicals under consideration in Polar Prop, hexamethylenetetramine is likely to be present as an impurity within the polymer matrix rather than a compound that may drive risks (the Santrol MSDS reports hexamethylenetetramine at concentrations less than 0.01% in Polar Prop). Hexamethylenetetramine does not rank in the top three most hazardous chemicals in each of the three techniques used in the assessment, when assessed with other Schlumberger chemicals. According to the process outlined in the risk assessment for the Schlumberger methodology, hexamethylenetetramine is not considered to be a COPC with regard terrestrial toxicity.

4.0 CRYSTALLINE SILICA

Crystalline silica has not been assessed for aquatic toxicity and terrestrial toxicity as it is considered essentially sand and based on physical properties it was not considered appropriate to assess the limited aquatic and terrestrial data in the hazard ranking. Available chemical information for crystalline silica is provided in the Golder (2011) Risk Assessment.

4.1 Human Health

A human health toxicity overview for crystalline silica is attached to this Technical Memorandum. Inhalation of dust is considered the most significant pathway for crystalline silica. Respirable quartz dust particles can be inhaled and deposited in the lung. Silicosis and pulmonary tuberculosis are associated with occupational exposure to quartz dust. Also, there is sufficient evidence in humans for the carcinogenicity of inhaled crystalline silica.

Statistically significant increases in deaths or cases of bronchitis, emphysema, chronic obstructive pulmonary disease, autoimmune related diseases (scleroderma, rheumatoid arthritis, systemic lupus erythematosus) and renal diseases have also been reported.

5.0 CONCLUSIONS

The individual constituents of Polar Prop are considered unlikely to pose a hazard to people and the environment. Although assessing the hazard from the combined effects of the constituents when present in a mixture (Polar prop) was beyond the scope of this assessment, Polar Prop is also considered unlikely to pose a hazard to people and the environment.

6.0 LIMITATIONS

Your attention is drawn to the document “Limitations”, which is included as an attachment to this Technical Memorandum. The statements presented in this document are intended to advise you of what your realistic expectations of this Technical Memorandum should be. The document is not intended to reduce the level of responsibility accepted by Golder Associates, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.

7.0 REFERENCES

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Carolyn Brumley
Associate

John Frangos
Principal Toxicologist

LB/CB/lb

Attachments

1) Chemical Product Sheet Hexamethylenetetramine.
2) Human health Toxicity Overview Crystalline Silica.
3) Limitations.

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Name	Hexamethylenetetramine
Synonyms	Hexamine; Methenamine; Urotropine; 1,3,5,7-tetraazaadamantane, Formin, Aminoform
CAS number	100-97-0
Molecular formula	C6H12N4
Product name	Hexamethylenetetramine

Physical Properties	Value	Reference
Phase/state	White, crystalline powder or colorless, lustrous crystals	HSDB 2012
Molecular weight	140.19 g/mol	HSDB 2012
Melting point	65.06 °C	EPISUITE
	>250 °C	CRC 1994
	280°C sublimes	Merck 1996
Boiling point	208.59 °C	EPISUITE
	sublimes	CRC 1994
Density/ specific gravity	1.331 at -5°C	HSDB 2012
	1.7 at 25°C	HSDB 2012
Vapour pressure	4.0X10-3 mmHg at 25 °C (experimental)	HSDB 2012
Solubility	76.7 g/m^3 at 25°C	EPISUITE
	1g soluble in 1.5ml water, or 66.6g/100mL	HSDB 2012
Henrys law constant	1.6X10-9 atm m^3/mole (derived)	HSDB 2012
Log organic carbon partition coefficient (log Koc)	1.74 (based on Koc 55 (SRC))	HSDB 2012
Log octanol-water partition coefficient (log Kow)	-4.15 (estimated)	HSDB 2012

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation		
Aerobic BOD	In a 5-day BOD test using a sewage seed, methenamine reached 2.02% of its theoretical BOD	HSDB 2012
Anaerobic BOD	No data found	
Ready Biodegradability Prediction	No	EPISUITE
Fugacity		
Air %	0.0102	EPISUITE
Water %	39.5	EPISUITE
Soil %	60.4	EPISUITE
Sediment %	0.0957	EPISUITE
Bioconcentration factor (BCF)	3.162 L/kg	EPISUITE
Biotransformation half-life	8.324E-06 days	EPISUITE

Notes: 1 EPI Suite™ v4.0, United States Environmental Protection Agency.

2 CRC Handbook of Chemistry and Physics 1913 – 1995 75th Edition, 1994 CRC Press Inc

3. Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line 1 February 2012

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NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Estimated acute toxicity data							
Common name	**Species name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Concentration (g/m^3)**	**Reference**
Water Flea	Daphnia magna	EC50*	ITX	IMBL	1	35589000	ECOTOX
Water Flea	Daphnia magna	EC50*	ITX	IMBL	2	29868000	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	44600000	ECOTOX
Estimated chronic toxicity data							
Data not available							

Media Type: freshwater

IMBL: immobile

ABND: abundance

ITX : Intoxicated

MOR/MORT: Mortality

POP: Population

REP: Reproduction

PROG : Progeny Counts

SEXR : Sex ratio

FCND: Fecundity

HTCH : Hatch

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

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WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.
ECOSAR US Environmental Protection Agency ECOSAR Class Program.

NA = not assessed.

Name	Silica
Synonyms	Crystalline silica (Quartz)
CAS number	14808-60-7
Molecular formula	SiO_2

Human Health Toxicity Overview	References
Silicon is the second most abundant chemical element, after oxygen, in the earth' s crust accounting for 28.15% of its mass and quartz, is by far the most common form of silica in nature, it comprises 12% by volume of the crust. It is a frequently occurring solid component of most natural mineral dusts. Human exposures to quartz occur most often during occupational activities that involve the movement of earth, disturbance of silica containing products (masonry, concrete), or use or manufacture of silica containing products. Environmental exposure to ambient quartz dust can occur during natural, industrial and agricultural activities.	1

Human Health Toxicity Summary	Reference
Inhalation Respirable quartz dust particles can be inhaled and deposited in the lung. There are many epidemiological studies of occupational cohorts exposed to respirable quartz dust. Silicosis, lung cancer and pulmonary tuberculosis are associated with occupational exposure to quartz dust. Statistically significant increases in deaths or cases of bronchitis, emphysema, chronic obstructive pulmonary disease, autoimmune related diseases (scleroderma, rheumatoid arthritis, systemic lupus erythematosus) and renal diseases have been reported. Silicosis is the critical effect for hazard identification and risk assessment.	1
Carcinogenicity There is sufficient evidence in humans for the carcinogenicity of inhaled crystalline silica in the form of quartz or cristobalite from occupational sources. There is sufficient evidence in experimental animals for the carcinogenicity of quartz and cristobalite Crystalline silica inhaled in the form of quartz or cristobalite from occupational sources is carcinogenic to humans (Group 1). A2; Suspected human carcinogen. /Silica, Crystalline - alpha-Quartz (14808-60-7, 1317-95-9); and Cristobalite (14464-46-1)	1 2

Toxicity Values	Value	Reference
Animal Studies	LD50	
Rat	iv 500 mg/kg bw/Quartz (10-200 um)/	1
Human Toxicity Values		
TWA	0.1 mg/m^3	3

Human Health Toxicity Ranking		
Carcinogenicity.	H	3
Mutagenicity/genotoxicity.	NA	
Reproductive toxicity.	NA	
Developmental toxicity.	NA	
Endocrine disruption.	NA	
Neurotoxicity.	NA	
Acute toxicity (oral, dermal or inhalation).	M	2
Corrosion/irritation of the skin or eye.	NA	
Sensitisation of the skin or respiratory system.	H	3
Immune system effects.	NA	
Systemic toxicity/Organ effects.	NA	
Explosive potential.	L	1
Flammable potential	L	1
Sum		**10**
Number of points		5
Toxicity Score		**2**

Notes

1. [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT.
2. American Conference of Governmental Industrial Hygienists TLVs and BEIs. Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. Cincinnati, OH, 2008, p. 51
3. Safe Work Australia Hazardous Substance Information System (HSIS) (Accessed June 2011)

NA No information available

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Santos

APPENDIX H.3 ENVIRONMENTAL HAZARD ASSESSMENT OF OF CONSTITUENTS IN LITEPROP 125

7 May 2013 Project No. 117636002-7000-011-L-Rev0

Andrew Stannard
Santos Ltd
Level 22, 32 Turbot Street
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ENVIRONMENTAL HAZARD ASSESSMENT OF CONSTITUENTS IN LITEPROP 125

Dear Andrew,

1.0 INTRODUCTION

Santos Ltd (Santos) has requested that Golder Associates Pty Ltd (Golder) undertake a review of LiteProp 125 in regard to its toxicity to human health and toxicity to both aquatic and terrestrial environments. LiteProp 125 is a resin coated cellulose and is used a "proppant" to break open oil-bearing rock beneath the earth's surface (BJ Services, 2004). There are three compounds present within LiteProp 125, namely:

- Raw Walnut Hulls (85.56%);
- Plenco resin (12.83%); and
- Mod Acid (1.6%).

This letter discusses each of these constituents of LiteProp 125 (raw walnut hulls, Plenco resin and Mod Acid) with regard toxicity to human health and the environment. Where possible the techniques used to assess the human health and environmental toxicity of constituents in LiteProp 125 have followed the approach outline in Attachment 1. However, where there was insufficient chemical information to be able to undertake a quantitative hazard assessment for a constituent, a qualitative assessment was undertaken using available information.

This hazard assessment did not consider the combined effects of the constituents when present in a mixture (LiteProp 125). Assessment of mixtures is considered beyond the scope of a screening level human health and ecological risk assessment.

2.0 RAW WALNUT HULLS

2.1 Human Health Hazard Assessment

Raw walnut shells are naturally occurring products that on initial review present limited hazards to human health, but these require some qualification. Hazards associated with these shells may include physical, chemical and biological. Should these shells be ground into a fine particulate, (e.g. similar to dusts) then the inhalation of such dusts has been associated with adverse cardio-pulmonary health effects, both acute and chronic. Control of exposure to such dusts would be a risk management measure, particularly in the occupational setting but also if in close proximity to residential areas. As an organic dust, the hazards of exposure are more diverse than for inorganic dust due to compositional variance. Organic dusts in addition to risks associated with the physical particle size (i.e. inspirable and respirable intakes) may contain microbial agents and microbial toxins (e.g. endotoxins and mycotoxins, see Rylander and Shilling, 1998). Furthermore certain chemicals such as tannins are associated with adverse organic dust exposures, while

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additional hazardous chemicals may include chlorinated cyclodiene pesticide residues if these shells are sourced from third world countries still using these environmentally incalcitrant pesticides which exhibit a long biological half-life in the human body.

2.2 Ecological Hazard Assessment

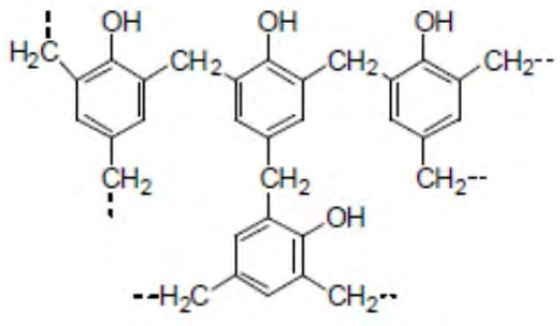
Raw Walnut Hulls are used as a substitute for sand particles and have not been assessed for aquatic toxicity and terrestrial toxicity as the particles are considered essentially non-hazardous if they are in their natural state (i.e., have not been treated with pesticides as described in section 2.1 above).

3.0 PLENCO RESIN

Plenco resin refers to the manufacturing company, Plenco, a plastics engineering company. Plenco manufactures Novolac resins which are phenol-formaldehyde polymers and Resol resins which are phenol-methylene glycol polymers (Plenco, 2012).

The human health toxicity profile discussed below presents an overview of the toxicity of phenol formaldehyde resins and their impurities. The description is generic to the class of resins known as phenol formaldehyde resins as the exact nature of the resin in LiteProp 125 is confidential. The constituents and percentages provided to Golder Associates of residual phenol and formaldehyde levels in the polymer are as follows; phenol (<1.5%) and formaldehyde (<1%). In the resin manufacturing process, the phenol and formaldehyde combine to form the resin; the process, chemistries, and residual concentrations are understood to be the same as in most common pre-cured resin-coated proppants (pers comm. Baker Hughes). A typical structure of a phenol formaldehyde resin is provided in Figure 1.

Figure 1: Typical Structure Phenol Formaldehyde Resin



3.1 Chemical Information

Phenol formaldehyde resins are a product of the polymeric reaction of phenol and formaldehyde crosslinked with an amine compound (hexamethylenetetramine). The polymer is categorised with the chemical abstract services number 9003-35-4 (BJ Services, 2006). The resulting resin has a variable composition that can be described as a mixture of crosslinked 2-ring bisphenol F plus components with 3 or more rings. The number average molecular weight of a cured crosslinked novolac polymer is typically much greater than 1000 daltons (US EPA 1998). No information was provided to Golder Associates that LiteProp 125 has residual hexamethylenetetramine content, however, information on hexamethylenetetramine has been provided in this letter as the cross-linking agent is common to these polymers (BJ Services, 2006).

Plenco (Novolac) resins are commonly used in a wide variety of industrial and also food contact applications. A similar polymer, epoxy phenolic novolac resins (Novolac Glycidyl Ether, NOGE) is used in the production of heavy duty coatings applied as clear coats in food packaging applications. The use of these coatings has been reviewed by the European Food Safety Authority (EFSA 2005).

3.2 Novolac Resins

This assessment of phenol-formaldehyde resins represents an assessment of hazard (i.e. intrinsic toxicological properties) rather than an assessment of risks (i.e., the probability of adverse human health

effects during use). The aim of the hazard assessment is to provide a semi-quantitative hierarchy or hazard ranking of chemicals based on human health toxicity including both physical and chemical hazards to identify contaminants of potential concern (COPC). Further evaluation of the risk posed by such COPCs in terms of exposure pathways and fate and transport modelling has been presented in Section 7 of the Golder Associates (2011) Risk Assessment, dated 12 July 2011 (Ref No 117636002-7000-004-R).

Section 6 (pp130-143) of the Risk Assessment, (Golder 2011), provides a detailed basis to the human health hazard ranking. An extract of the report is presented in the attachment to this letter. This methodology in general terms is based on a range of toxicological and fate and transport properties with associated ranking thresholds consistent with OECD and UN Global Harmonisation Systems. The use of these thresholds allows a qualification and scoring across these parameters with an averaging of the scoring across data sets. No weighting is placed on the various parameters examined.

Novolac polymers are not classified as hazardous substances by the supplier (BJ Services, 2006). There is no reason to suspect that this classification is inaccurate based on the present assessment (according to the NOHSC (2004) "*Approved Criteria for Classifying Hazardous Substances, 3rd Edition*"). The cross-linked Novolac polymer is likely to have a number average molecular weight of greater than 1000 (US EPA 1998) and as such is unlikely to cross biological membranes to cause toxicity. The European Food Safety Authority has evaluated the safety of low molecular weight (2250-900 daltons) epoxy phenolic novolac resins (Novolac Glycidyl Ether, NOGE). The NOGE is an analogous substance to the non-crosslinked novolac polymer. The European Food Safety Authority (EFSA 2005) did not identify any safety concerns for the use of NOGE as a starting material in food contact applications. The summary of the hazard ranking for Plenco (Novolac) resin is summarised in Table 1 below. The overall toxicity score reports a low level of concern (Score 1.0). This reflects the low toxicity potential of cured Novolac polymers.

Table 1: Plenco (Novolac) Polymer in Human Health Toxicity Score

Chemical Name	Hazard Classification NOHSC (2004)	Carcinogenicity	Mutagenicity/ genotoxicity	Developmental toxicity	Acute toxicity	Systemic toxicity/ Organ effects	Overall Toxicity Score
Plenco (Novolac) polymer in LiteProp 125	**Non hazardous**	**1**	**1**	**1**	**1**	**1**	**1**

Both monomers used in the production of this resin are left in low residual amounts in the final polymer which is a "brown, granular solid with a mild odour" (BJ Services, 2006) (refer above). While both phenol and formaldehyde exhibit moderate to high hazards (refer attached toxicity profiles) in terms of the pure substances, these residual amounts in the polymer are low and in general terms would present a low hazard. In certain circumstances (e.g. where large masses of this polymer are present within confined environments), off-gassing may result in higher atmospheric concentrations and these may warrant closer attention. These would tend to prevail in the occupational setting.

3.3 Hexamethylenetetramine

Hexamethylenetetramine is used as a curing agent for phenolic resins and also as a urinary tract anti infective drug (Ymparisto, 2012). Hexamethylenetetramine is also used in eye make-up preparations; as a preservative in lotions and creams; as a textile treating agent; a rubber accelerator and a chemical intermediate. When heated during the phenol-formaldehyde resin curing process, hexamethylenetetramine thermally decomposes to ammonia and formaldehyde. Chemical information for hexamethylenetetramine is attached to this letter in the form of a chemical product sheet.

A brief summary of human health effects of hexamethylenetetramine has been completed with information obtained from the hazardous substances data bank (HSDB, 2012).

Adverse effects of hexamethylenetetramine following administration in the treatment of urinary tract infections have been reported in less than 3.5% of patients receiving hexamethylenetetramine and its salts.

The most frequent adverse effects are gastro-intestinal disturbances including nausea, vomiting, diarrhoea, abdominal cramps, and anorexia. Rarely, hypersensitivity reactions including rash, pruritus, urticaria, and stomatitis have occurred. Other adverse effects reported rarely are headache, dyspnea, generalised edema, tinnitus, muscle cramps, dysuria, and microscopic or, rarely, gross haematuria (HSDB, 2012).

Large oral doses of hexamethylenetetramine have been observed to cause irritation (vomiting and pain) with inflammatory lesions in renal tubules and renal pelvis causing impaired renal function. Hexamethylenetetramine is distributed into breast milk and has the potential for serious adverse effects in nursing infants. HSDB (2012) also states that a probable lethal dose for humans is approximately 0.5 kg for a 70 kg man.

Hexamethylenetetramine is a skin sensitiser and an irritant to the skin, eyes and mucous membranes. Inhalation may cause asthma-like reactions in previously sensitized individuals (HSDB, 2012).

Further evaluation of the LiteProp 125 polymer could made if the presence and residual concentration or absence of this cross-linking agent could be verified.

3.4 Human Health Hazard Assessment Summary

Taken collectively, the cured Plenco (novolac) polymer in LiteProp 125 exhibits a low order of human health toxicity and hazard ranking. Ingestion of trace levels of this polymer is unlikely to result in adverse health effects. Qualifying comments include the potential for off-gassing of low concentrations of residual monomers in certain confined occupational settings which may warrant closer examination. Short-term environmental spills in open environments are unlikely to result in exposures leading to adverse human health effects. The content and implications of residual hexamethylenetetramine (cross-linking agent) require confirmation.

3.5 Aquatic Ecological Hazard Assessment

Chemical data for plenco resin was insufficient to be able to undertake the aquatic toxicity assessment based on persistence (P), bioaccumulation (B) and toxic (T) potential (hereafter referred to as PBT) as outlined in Attachment 1. As such, a qualitative assessment has been undertaken for phenol-formaldehyde resins utilising available information. In general, polymers such as phenol-formaldehyde resins which are characterised by high molecular weights and negligible solubility are slow to biodegrade (Kaplan, 1979) and are considered environmentally inert and persistent.

Insufficient information was available for the proprietary Plenco resin in LiteProp 125 to identify ecotoxicological data and physico-chemical parameters. Information relating to the fatty acid modified epoxy Novolac acrylate (polymer CN-113, used as a binder in printing ink formulations) was reviewed for information that may be used as a surrogate in assessing hazard. This information was obtained from a full public report on CN-113 (NICNAS, 1996).

The NICNAS (1996) review on CN113 states that no ecotoxicological data were provided, which is acceptable for polymers of number average molecular weight of greater than 1000, according to the Industrial Chemicals (Notification and Assessment) Act 1989. NICNAS considered that, due to its high number average molecular weight, the polymer is not expected to cross biological membranes. They note that the maximum percentage of low molecular weight species present in the mixture is <25% for molecular weight <1000 and <5% for molecular weights <500. NICNAS note that CN-113 is formulated into a printing ink, which is cured by UV light and used on paper/plastic bottles. Once cured, the polymer is inextricably bound within the matrix of the printing ink.

The NICNAS (1996) review concludes that the low level of environmental exposure of the polymer as a result of normal use, together with its expected lack of biological activity, indicate that the overall environmental hazard should be negligible.

The phenol/formaldehyde polymer present in LiteProp 125 is also likely to have a number average molecular weight of greater than 1000 and as such it is considered likely that plenco resin will exhibit the following characteristics:

- Very low water solubility;
- Non-volatile;

- Immisciblity with water;
- Low likelihood it will cross biological membranes to cause toxicity.

Mod Acid is used as a curing agent for the phenol-formaldehyde resin to contribute an element of hardness to the coating. As pure uncured phenol/formaldehyde (Plenco) resin will not be introduced into the environment in this instance, and based on the likelihood that the resin is not biologically active in this form, the conclusions regarding minimal hazard drawn from the NICNAS (1996) review of CN-113 may be considered applicable here.

3.6 Terrestrial Ecological Hazard Assessment

There was insufficient information for plenco resin and its surrogate polymer CN-113 to be able to carry out a terrestrial hazard assessment.

3.7 Ecological Hazard Assessment Summary

There is limited information available relating to the ecological toxicity of the phenol-formaldehyde polymer plenco resin. Based on professional judgment of the likely physico-chemical parameters for this polymer, plenco resin in its current form is unlikely to pose a significant toxicological hazard to the freshwater environment.

4.0 O,P-TOLUENESULFONIC ACID / XYLENESULFONIC ACID MIXTURE

The primary constituent of Mod Acid, which is used as a curing agent for the phenol-formaldehyde resin, is o,p -toluenesulfonic acid and xylenesulfonic acid mixture (CAS # 25321-41-9, >92%). Also present are sulphuric acid (<2%), toluene (<1%) and xylene (<1%). During the manufacturing process the solvents are driven off through evaporation (pers comm. Baker Hughes, May 2012). Chemical information for o,p-toluenesulfonic acid/ xylenesulfonic acid mixture (CAS #25321-41-9) is attached to this letter in the form of a chemical product sheet. Due to the limited experimental chemical data available for this mixture a chemical product sheet for p-toluenesulfonic acid (CAS# 104-15-4) is also attached.

As various salts, toluenesulfonate and xylenesulfonate, are hydrotropes commonly used as coupling agents to solubilise the water insoluble and often incompatible functional ingredients of household and industrial cleaning products and personal care products. HERA (Human and Environmental Risk Assessments on ingredients of household cleaning products) have undertaken a risk assessment on hydrotopes, including the sodium salts of toluenesulfonate and xylenesulfonate (HERA, 2005). In solution these salts will dissociate and become acids. In the absence of available environmental fate and toxicological information on o,p-toluensulfonic acid/xylenesulfonic acid mixture, information available for the sulfonate salts of xylene and toluene have been considered in the environmental assessment. Human health data were available on hydrotropes as a functional group.

4.1 Human Health Hazard Assessment

While sulphuric acid, toluene and xylene exhibit a moderate to high order of health hazard this assessment reflects exposure to the pure substances or to high concentrations. The use of sulphuric acid as an acidic catalyst (trace) and the low residual levels of toluene and xylene are not considered to reflect a level of concern as they represent a trace concentration within a low percentage component (Mod acid) of the final polymer.

The major component of Mod acid comprises a mixture of hydrotropes, specifically, o,p -toluenesulfonic acid and xylenesulfonic acid. These are a part of a group or similar organic sulfonates used specifically as coupling agents to solubilise the water soluble and incompatible functional ingredients of household and institutional cleaning and personal care products. The toxicity profile and hazard ranking is provided in the attachments. The hydrotropes in general exhibit a close consistency in their structure, use, fate and health and environmental effects. They exhibit a low order of acute and chronic toxicity and hazard to human health. Their major adverse health effects are limited to irritant effects on skin, eyes and mucous membranes and systemic effects at high doses and these reflect exposure to the pure or high concentration solutions. At final use concentrations in the order of a few percent the low hazard ranking is further reduced.

4.2 Aquatic Ecological Hazard Assessment

The methodology used to assess the PBT potential of ,p-toluenesulfonic acid/xylenesulfonic acid mixture and potential surrogates is outlined in Attachment 1.

Sufficient chemical information is available for o,p-toluenesulfonic acid/xylenesulfonic acid mixture and p-toluenesulfonic acid to be able to complete an assessment of PBT using data from EPISUITE.

An assessment of PBT of the sulfonate salts of toluene and xylene correlates well with the assessment of o,p-toluenesulfonic acid/xylenesulfonic acid mixture and supports the use of the sulfonate salts as surrogates for the assessment of o,p-toluenesulfonic acid/xylenesulfonic acid mixture. A summary of bioaccumulation and persistence data used in the assessment is provided in Table 2 below. The values corresponding to the highest hazard score were used in the assessment.

Table 2: Persistence and Bioaccumulation Data Used in the Aquatic Toxicity Assessment

Fraccing Chemical	Solubility mg/L	Henry's Law Constant atm-m^3/mol	Log Koc	Log Kow	BCF L/kg	Anaerobic degradation in Water
o,p-toluenesulfonic acid/xylenesulfonic acid mixture	$5.9x10^{4}$ – $1x10^{6}$ (est)	$1.64x10^{-11}$ – $3.06x10^{-9}$ (est)	0.886-1.420 (est)	-0.07 (est)	3.162 (est)	No
p-toluenesulfonic acid	620,000 (exp)	$3.248x10^{-12}$ – $2.78x10^{-9}$ (est)	0.582-1.206 (est)	-0.62 (est)	3.162 (est)	No
Xylene and Toluene sulfonate salts	400,000-553,000 (exp)	$3.06x10^{-9}$ (est)	N/A	-2.7 (exp)	3 (est)	No

The persistence and bioaccumulation scores for the toluene and xylene sulfonate salts were combined with toxicity scores from the aquatic toxicity data reported in the HERA assessment (HERA, 2005). In summary the sulfonate salts of xylene and toluene exhibit low acute and chronic toxicity. Acute toxicity data is available for fish, invertebrate and algae. LC50 data range from 1060 mg/L for Bluegill to >400 mg/L for flathead minnows. Only two chronic toxicity data are available for xylene sulfonate salts. The NOECs for the Na and Ca xylene sulfonate salts are 31 mg/L and 75 mg/L, respectively, based on a 96-hr *Selenastrum* test (HERA, 2005).

In the absence of aquatic toxicity data for o,p-toluenesulfonic acid/xylenesulfonic acid mixture, data were modelled using EPISUITE™ ECOSAR™ software. ECOSAR™ (Ecological Structure Activity Relationships) estimates the toxicity of chemicals to fish, aquatic invertebrates and algae in water. ECOSAR™ predicted toxicity values all indicate that the o,p-toluenesulfonic acid/xylenesulfonic acid mixture would have a low hazard ranking and would be less toxic than the experimental results for the sulfonate salts of xylene and toluene presented above (see the chemical product sheet attached).

The o,p-toluenesulfonic acid/xylenesulfonic acid mixture and the combined data for the xylene and toluene sulfonate salts were scored based on the PBT potential to the aquatic environment. Possible overall scores range from a minimum of 1 (low hazard), to a maximum of 3 (high hazard). The use of averages ensures that where there are one or more data gaps, the score represents the average of available parameters. In the assessment of toxicity, the highest hazard score assigned to either acute or chronic data was adopted at the final hazard score for T. For o,p-toluenesulfonic acid/xylenesulfonic mixture a low hazard ranking of 1 for T was adopted based on the ECOSAR™ results and the use of surrogate toxicity data.

Overall scores (the environmental hazard scores) were calculated based on the average of the sum of the P, B and T scores. The overall score for o,p-toluenesulfonic acid/xylenesulfonic acid mixture, p-toluenesulfonic acid and the combined assessment of toluene and xylene sulfonate salts are presented in Table 3 below.

Table 3: Environmental Hazard Score for o,p-toluenesulfonic acid/xylenesulfonic acid mixture and surrogates

Fraccing Chemical	CASRN	Overall Environmental Hazard Score	Environmental Hazard Category
o,p-toluenesulfonic acid/xylenesulfonic acid mixture	25321-41-9	1.3	Low
p-toluenesulfonic acid	104-15-4	1.3	Low
Xylene and Toluene sulfonate salts	various	1.3	Low

The o,p-toluenesulfonic acid/xylenesulfonic acid mixture and the surrogates used to supplement environmental fate and toxicity data have been assigned environmental hazard scores of 1.3 and are ranked as a 'low hazard'. The similar hazard scores of the xylene and toluene salts and p-toluenesulfonic acid support the 'low hazard' rank of o,p-toluenesulfonic acid/xylenesulfonic acid mixture. As o,p-toluenesulfonic acid/xylenesulfonic acid mixture is not ranked as 'high hazard' it is not considered to be a chemical of potential concern (COPC) from an aquatic toxicology perspective.

4.3 Terrestrial Ecological Hazard

No terrestrial toxicity data were identified for o,p-toluenesulfonic acid/xylenesulfonic acid mixture or for the sulfonate salts of toluene or xylene in the preparation of this letter. However given the low potential for the acid to reach the terrestrial compartment and the low likelihood of persistence or bioaccumulation HERA did not consider this a deficiency in their assessment of xylene and toluene sulfonate salts (HERA, 2005). Based on the HERA assessment of xylene and toluene sulfonate salts, and professional judgment of the likely physic-chemico parameters for o,p-toluenesulfonic acid/xylenesulfonic acid mixture it is not considered to be a COPC from an terrestrial toxicology perspective.

5.0 SUMMARY

Based on the available information, the main constituents of LiteProp (raw walnut hulls, Plenco resin and Mod Acid) would support the case of presenting a low hazard to human health and the environment. Additional confidence to this assessment requires information on the following:

- the walnut hulls (whether they may contain residual biological or chemical hazards);
- the exact nature of the phenol-formaldehyde resin and it's chemical and toxicological properties including residual impurities;
- the hazards of these constituents in a mixture, e.g. a review of the toxicodynamic properties; and
- whether the hazards of each constituent would change in high temperature and pressure environments.

6.0 REFERENCES

Australian Government (1989). Industrial Chemicals (Notification and Assessment) Act 1989. Accessed at: http://www.comlaw.gov.au/Details/C2012C00082.

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7.0 LIMITATIONS

Your attention is drawn to the document - "Limitations" (LEG04, RL1), which is attached to this report. The statements presented in this document are intended to advise you of what your realistic expectations of this report should be. The document is not intended to reduce the level of responsibility accepted by Golder Associates, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.

8.0 CLOSURE

We trust that this information meets your requirements. Please contact the undersigned if you have any questions or feedback in relation to this information.

GOLDER ASSOCIATES PTY LTD



Kirsten Broadgate
Senior Environmental Scientist



Len Turczynowicz
Principal Risk Assessor

SDB/LT/sdb

Attachments:

1) Environmental and human health hazard assessment approach.
2) Chemical Product Sheet o,p-Toluenesulfonic Acid/Xylenesulfonic Acid Mixture.
3) Chemical Product Sheet p-Toluenesulfonic Acid.
4) Chemical Product Sheet for hexamethylenetetramine.
5) Human health toxicity profiles for phenol, formaldehyde, xylene, toluene, sulphuric acid and o,p-toluenesulfonic acid/xylenesulfonic acid Mixture.
6) Limitations (LEG04, RL1).

1.0 ENVIRONMENTAL HAZARD ASSESSMENT

An environmental hazard assessment was undertaken to rank the hydraulic fracturing chemicals based on persistence (P), bioaccumulation (B) and toxic (T) potential (hereafter referred to as PBT). From this assessment, those chemicals ranked as a high hazard are considered to be COPC. It should be noted that the selection of a chemical as a COPC does not indicate an unacceptable risk; rather it indicates that potential exposures to these chemicals should be evaluated in greater detail to assess whether they might present an unacceptable risk.

1.1 Chemical information sheets

In order to assess environmental hazards, readily available chemical and physical properties and ecotoxicological data were collated for the chemicals assessed. In addition, published water quality guidelines were identified and collated. This information was compiled into a chemical information sheet for each chemical.

1.1.1 Chemical and physical properties

Chemical and physical properties were obtained from the following sources in order of priority:

1) The Material Safety Datasheet (MSDS) and Product Disclosure Statement provided to Golder Associates by Santos and Baker Hughes (BJ Services, 2004; Fritz Industries 2012);

2) Hazardous Substances Databank (HSDB);

3) Modelled data from USEPA (2012) EPISUITE™ (Estimation Programs Interface Suite™ for Microsoft® Windows) modelling software (only when data were not available from the MSDS or the HSDB).

USEPA (2012) EPISUITE™ software is developed by Syracuse Research Corporation (SRC) for the USEPA Office of Pollution Prevention and Toxics. EPISUITE™ provides a package of modelling software programs that can estimate physical/chemical, environmental fate and ecotoxicity data for organic chemicals. Inorganic chemicals should not be evaluated using EPISUITE™ because the estimation methods used are developed based on organic chemicals.

In using EPISUITE™, the following limitations for modelling organic chemicals are noted:

Chemicals that rapidly hydrolyse are unsuitable to be modelled namely, acid halides, isocyanates, sulphonyl chlorides, siloxanes, and alpha-chloro ethers. No such chemicals were identified in the list of hydraulic fracturing chemicals considered for this study.

Data generated for organic salts may not be reliable, namely cationic salts of Group I, Group II, transition metals, Actinides, and Lanthanides. These should not be profiled because there are not adequate data in the estimation models databases to predict properties with confidence. Organic salts however of Sodium (Na), Potassium (K), and Ammonium (NH_4^+) may be evaluated reliably. No such chemicals are identified in the list of the hydraulic fracturing chemicals considered for this study.

Organo metallic compounds should not be evaluated. No such chemicals were identified in the list of the hydraulic fracturing chemicals considered for this study.

Highly reactive compounds should not be modelled. No such chemicals were identified in the list of the hydraulic fracturing chemicals considered for this study.

High molecular weight compounds with a molecular weight greater than1000 should not be modelled. As gelatine and Guar gum are identified in the list of hydraulic fracturing chemicals and would fall into this category, they have therefore not been subject to modelling by EPISUITE™.

The EPISUITE™ estimation programs are simple to use, requiring only one input (e.g., CASRN or SMILES notation[1]) from the user and a nomination of the program to be used based on the data required by the user. EPISUITE™ includes a database of chemical and physical properties, algorithms, and Quantitative Structure Activity Relationships (QSAR) models with which to estimate parameters. The following programs were used to generate physical and chemical data for this study:

- KOWWIN™ - octanol/water partition coefficient (Kow);
- HENRYWIN™ - Henry's Law Constant;
- BIOWIN™ - Biodegradation rate;
- LEV3EPI™ - Fugacity model to estimate partitioning to soil air, water and sediment;
- KOCWIN™ - Soil organic carbon partition coefficient (Koc);and
- BCFBAF™ - Bioconcentration factor.

1.1.2 Environmental and drinking water guidelines

In addition to the chemical, physical and toxicological data collated for use in the environmental hazard assessment, environmental and human health guidelines were also obtained. These guidelines were not used in the assessment of environmental hazard but may be used in the exposure assessment of chemicals which are the subject of environmental fate and transport modelling. Guidelines were obtained from the following sources in order of priority:

1) Australian and New Zealand Guidelines for Fresh and Marine Water Quality for protection of aquatic ecosystems and stock watering (ANZECC & ARMCANZ, 2000);
2) Australian Drinking Water Guidelines (NHMRC and NRMMC, 2004);
3) World Health Organisation (WHO, 2006) Guidelines for Drinking-water Quality (Third Edition);
4) United States Environment Protection Authority (USEPA) National Recommended Water Quality Criteria (2009) for protection of aquatic life and human health;
5) International Agency for Research on Cancer (IARC) Monographs on the Evaluation of Carcinogenic Risks to Humans; and
6) Drinking-water Standards for New Zealand 2005 (Revised 2008, Ministry of Health).

1.1.3 Toxicity information

Acute and chronic aquatic ecotoxicological data were obtained from the following sources in order of priority:

1) USEPA (2009) ECOTOXicology Database Version 4.0; and
2) Australasian Journal of Ecotoxicology.

Where ecotoxicological data were not available for the chemicals of interest or a suitable surrogate, data were modelled using EPISUITE™ ECOSAR™ software. ECOSAR™ (stands for Ecological Structure Activity Relationships) estimates the toxicity of chemicals to fish, aquatic invertebrates and algae in water. Toxic effect predictions are made using a set of quantitative structure-activity relationships (QSARs) models. QSARs predict the aquatic toxicity of untested chemicals based on their structural similarity to chemicals for which aquatic toxicity data are available. The toxicity data used to build the QSARs come from a database of publicly available and confidential data submitted to the US EPA New Chemicals Program. The QSARs used in ECOSAR™ correlate a compound's physicochemical properties and its aquatic toxicity within

[1] SMILES (**S**implified **M**olecular **I**nput **L**ine **E**ntry **S**ystem) string is a linear notation for chemical structures.

specific chemical classes, and applies rules for selecting the appropriate chemical class for the compound. ECOSAR™ generates acute (short-term) toxicity and, when available, chronic (long-term or delayed) toxicity.

1.2 Hazard versus risk

The approach presented in the following paragraphs is an assessment of environmental hazard, rather than environmental risk. Risk assessment of chemicals in the environment is based on a comparison between the levels to which an organism in a particular environmental compartment (e.g. water) is exposed, and a maximum level which an organism can tolerate based on a defined exposure scenario (in an environmental compartment) without significant adverse effect. The environmental hazard assessment presented herein, is not a risk assessment *per se* because it does not consider likely exposure concentrations for most of the hydraulic fracturing chemicals. A qualitative assessment of the risk will be conducted based on an identification of relevant exposure pathways and fate and transport modelling of COPC associated with the hydraulic fracturing fluid.

Approaches to ranking or screening chemicals for the purposes of assessing relative "hazard" or "risk" include likelihood and consequence matrices. In these matrices, a chemical may be scored high for consequence (which may be a function of PBT) but low for likelihood (which may be a function of whether the chemical is considered likely to be present in the environment at hazardous concentrations). Overall, such a chemical may then score a relatively lower hazard or risk than would be identified from its consequence score alone. The environmental hazard assessment approach here works on the premise of potential for PBT; that is, the data that may apply to "consequence". The assessment of "likelihood" is assessed for those chemicals selected as COPC through fate and transport modelling and the assessment of complete exposure pathways.

1.3 Hazard assessment approach

The environmental hazard assessment approach developed for this study is consistent with national and international guidance for assessment of potential for PBT in the risk assessment, classification, and regulation of chemicals. Physical and chemical properties that affect the fate and behaviour of chemicals in the environment, degradation rates, partition coefficients, and aquatic ecotoxicological data are used in assessment of environmental mobility and PBT potential.

The Australian National Framework for Chemicals Environmental Management (NChEM) guidance manuals were consulted in preparation of the environmental hazard assessment approach, namely:

- EPHC (2009a). Environmental Risk Assessment Guidance Manual for Industrial Chemicals; and
- EPHC (2009b). Environmental Risk Assessment Guidance Manual for Agricultural and Veterinary Chemicals.

These guidance manuals present the data requirements and methodology for assessment for environmental hazard and risk assessment of industrial and agriculture and veterinary chemicals, consistent with international best practice. NChEM guidance is prepared by the National Environment Protection and Heritage Council (EPHC) for the Department of the Environment, Water, Heritage and the Arts (DEWHA). DEWHA undertakes environmental risk assessments of industrial chemicals for the National Industrial Chemicals Notification and Assessment Scheme (NICNAS) and of agricultural and veterinary chemicals for the Australian Pesticides and Veterinary Medicines Authority (APVMA).

In addition, the following international literature for PBT assessment was consulted:

- CCME (2008) Canadian Council of Ministers of the Environment The National Classification System for Contaminated Sites (NCSCS) Guidance Document;
- Christensen et al. (2003) Assessment Tools under the New European Union Chemicals Policy;

- Environment Canada (2003) Existing Substances Branch Guidance Manual for the Categorization of Organic and Inorganic Substances on Canada's Domestic Substances List, Determining Persistence, Bioaccumulation Potential, and Inherent Toxicity to Non-human Organisms;
- European Commission (2003) Technical Guidance Document on Risk Assessment in support of Commission Directive 93/67/EEC on Risk Assessment for New Notified Substances, Part II Chapter 3 Environmental Risk Assessment;
- ECETOC (2005) Risk Assessment of PBT Chemicals;
- Franke et al. (1994) The Assessment of Bioaccumulation;
- Langley (1993) Refining Exposure Assessment. In: The Health Risk Assessment and Management of Contaminated Sites. Proceeding of the Second National Workshop on the Health Risk Assessment and Management of Contaminated Sites;
- Swann et al. (1983) A rapid method for the estimation of the environmental parameters octanol/water partition coefficient, soil sorption constant, water to air ratio, and water solubility. Residue Reviews; and
- UNECE (2009) Globally Harmonised System (GHS) of Classification and Labelling of Chemicals. Revision 3. Part 4 Environmental Hazards and Annex 9 Guidance on hazards to the aquatic environment.

1.4 Environmental hazard scores

The environmental hazard assessment approach presented herein awards highest scores to those physical, chemical and toxicological values considered to pose high environmental hazard. The parameter ranges and scores assigned to each physical, chemical and toxicological value used are discussed in the following sections. The environmental hazard assessment categorised chemicals into three hazard scenarios, as follows:

- High Hazard – assigned scores of 3;
- Moderate Hazard - assigned scores of 2; and
- Low Hazard - assigned scores of 1.

For each chemical, an average score for each of P and B was calculated. The use of averages ensures that where there are one or more data gaps, the score represents the average of available parameters. In the assessment of T, the highest hazard score assigned to either acute or chronic data was adopted at the final hazard score for T. The approach for assessment of T differed from P and B because some chemicals have few aquatic ecotoxicological data. This resulted in weighting of the assessment towards T and is considered conservative and appropriate for a screening level risk assessment. An overall score (the environmental hazard score) for each chemical was calculated based on the average of the sum of the P, B and T scores. Possible overall scores range from a minimum of 1 (low hazard), to a maximum of 3 (high hazard). The overall hazard score is calculated to one significant figure, whereas the individual and total P, B or T scores represent whole numbers.

The scoring system is semi-quantitative in that scores are assigned to ranges for a particular parameter (see section 1.6). The scores are largely assigned using professional judgement following consideration of the guidance for chemical assessment in the literature for PBT assessment as identified in section 1.6.

The hazard assessment was limited to PBT, consistent with the parameters identified in the published literature. Not all the physical and chemical parameters collated for the hydraulic fracturing chemicals presented in the chemical information sheets were used in the environmental hazard assessment.

The ranges set for this study are considered a *relative assessment*. The ranges were assigned with the intent of incorporating the precautionary principle i.e., designed to be inherently conservative and therefore biased towards capturing, rather than rejecting chemicals that are likely to pose PBT hazard.

The individual scores assigned to the respective ranges for each parameter are presented in section 1.6.

1.5 Assessment of organic versus inorganic substances

The approach for the assessment of inorganic and organic substances differs. The approach for the assessment of inorganic substances[2] was devised based predominantly on guidance published by Environment Canada (2003). Environment Canada (2003) describe an approach for the assessment of "metal-containing inorganic salts, organic-metal salts, and ionizable inorganics". Following the Environment Canada (2003) approach, toxicity is considered in conjunction with persistence, and bioaccumulation is considered only if persistence cannot be assessed. The assessment of bioaccumulation potential of inorganic chemicals is more difficult to interpret in hazard assessment.

Non-metal-containing inorganic substances may be assessed following guidance for organic substances.

Justification for the scores assigned to the individual parameters and the adopted ranges are discussed in the following section.

1.6 Environmental hazard assessment parameters

The physical, chemical and ecotoxicological data collated and assessed in the environmental hazard assessment are presented in the chemical information sheets and summarised below in Table 1.

Table 1: Physical, chemical and toxicological parameters used in environmental hazard assessment

PBT	Applicable to Organic / Inorganic Chemicals	Parameter	Units
Persistence	Inorganic / Organic	Solubility	g/m^3
	Organic	Henry's Law constant	atm m^3/mol
	Organic	log K_{oc}	L/kg
	Organic	Anaerobic degradation in water	Qualitative
Bioaccumulation	Organic	BCF	unitless
	Organic	log K_{ow}	unitless
Toxicity	Inorganic / Organic	Aquatic ecotoxicological data for: • Plants; • Invertebrates; and • Fish. Acute LC50 Chronic NOEC Chronic LOEC Chronic EC50	mg/L

The following sections describe in more detail the parameters used, the ranges set and the scores assigned in the environmental hazard assessment.

[2] Inorganic substances may be described as metal-containing inorganic salts, organic-metal salts, and ionizable inorganics.

1.6.1 Data gaps

Where data was not available for a chemical, data for a suitable surrogate was used in the hazard assessment. Surrogates were identified from the MSDS in that where a hydraulic fracturing additive is a mixture; the chemical representing the greatest proportion of the additive (usually greater 95% of the mixture) was adopted. Where a suitable surrogate chemical was not available, data were modelled using EPISUITE™. Where data could not be modelled, the parameter was excluded from the environmental hazard assessment.

1.6.2 Persistence

The approach for assessment of persistence for inorganic and organic chemicals differs.

Inorganic chemicals were assessed based on solubility, and solubility was considered in conjunction with toxicity.

Organic chemicals were assessed based on solubility, Henry's Law Constant, K_{oc}, and aerobic degradation half-life in water. In all cases, the assessment of persistence in organic chemicals was based on at least three out of a total of four persistence parameters.

1.6.3 Solubility

Aqueous solubility is measured in units of mg/L (or g/m^3) at temperatures of 20°C – 25°C. Aqueous solubility is temperature dependent. The solubility of a chemical will influence the rate of migration (or mobility) of that chemical in the environment. An increase in solubility leads to a decrease in adsorption to soil and greater mobility (Langley, 1993). Poor solubility may result in low bioavailability and lower biodegradation rates. A poorly soluble chemical may be considered to have a tendency to persist and therefore have more time to exert a toxic effect. Conversely, high solubility could also imply greater mobility, greater bioavailability and greater hazard. Solubility, rather than effective solubility[3], was adopted in this hazard assessment for simplicity. Effective solubility is a more accurate measure of chemical availability and mobility. However, effective solubility cannot be reliably predicted or modelled and is dependent on the chemical mixture and environmental factors (e.g. pH, temperature, oxidising or reducing conditions, etc). Solubility is a conservative and simple measure of mobility and availability of a chemical in groundwater and hence was used in this hazard assessment.

Organic substances with low water solubility typically have high predicted bioaccumulation factors and / or high log K_{ow} and hence may be considered highly bioaccumulative unless there is evidence to suggest otherwise (Environment Canada, 2003).

Inorganic substances generally need to be dissolved in water to exert deleterious effects (to aquatic receptors) and consequently solubility should be considered in conjunction with aquatic toxicity, as recommended by Environment Canada (2003). Environment Canada (2003) recommends that when the solubility of the substance is greater than the acute toxicity, the substance is likely to pose a hazard. Herein, the lowest acute ecotoxicological endpoint obtained for the chemical of interest was used for data considered in assessment of toxic potential). Where solubility data were not found for the inorganic chemicals considered, solubility was assumed to be greater than acute toxicity. This is conservative and results in a high hazard classification.

Low solubility was assigned a high hazard (based on likelihood of persistence and high bioaccumulation tendency) for organic chemicals. Conversely, low solubility was assigned a low hazard for inorganic chemicals. The hazard category ranges and scores adopted in this study are summarised in Table 2 and Table 3 for organic and inorganic substances, respectively. These have been derived based on professional judgement (noting that the UNECE (2009) consider a substance with a solubility of less than 1 mg/L to be poorly soluble).

[3] Effective Solubility is the solubility of a compound that will dissolve from a chemical mixture (e.g., gasoline). The effective solubility of a compound from a chemical mixture is less than its aqueous solubility

Table 2: Solubility ranges and scores for organic substances

Hazard Category	Solubility Range (mg/L)	Score
High Hazard	<10	3
Moderate Hazard	10-100	2
Low Hazard	>100	1

Table 3: Solubility ranges and scores for inorganic substances

Hazard Category	Solubility Range (mg/L)	Score
High Hazard	>10	3
Moderate Hazard	1 – 10	2
Low Hazard	<1	1

The ranges and scores for the assessment of solubility in conjunction with aquatic toxicity for inorganic chemicals are presented in Table 4. The ranges are set following Environment Canada (2003). Because only two categories exist in this threshold assessment of solubility in conjunction with acute toxicity, scores of 1 or 3 are assigned. A moderate hazard score of 2 is not possible.

Table 4: Solubility considered in conjunction with acute toxicity (Inorganic substances), ranges and scores

Hazard Category	Solubility Range (mg/L)	Score
High Hazard	Solubility > acute toxicity	3
Moderate / Low Hazard	Solubility < acute toxicity	1

1.6.3.1 Henry's Law Constant

Henry's Law is a partition coefficient which is a measure of the tendency of a substance to partition into air from water at constant temperature and pressure. It can be used as a measure of environmental fate and transport of a substance. Henry's Law Constant is calculated using vapour pressure, molecular weight and water solubility for a chemical and is commonly expressed either as 'dimensionless' (i.e., no units) or in 'dimensions' (i.e., units of atmospheres (atm) m^3/mol or Pa m^3 mol^{-1}). Henry's Law Constant data are used in the environmental hazard assessment even though one of the parameters on which it is based (namely solubility) is assessed and scored separately.

Interpreted ranges (in terms of volatility and hence environmental persistence potential) for Henry's Law Constant were available in the literature reviewed as part of this report.

Organic chemicals with a low Henry's Law Constant (i.e., low volatility and high solubility) are likely to be more persistent in the environment. Organic chemicals with a high Henry's Law Constant (i.e., high volatility, low water solubility) are likely to be less persistent in the environment. Organic chemicals with a low Henry's Law Constant were scored a greater environmental hazard in this assessment.

Henry's Law Constant scores are assigned based on ranges provided in CCME (2008), Langley (1993) and professional judgement. The parameter ranges are summarised in Table 5.

Inorganic chemicals were not assessed using Henry's Law Constant.

Table 5: Henry's Law Constant ranges and scores

Hazard Category	Henry's Law Constant Range (atm m^3/mol)	Score
High Hazard	$<6.1x10^{-09}$	3
Moderate Hazard	$6.1x10^{-09}$- $6.1x10^{-05}$	2
Low Hazard	$>6.1x10^{-05}$	1

1.6.3.2 Soil adsorption partition coefficient (Koc)

The soil organic carbon-water partitioning coefficient is the ratio of the mass of a chemical that is adsorbed in the soil per unit mass of organic carbon in the soil. It is a measure of the tendency for organic substances to be adsorbed by soil or sediment. K_{oc} values are useful in predicting the mobility of organic contaminants in soil and sediment. Higher K_{oc} values correlate to less mobile organic chemicals while lower K_{oc} values correlate to more mobile organic chemicals. Less mobile organic chemicals (i.e., greater tendency to persist) are considered in this assessment to be a greater environmental hazard. The parameter ranges and assigned scores for K_{oc} used are presented in Table 6. These ranges were derived after consideration of information provided in CCME (2008); Langley (1993) and Swann et al. (1983) and professional judgement.

Inorganic chemicals were not assessed using K_{oc}.

Table 6: Log K_{oc} ranges and scores

Hazard Category	Log K_{oc} Range (L/kg)	Score
High Hazard	>3.7	3
Moderate Hazard	3.7-2.7	2
Low Hazard	<2.7	1

1.6.3.3 Biodegradation

Degradation takes into account physical, biological, and chemical changes in a chemical over time (Langley, 1993). Biodegradation is "the process by which organic substances is decomposed by micro-organisms (mainly aerobic bacteria) into simpler substances such as carbon dioxide, water and ammonia" (UN, 1997 cited in OECD, 2010). The rate of biodegradation is frequently described by the half-life (days) as an indication of the length of time required for the chemical to reach half its original concentration. The longer the time taken for a substance to degrade, the more environmentally persistent that chemical is considered to be. Longer biodegradation rates were considered to be indicative of higher environmental hazard. Anaerobic biodegradation half-lives were sought on the basis that the groundwater environment is likely to be anaerobic. The lack of quantitative, measured data in the literature reviewed resulted in generating modelled data from EPISUTE™ BIOWIN™. The modelled data produced by BIOWIN™ are qualitative only, not half-lives, and represent one of two potential outputs: biodegrades fast, or does not biodegrade fasts. A summary of the nominated anaerobic degradation hazards in and the associated scores assigned is presented in Table 7. These ranges are based on professional judgement.

Table 7: Anaerobic biodegradation ranges in water and scores

Hazard Category	Anaerobic Biodegradation Range in Water (days)	Score
High Hazard	Does not biodegrade fast	3
Moderate Hazard	Not assigned	Not assigned

Hazard Category	Anaerobic Biodegradation Range in Water (days)	Score
Low Hazard	Biodegrades fast	1

1.6.4 Bioaccumulation

Assessment of bioaccumulation potential was assessed for organic chemicals only. Two parameters were assessed, and an average of the scores calculated.

Bioaccumulation was not assessed for inorganic chemicals in accordance with guidance in Environment Canada (2003).

1.6.4.1 Octanol / water partition coefficient (Kow)

The octanol-water partition coefficient (K_{ow}) is the ratio of the solubility of a chemical in octanol divided by its solubility in water. It is a measure of the preference for an organic substance to dissolve in an organic solvent or water and is used as a measure of lipophilicity and movement of a substance across a cell membrane. It is usually expressed as Log K_{ow}. It can be used as a measure of environmental fate and transport of a chemical.

There is general consensus in the literature that a Log K_{ow} of less than 3.5 represents low or moderate potential to bioaccumulate, and a Log K_{ow} of greater than 3.5 represents an increased potential to bioaccumulate. UNECE (2009) consider that substances with Log K_{ow} less than 4 have no potential to bioaccumulate. UNECE (2009) and CCME (2008) consider that substances with Log K_{ow} greater than 4 have the potential to bioaccumulate. European Commission (2003) consider that substances with Log K_{ow} greater than 4.5 have the potential to bioaccumulate. The ranges and the associated scores adopted in this study are summarised in Table 8 and are largely based on the classes provided by European Commission (2003), UNECE (2009), CCME (2008) and professional judgment.

K_{ow} is assessed for organic chemicals only.

Table 8: Log K_{ow} ranges and scores

Hazard Category	Log K_{ow} Range (unitless)	Score
High Hazard	>4	3
Moderate Hazard	2-4	2
Low Hazard	<2	1

1.6.4.2 Bioconcentration factor (BCF)

The bioconcentration factor (BCF) is a measure of the tendency for a substance in water to accumulate in organisms, in particular, fish. This parameter is an important determinant for uptake into organisms, potential for biomagnification and secondary poisoning (food chain transfer to higher trophic levels). The higher the BCF, the greater the potential for bioconcentration and, therefore, secondary poisoning. The parameter ranges and scores used are summarised in Table 9. These ranges have been derived after consideration of information provided in Franke et al. (1994, predominantly); European Commission (2003); UNECE (2009) and professional judgment.

BCF is assessed for organic chemicals only.

Table 9: BCF ranges and scores

Hazard Category	BCF Range (unitless)	Score
High Hazard	>100	3
Moderate Hazard	100-30	2
Low Hazard	<30	1

1.6.5 Toxicity

In the assessment of T potential, the highest hazard score assigned to either the acute or chronic data was used because there were frequently insufficient data to enable an assessment of both acute and chronic toxicity. This results in weighting of the assessment towards T. This approach considered conservative and appropriate for a screening level hazard assessment.

1.6.5.1 Aquatic ecotoxicology

To assess the toxic (T) potential of the chemicals, readily available acute (i.e., predominantly L(E)C_{50}[4]) and chronic (i.e., NOEC[5], LOEC[6], MATC[7] and EC_{50}) data for aquatic organisms were collated.

Chronic ecotoxicology data are preferred over acute because exposure occurs over a longer time-period, usually during a significant period of the organism's life-cycle or during a sensitive life-stage. However, there is a predominance of acute ecotoxicological data available in the literature compared to chronic. The species groupings considered (plants, invertebrates and fish) and endpoints considered (acute, chronic) were given equal weighting.

The following trophic level groupings were considered for aquatic organisms:

- Plant;
- Invertebrate; and
- Fish.

As freshwater aquatic organisms are considered the receptor of concern for the hydraulic fracturing chemicals, freshwater ecotoxicological data were used in the assessment of toxic potential. There are generally few aquatic ecotoxicological data available for amphibians and reptiles, and no guidance was found in the international literature on the assessment of hazard for these receptor groups. Hence these receptors groups were excluded from the assessment of T.

The data downloaded data from USEPA ECOTOX database were screened. The following endpoints were selected: mortality (acute), growth (chronic) and reproduction (chronic) for plants, invertebrates and fish. Additional screening included the following:

- Studies shorter than 24hrs were not considered;
- Chronic mortality exposures were not considered; and
- L(E)C_x endpoints other than L(E)C_{50} were not considered, namely EC_0, EC_{100}, EC_{10}, EC_{20}, etc.

Although included in the environmental hazard assessment, NOECs are not statistical or empirical point estimates of ecological effect. NOECs are hypothesis based and reflect the test design (i.e., concentrations

[4] Lethal (or effect) concentration that kills (or effects) 50% of the test population.

[5] No observed effect concentration.

[6] Lowest observed effect concentration.

[7] Maximum acceptable tolerable concentration.

of exposure) rather than the dose-response curve. However, NOECs are well documented in the literature and are commonly used in ecological risk assessment and in derivation of risk-based ecological guidelines. Additional chronic endpoints namely LOEC, MATC and EC_{50} were included in the hazard assessment to reduce the uncertainly associated with NOEC data.

Where modelled data were generated using EPISUITE™ ECOSAR™ the chronic data do not specify the endpoint (i.e., it is not known if the endpoint is NOEC or LOEC/MATC, or EC_{50}.) The chronic data were assumed to be LOEC/MATC or EC_{50} endpoints which results in a higher (more conservative) hazard classification.

The chronic aquatic ecotoxicology ranges (for plants, invertebrates and fish) were assigned after consideration of information provided in European Commission (2003); UNECE (2009) and professional judgement. As a conservative approach to assessment of T, the lowest chronic effect concentration for each of NOEC, LOEC/MATC, and EC_{50}, and the lowest acute effect concentration for $L(E)C_{50}$ was identified for each chemical and scored. The ranges and scores adopted in the hazard assessment are summarised in Table 10 and Table 11.

Table 10: Chronic aquatic NOEC ecotoxicology ranges and scores

Hazard Category	Chronic Aquatic NOEC Range (mg/L)	Score
High Hazard	<0.01	3
Moderate Hazard	0.01 – 0. 1	2
Low Hazard	>0.1	1

Table 11: Chronic aquatic LOEC/MATC and EC_{50} ecotoxicology ranges and scores

Hazard Category	Chronic Aquatic LOEC, MATC and EC_{50}Range (mg/L)	Score
High Hazard	<0.1	3
Moderate Hazard	0.1 – 1	2
Low Hazard	>1	1

The acute aquatic ecotoxicity ranges (for plants, invertebrates and fish) were assigned after consideration of information provided in European Commission (2003); UNECE (2005) and professional judgement. The ranges and scores adopted in the Hazard Ranking Scheme are summarised in Table 12.

Table 12: Acute aquatic $L(E)C_{50}$ ecotoxicology ranges and scores

Hazard Category	Acute Aquatic $L(E)C_{50}$ Range (mg/L)	Score
High Hazard	<1	3
Moderate Hazard	1 – 100	2
Low Hazard	>100	1

1.6.6 Environmental hazard ranking

As described in section 1.4, for each chemical, an average score for each of P and B was calculated. Possible overall scores range from a minimum of 1 (low hazard), to a maximum of 3 (high hazard). The use

of averages ensures that where there are one or more data gaps, the score represents the average of available parameters.

In the assessment of T, the highest hazard score assigned to either acute or chronic data was adopted at the final hazard score for T. Again, possible scores range from a minimum of 1 (low hazard), 2 (moderate hazard) to a maximum of 3 (high hazard). The approach for assessment of T differed from P and B because some chemicals have few aquatic ecotoxicological data. This resulted in weighting of the assessment towards T and is considered conservative and appropriate for a screening level risk assessment.

An overall score (the environmental hazard score) for each chemical was calculated based on the average of the sum of the P, B and T scores and ranged from a minimum of 1 to a maximum of 3. The overall hazard score is calculated to one significant figure, whereas the individual and total P, B or T scores represent whole numbers.

It should be noted that aquatic toxicological scores for some chemicals were based on modelled, rather than measured data. The modelled toxicological data were from EPISUITE (refer to section 1.1.3). The degree of uncertainty associated with the toxicological data increases when modelled data are used, and the ranks of chemicals scored using these data should be interpreted with this in mind.

1.6.7 Identification of aquatic chemicals of potential concern (COPC)

Based on the ranking of the hydraulic fracturing chemicals, the organic chemicals identified with a high hazard ranking were selected as COPC.

1.6.8 Evaluation of mixture toxicity

It is noted that the CG requirements in (b) refer to the provision of "...*toxicity data for each active ingredient and any mixture toxicity information*". In the environmental hazard evaluation, consideration was given to the available environmental fate, persistence and toxicity information presented in the material safety data sheet (MSDS). Where additional information was required to assess environmental hazard, data were sought for the appropriate chemical constituent namely, the active ingredient(s). Where data for active ingredients were unavailable, data for a suitable surrogate chemical were adopted. This is documented in this report for transparency.

The environmental hazard assessment did not consider the combined effects of the hydraulic fracturing chemicals when present in mixture. Assessment of mixtures is considered beyond the scope of a screening level risk assessment. Approaches for environmental risk assessment of individual chemicals are inherently conservative and designed to over-estimate risk as a precautionary approach and in recognition of the uncertainty surrounding effects of mixtures. This is implicit in the approach adopted in this report for the ecological risk assessment of hydraulic fracturing chemicals.

Methodologies for estimating combined effects of mixtures are in development. The current, international best practice and accepted approach for assessment of mixtures remains the additive approach as a default, conservative position. Additive approaches assume chemicals have the same mechanism of action, in other words toxic effect is manifest in the same manner (e.g., narcosis) at the same location (e.g., central nervous system).

Guidance in Australia for assessment of mixtures is limited to direct toxicity assessment (DTA) described in the Australian Water Quality Guidelines (ANZECC & ARMCANZ, 2000). Direct toxicity assessment entails collection of an environmental sample containing the chemical mixture and undertaking ecotoxicological testing (exposing test organisms to the environmental sample and measuring effect). The National framework for Chemicals Environmental Management (NChEM) guidance remains largely silent on approaches for assessment of mixtures and instead advocates consideration of individual chemical constituents in risk assessment, which was the approach adopted in this risk assessment. The National Environmental Protection Council (NEPC) released a Draft of the National Environment Protection (Site Assessment) Measure (NEPM) revision for public consultation in October 2010. In this draft document reference is made to use of the additive approach in assessment of mixtures.

A recent study (Kortenkamp et al., 2009) was published documenting a review of the current scientific knowledge and regulatory approaches for assessment of mixtures. This study was commissioned by the European Commission Directorate General for Environment and released in December 2009 for public comment. The Environment Council is expected to respond to these comments in December 2010 and so the report remains a study of approaches and is not policy or regulatory guidance.

Hence, pending the formalization and regulatory endorsement of mixture toxicity assessment guidelines in Australia, the conservative assessment of the individual active ingredients of hydraulic fracturing fluid mixtures (or their surrogates) was considered appropriate for this ecological risk assessment.

1.7 Exclusions and limitations

The environmental hazard assessment is a relative assessment and not a comprehensive evaluation of environmental hazards. The following limitations with regard to the hazard assessment and source data are noted:

- The approaches consulted for assessment of PBT in devising the environmental hazard assessment approach are predominantly focussed on the assessment of organic chemicals. There is limited guidance for PBT assessment of inorganic chemicals;
- The environmental hazard assessment approach is subject to professional judgment and the evaluator's subjectivity in designating the parameter ranges for each parameter assessed;
- The environmental hazard assessment did not consider, *inter alia*:
  - breakdown or reactive products of the chemicals that may pose more or less of an environmental hazard than the parent compound;
  - the quality, adequacy or accuracy of the available information sourced, noting that only sources considered to be reputable were used;
  - endocrine disruption effects that are not assessed by standard ecotoxicological tests;
  - the combined effects of these chemicals when present in mixture (see comments in section 1.6.8 regarding mixture toxicity information);
- The data collated in the chemical information sheets were treated the same regardless of whether the data are measured experimental values or estimated / calculated values;
- The test endpoint description in the (secondary) sources consulted was relied upon although it should be noted that true chronic and acute NOEC, LOEC, MATC and L(E)C_{50} are dependent on a variety of factors such as test duration, species tested, stage in the life-cycle, etc. which can only be verified by review of the primary literature;
- It is noted in relation to the aquatic ecotoxicological data that the species *Daphnia magna* are a sensitive species, frequently displaying sensitivity to chemicals orders of magnitude greater than other invertebrate species;
- Sources of Australian aquatic ecotoxicological data were consulted but the information is very limited. Furthermore, many species reported in the Australian literature are not necessarily indigenous species;
- The environmental hazard assessment approach devised for this study will not adequately assess chemicals which are:
  - hydrophilic i.e., are highly soluble and have low K_{ow}. Where aquatic ecotoxicological data are limited for these types of chemicals, toxicity may be underestimated because there is potential for these chemicals to be highly toxic.

  - poorly biodegradable, have low acute toxicity, but are bioaccumulative (based on the BCF or K_{ow}). These chemicals may exert chronic toxicity.

- Use of surrogate toxicity data for hydraulic fracturing chemicals which are best described as mixtures may further bias the hazard assessment towards assessment of T potential. Where a highly toxic chemical is present in only small quantities the effect on the overall hazard assessment is greater compared to a chemical with lower toxicity.

- Toxicological data were obtained for surrogate chemicals and/or modelled data using ECOSAR, as discussed above.

2.0 HUMAN HEALTH TOXICITY ASSESSMENT

2.1 Objective

The assessment of toxicity represents an assessment of hazard rather than risk. The aim of the hazard assessment is to provide a semi-quantitative hierarchy of health concern or hazard ranking of chemicals based on human health toxicity to identify COPC. Further evaluation of the risk posed by the COPC can be provided with an evaluation of exposure pathways and fate and transport modelling. There are various qualifications related to the hazard ranking process and these are summarised in the concluding comments of each human health toxicity profile.

2.2 Hazard Ranking Methodology

A variety of hazard ranking or chemical screening methods are available and some have been published in the peer-reviewed literature. These include:

- The Waste Minimisation Prioritization Tool (WMPT) and the Toxic Equivalency Potential (TEP) that were developed by the United States Environment Protection Agency (USEPA), described in Pennington and Bare (2001). The former examines screening in terms of key physical-chemical properties and includes measures for persistence, bioaccumulation and toxicity (PBT) that are calculated. Each PBT measure is scored to provide a single measure of relative concern. TEPs evaluate chemical fate, multi-pathway exposure and toxicity using a model-based approach. The latter was considered by the authors to represent a less subjective and thus improved approach. TEPs are based on a generic version of CalTox, an integrated multimedia fate, multi-pathway exposure and toxicity model initially developed for human health risk assessments.

- Pittinger et al. (2003) discussed approaches from a number of areas. These included:

  - the American Industrial Health Council (AIHC);

  - European Risk Ranking Method (EURAM);

  - US Chemical Hazard Evaluation for Management Strategies (CHEMS-1);

  - US Risk Screening Environmental Indicators;

  - US EPA Clusters Scoring System for particular tasks;

  - Exposure, Fate Assessment Screening Tool (E-FAST) used in US EPA's New Chemicals Program; and

  - the Organisation for Economic Co-operation and Development's (OECD's) "*Tools for R&D Screening*" which is part of the OECD's Chemical Risk Management Program.

  In all of these approaches the nature of the hazard, the specific scenario and exposure determinants tend to dictate the tools to be used.

- More recent approaches included the use of indoor air exposure data against air health guidelines to rank 267 chemicals to 31 chemicals posing hazards with nine chemicals eventually identified as priority pollutants (Logue et al., 2011) and an approach for a relative risk ranking of selected substances on the Canadian National Pollutant Release Inventory (Dunn, 2009).

- OECD (2001) published an initial approach to a harmonised integrated classification system for human health and environmental hazards of chemical substances and mixtures which was updated to a Globally Harmonised System of Classification and Labelling of Chemicals (GHS) in 2003, with updates in 2005, 2007 and then in 2009 (UN, 2009). These guidelines provide categorisation across ten toxicity parameters and provide specific guidance for separation into those categories based on available toxicological data. The approach ranks substances within the respective categories but not across the toxicological parameters.

- US EPA Design for the Environment (DfE). DfE focuses on the principles of green chemistry and applies these principles to work towards the replacement of hazardous chemicals by safer chemicals and considers a broader range of variables.

A recent open source document from the Clean Production Organisation (2009) considered a ranking approach for these principles with the objectives of achieving safer chemical use. This "*Green Screen for Safer Chemicals*" (Green Screen) provides an integration of data and categorisations from US EPA, European Union (EU), United Nations GHS, International Agency for Research on Cancer (IARC) and US National Toxicology Program (NTP) sources to establish Very High (VH), High (H), Moderate (M), and Low (L) categories. The basis of the evaluation is to produce an overall categorisation into four benchmark levels with Benchmark 4 reflecting a preferred safer chemical – a "green" objective. While the overall objectives differ somewhat from the objectives of this study the basis to the use of data reflects current approaches in hazard categorisation and includes toxicological parameters drawn from the UN GHS, IARC and other reputable sources. It also includes a consideration of endocrine disruptor potential and the physical hazards of being explosive and flammable. As such this approach to the hazard ranking has been utilised.

It should be noted that Green Screen includes an evaluation of persistence, bioaccumulation and aquatic toxicity (PBT). Rather than use the classification outlined in Green Screen the PBT analysis is treated separately in the ecotoxicological evaluations. This is considered appropriate as this evaluation considers a comprehensive evaluation looking at multiple parameters. In addition the classification of high, medium and low categories utilises more sensitive values for the cut off parameters and is therefore considered a more conservative assessment. The classification scheme does not use a Very High grouping with any chemical placed in the High group considered a COPC. The Very High grouping in Green Screen relates only to the PB assessment, as such this grouping has not been used in this assessment.

The parameters evaluated in Green Screen are:

- Bioaccumulation potential
- Persistence
- Aquatic Toxicity
- Acute toxicity (oral, dermal or inhalation)
- Corrosion/irritation of the skin or eye
- Sensitisation of the skin or respiratory system
- Carcinogenicity
- Developmental toxicity
- Mutagenicity/genotoxicity

- Reproductive toxicity
- Neurotoxicity
- Endocrine disruption
- Systemic toxicity/Organ effects
- Immune system effects
- Explosive potential
- Flammable potential.

Further discussion of these parameters is provided in the subsequent sections, including the threshold values used for each parameter.

2.2.1 Human Health Parameters

A description of each parameter is provided below, along with the threshold values for each parameter as presented in Table 1, Green Screen. The threshold values in Green Screen are drawn from the following sources:

- EU's recently enacted chemicals policy legislation (Registration, Evaluation and Authorization of Chemicals–REACH) (EU 2006);
- United Nations (2009) Globally Harmonized System of Classification and Labelling of Chemicals (GHS). Second revised edition. United Nations, New York and Geneva;
- The International Agency for Research on Cancer (IARC) monographs on Carcinogens, available at http://monographs.iarc.fr;
- US Environmental Protection Agency, Design for Environment Program. (USEPA DfE) 2005. Environmental Profiles of Chemical Flame-Retardant Alternatives for Low-Density Polyurethane Foam;
- US Department of Health and Human Services, Public Health Service, National Toxicology Program (US NTP). 2005. Report on Carcinogens, Eleventh Edition;
- State of California, Environmental Protection Agency, Office of Environmental Health Hazard Assessment. 2006. Chemicals Known to the State to Cause Cancer or Reproductive Toxicity;
- Japan Ministry of Environment. 1998. Endocrine Disrupting Chemicals Database, Table of Chemicals Suspected of Having Endocrine Disrupting Effects; and
- US Department of Labour Occupational Safety and Health Administration (OSHA) List of OSHA carcinogens, available at http://www.epa.gov/tri/chemical/carcinog.pdf.

2.2.1.1 Acute Toxicity

Acute toxicity refers to the occurrence of adverse effects following exposure to a single dose of a substance or multiple doses within a 24 hour period (OECD 2009). In toxicity studies acute effects are often characterised by lethality, commonly reported in lethal dose or concentration at which 50% of the animals tested die (LD50 or LC50). Non-lethal acute effects are sometimes included. Routes of administration commonly used are the oral, dermal and inhalation pathways.

The threshold values for acute toxicity are presented in Table 13.

Table 13: Acute toxicity (oral, dermal or inhalation) threshold values

High	Medium	Low
■ LD50 <50 mg/kg bodyweight (oral) ■ LD50 <200 mg/kg bodyweight (dermal) ■ LC50 <500 ppm (gas) ■ LC50 <2.0 mg/l (vapour) ■ LC50 <0.5 mg/l (dust or mist) ■ US EPA Extremely Hazardous Substance List ■ GHS Category 1 or 2	■ LD50 50-2000 mg/kg bodyweight (oral) ■ LD50 200-2000 mg/kg bodyweight (dermal) ■ LC50 500-5000 ppm (gas) ■ LC50 2-20 mg/l (vapour) ■ LC50 0.5-5 mg/l (dust or mist) ■ GHS Category 3 or 4	No basis for concern identified

2.2.1.2 Corrosion/Irritation of skin or eye

Skin corrosion is the production of irreversible damage to the skin namely, visible necrosis through the epidermis and into the dermis following the application of a substance for up to four hours (OECD, 2009). Corrosion is often indicated by ulcers and bleeding and after 14 days discolouration of the skin, alopecia and scars. Skin irritation is the production of reversible damage to the skin following application of a substance (OECD, 2009).

Serious eye damage (i.e. corrosion) is indicated by tissue damage of the eye or serious physical decay of vision following application of the anterior surface of the eye which is not fully reversible within 21 days (OECD, 2009). Eye irritation is indicated by changes in the eye following application of the anterior surface of the eye which is fully reversible within 21 days (OECD, 2009).

The threshold values for corrosion/Irritation of the skin or eye are presented in Table 14.

Table 14: Corrosion/Irritation of the skin or eye ranking threshold

High	Medium	Low
■ Evidence of irreversible effects in studies of human populations ■ Weight of evidence of irreversible effects in animal studies ■ GHS Category 1 (skin or eye)	■ Evidence of reversible effects in humans or animals ■ GHS Category 2 or 3 — skin irritation ■ GHS Category 2A or 2B — eye	No basis for concern identified

2.2.1.3 Sensitisation of skin or respiratory system

A respiratory sensitiser is a substance that will lead to hypersensitivity of the airways following inhalation of the substance. A skin sensitizer is a substance that will lead to an allergic response following skin contact (OECD 2009).

The threshold values for sensitisation of the skin or respiratory system are presented in Table 15.

Table 15: Sensitisation of the skin or respiratory system ranking threshold

High	Medium	Low
■ Evidence of adverse effects in humans; ■ Weight of evidence demonstrates potential for adverse effects in humans ■ GHS Category 1 – (skin or respiratory) ■ Positive responses in predictive Human Repeat ■ Insult Patch Tests (HRIPT) (skin)	■ Suggestive animal studies ■ Analog data ■ Chemical class known to produce toxicity	■ No basis for concern identified

2.2.1.4 Carcinogenicity

A carcinogen is a substance or a mixture which induces cancer or increases its incidence. The classification of a substance or mixture as a carcinogenic hazard is based on its inherent properties and does not provide information on the level of human cancer risk which the use of a substance may represent (OECD, 2009).

The threshold values for carcinogenicity are presented in Table 16.

Table 16: Carcinogenicity ranking thresholds

High	Medium	Low
■ Evidence of adverse effects in humans ■ Weight of evidence demonstrates potential for adverse effects in humans ■ NTP known or reasonably anticipated to be human carcinogen ■ OSHA carcinogen ■ California Prop 65 ■ IARC Group 1 or 2A ■ EU Category 1 or 2 ■ GHS Category 1A or 1B	■ Suggestive animal studies ■ Analog data ■ Chemical class known to produce toxicity ■ IARC Group 2B ■ EU Category 3 ■ GHS Category 2	■ No basis for concern identified ■ IARC Group 3 or 4

2.2.1.5 Developmental toxicity

Developmental toxicity refers to the *in utero* effects such as death, malformations, functional deficits and developmental delays (enHealth, 2004). It can also include delayed toxicity associated with epigenic effects during the sensitive phases of foetal development.

The threshold values for developmental toxicity are presented in Table 17.

Table 17: Developmental toxicity ranking threshold

High	Medium	Low
■ Evidence of adverse effects in humans ■ Weight of evidence demonstrates potential for adverse effects in humans ■ NTP Center for the Evaluation of Risks to Human Reproduction ■ California Prop 65	■ Suggestive animal studies; ■ Analog data ■ Chemical class known to produce toxicity	■ No basis for concern identified

2.2.1.6 Mutagenicity/Genotoxicity

Mutagenesis occurs when chemicals cause changes in the genetic material which can be transmitted during call division (Davis et al., 1994). The OECD (2009) indicate a mutagen is a chemical that may cause mutations in the germ cells of humans that can be transmitted to the progeny. A mutation is defined as a permanent change in the amount or structure of the genetic material in a cell. The more general terms genotoxic and genotoxicity apply to agents or processes which alter the structure, information content or segregation of DNA (OECD, 2009).

The threshold values for mutagenicity and genotoxicity are presented in Table 18.

Table 18: Mutagenicity/genotoxicity ranking thresholds

High	Medium	Low
■ Evidence of adverse effects in humans ■ Weight of evidence demonstrates potential for adverse effects in humans ■ EU Category 1 o r 2 ■ GHS Category 1A or 1B	■ Suggestive animal studies; ■ Analog data ■ Chemical class known to produce toxicity ■ EU Category 3 ■ GHS Category 2	■ No basis for concern identified

2.2.1.7 Reproductive toxicity

Reproductive toxicity includes adverse effects on sexual function and fertility in adult males and female as well as developmental toxicity in the offspring (OECD, 2009). This may include effects on mating behaviour, gonadal function, oestrous cycling, conception, implantation, parturification and lactation (Draft enHealth, 2010).

The threshold values for reproductive toxicology are presented in Table 19.

Table 19: Reproductive toxicity ranking thresholds

High	Medium	Low
■ Evidence of adverse effects in humans ■ Weight of evidence demonstrates potential for adverse effects in humans ■ NTP Centre for the Evaluation of Risks to Human Reproduction ■ California Prop 65 ■ EU Category 1 or 2 ■ GHS Category 1A or 1B	■ Suggestive animal studies; ■ Analog data ■ Chemical class known to produce toxicity ■ EU Category 3 ■ GHS Category 2	■ No basis for concern identified

2.2.1.8 Neurotoxicity

Neurotoxicity refers to any adverse effects on the structure or functional integrity of the developing or adult nervous system. Neurotoxic effects may involve a spectrum of biochemical, morphological, behavioural, and physiological abnormalities whose onset can vary from immediate to delayed following exposure to a toxic substance, and whose duration may be transient or persistent (US Department of Food and Drug Administration, 2000).

The threshold values for neurotoxicity are presented in Table 20.

Table 20: Neurotoxicity Ranking Thresholds

High	Medium	Low
■ Evidence of adverse effects in humans ■ Weight of evidence demonstrates potential for adverse effects in humans	■ Suggestive animal studies ■ Analog data ■ Chemical class known to produce toxicity	No basis for concern identified

2.2.1.9 Endocrine disruption

Endocrine disruptors are chemicals that may interfere with the body's endocrine system and produce adverse developmental, reproductive, neurological, and immune effects (OECD, 2009).

The threshold values for endocrine disruption are presented in Table 21.

Table 21: Endocrine Disruption Ranking Thresholds

High	Medium	Low
■ Evidence of adverse effects in humans ■ Weight of evidence demonstrates that mechanisms of action lead to adverse effects	■ Suggestive animal studies; ■ Analog data ■ Chemical class known to produce toxicity ■ EU Draft List - Category 1 or 2 ■ Japanese list	No basis for concern identified

2.2.1.10 Systemic toxicity/organ effects

This relates to substances that produce specific non- lethal organ toxicity arising either from a single or repeated dose. All significant health effects that can impair function, both reversible and irreversible, immediate and/or delayed are included (OECD, 2009).

The threshold values for systemic toxicity / organ effects are presented in Table 22.

Table 22: Systemic toxicity ranking thresholds

High	Medium	Low
■ Evidence of adverse effects in humans ■ Weight of evidence demonstrates potential for adverse effects in humans ■ GHS Category 1 — organ/systemic toxicity following single or repeated exposure	■ Suggestive animal studies; ■ Analog data ■ Chemical class known to produce toxicity ■ GHS Category 2 or 3 single exposure ■ Category 2 repeated exposure	No basis for concern identified

2.2.1.11 Immune system effects

The threshold values for immune system effects are presented in Table 23.

Table 23: Immune system ranking thresholds

High	Medium	Low
■ Evidence of adverse effects in humans ■ Weight of evidence demonstrates potential for adverse effects in humans	■ Suggestive animal studies ■ Analog data ■ Chemical class known to produce toxicity	No basis for concern identified

2.2.1.12 Explosive potential

An explosive substance is a solid or liquid which is capable by chemical reaction of producing gas at such high temperature and pressure and at such a speed as to cause damage to the surroundings (OECD, 2009).

The threshold values for explosive potential effects are presented in Table 24.

Table 24: Explosive potential threshold values

High	Medium	Low
■ GHS Category: Unstable Explosives or Divisions 1.1, 1.2 or 1.3	■ GHS Category: Divisions 1.4, 1.5	■ No basis for concern identified

2.2.1.13 Flammable Potential

A flammable liquid means a liquid having a flash point of not more than 93°C (OECD, 2009). A flammable solid is one which is readily combustible or may cause or contribute to fire through friction. A readily combustible solid is a powdered, granular or pasty substance which is dangerous if it can be ignited by brief contact with an ignition source and the flame spreads rapidly (OECD, 2009).

The threshold values for flammable potential effects are presented in Table 25.

Table 25: Flammable potential ranking thresholds

High	Medium	Low
■ GHS Category 1 - Flammable Gases ■ GHS Category 1 - Flammable Aerosols ■ GHS Category 1 or 2 — Flammable Liquids	■ GHS Category 2- Flammable Gases ■ GHS Category 2- Flammable Aerosols ■ GHS Category 3 or 4 — Flammable Liquids	No basis for concern identified

2.3 Human health toxicity ranking

2.3.1 Process of toxicity review

All chemicals considered are reviewed to determine if classified as "*hazardous*" or "*non-hazardous*" based on the NOHSC (2004) "*Approved Criteria for Classifying Hazardous Substances, 3rd Edition*". These classifications are based on a range of toxicological properties consistent with approaches used in hazard ranking and health risk assessment and are listed on the Safework Australia, Hazardous Substances Information System (HSIS). If chemicals are classified as non-hazardous due to no listing on HSIS no further review of human health toxicity is undertaken unless specific concerns were raised requiring further analysis. Limitations of the HSIS database are that the absence of a chemical may also be based on an absence of review although there are now some 900 substances on the HSIS database. Chemicals classified as hazardous are selected for review of human health toxicity information.

Toxicity information is collected from readily available human health toxicity data from the following online data bases:

- Safework Australia sources, specifically the Hazardous Substances Information System (HSIS)
- World Health Organisation sources such as International Program of Chemical Safety (IPCS) INCHEM, including International Chemical Assessment documents (CICADS) and Environmental Health Criteria (EHC) monographs
- United States sources such as:
  - United States National Medical Library of Medicine Toxicology (Toxnet) and Hazardous substances Data Bank (HSDB)
  - United States Environmental Protection Agency (US EPA) Integrated Risk Information System (IRIS)
  - Agency for Toxic Substances and Disease Registry (ASTDR) toxicological profiles
  - Risk Assessment Information System (RAIS).

If no information is available from these databases then the search is extended to access other sources of toxicity information with preference given to peer-reviewed data.

Toxicity information for each parameter is then categorised as High, Medium or Low concern according to the thresholds described in previous sections. The categories are numerically converted as follows:

- High = 3
- Moderate = 2
- Low = 1

The overall toxicity score for each chemical is generated by calculating the average based on the available data so that the scores are not biased by the amount of data for any one chemical, e.g. data on ten parameters, the summed total is divided by ten, data on four parameters, the summed total should be divided by 4, etc.The overall human health toxicity score is calculated to two significant figures, whereas the individual parameter scores represent whole numbers.

The scoring system is semi-quantitative in that scores are assigned to ranges for a particular parameter. The scores are largely assigned using some quantitative data and professional judgement following consideration of the guidance from the ranking thresholds specified for each parameter. There is no weighting applied for the severity of the adverse health effects.

2.4 Selection of human health COPC

From this assessment, chemicals identified as High and Moderate in the human health toxicity ranking according to the process outlined and where a score of 2.0 or greater is recorded are considered a COPC for human health. It should be noted that the selection of a chemical as a COPC does not indicate an unacceptable risk; rather it indicates that potential exposures to these chemicals should be evaluated in greater detail to test whether they might present an unacceptable risk.

As a qualifying comment it is important to note that adverse health effects are a reflection of intrinsic chemical or physical toxicity, the physico-chemical parameters of the substance concerned and the nature of the exposure setting and affected populations. It is not possible within a numerical ranking system to capture all possible exposure settings that may apply with product use and the subsequent potential chemical exposures. Subsequently qualitative comments have been provided for each of the ranked chemicals as concluding summary comments. In the case of those substances ranked in the >1.0 to <2.0 range these qualifying comments should be understood.

2.5 Combined PBT and human health COPC

The PBT analysis and the human health toxicity may be then considered together to provide an overall score to identify chemicals of high concern. The average of the PBT and human health scores are taken to provide an overall score. To remain consistent with the PBT analysis all chemicals with an overall score above 2.5 are considered of high concern.

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ATTACHMENT 2
Chemical Information Sheet – o,p-Toluenesulfonic acid/Xylenesulfonic acid mixture

Name	$_{O,P}$-Toluenesulfonic Acid/ Xylenesulfonic Acid Mixture
Synonyms	Benzenesulfonic acid, di-methyl-
CAS number	25321-41-9
Molecular formula	C8H10O3S1
Product name	$_{O,P}$- Toluenesulfonic Acid/Xylenesulfonic Acid Mixture

Physical Properties	Value	Reference
Phase/state	N/A	
Molecular weight	186.23	EPISUITE
Melting point	57°C (exp database)	EPISUITE
	107.58 °C (estimated)	EPISUITE
Boiling point	343.82 °C (estimated)	EPISUITE
Density/ specific gravity	N/A	
Vapour pressure	3.96 x10^{-6} mm Hg at 25°C (estimated from modified Grain method)	EPISUITE
Solubility	5.894 x10^{4} mg/L at 25°C (estimated from Log K_{ow})	EPISUITE EPISUITE
	1x10^{6} mg/L (estimated from fragments)	
Henrys law constant	3.06 x10^{-9} atm-m^3/mole (estimated from Bond method)	EPISUITE
	1.646 x 10^{-11} atm-m^3/mole (estimated from VP/Wsol)	EPISUITE
Log organic carbon partition coefficient (log Koc)	1.420 (estimated from MCI method)	EPISUITE
	0.886 (estimated from K_{ow} method)	EPISUITE
Log octanol-water partition coefficient (log Kow)	-0.07 (KOWWIN est)	EPISUITE

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation	N/A	
Aerobic BOD	N/A	
Anaerobic BOD	N/A	
Ready Biodegradability Prediction	No	EPISUITE
Fugacity		
Air %	0.0618	EPISUITE
Water %	25.2	EPISUITE
Soil %	74.6	EPISUITE
Sediment %	0.0739	EPISUITE
Bioconcentration factor (BCF)	3.162 L/kg	EPISUITE
Biotransformation half-life	0.03481 days	EPISUITE

Notes: 1 EPI Suite™ v4.0, United States Environmental Protection Agency.

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	

USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	
Estimated acute toxicity data				
Data not available				
Estimated chronic toxicity data				
Data not available				

Media Type: freshwater

IMBL: immobile

ABND: abundance

ITX : Intoxicated

MOR/MORT: Mortality

POP: Population

REP: Reproduction

PROG : Progeny Counts

SEXR : Sex ratio

FCND: Fecundity

HTCH : Hatch

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.
ECOSAR US Environmental Protection Agency ECOSAR Class Program.

NA = not assessed.

ATTACHMENT 3
Chemical Information Sheet - p toluene sulfonic acid

Name	p-Toluenesulfonic Acid
Synonyms	p-Methylbenzenesulfonic acid, 4-Methylbenzenesulfonic acid, Tosic acid
CAS number	104-15-4
Molecular formula	C7H8O3S1
Product name	p-Toluenesulfonic Acid

Physical Properties	Value	Reference
Phase/state	Monoclinic leaflets or prisms	HSDB 2012
Molecular weight	172.20	HSDB 2012
Melting point	106-107 °C anhydrous	HSDB 2012
	104.5 °C (experimental)	EPISUITE
	101.76 °C (estimated)	EPISUITE
Boiling point	140°C at 20 mm Hg (experimental)	HSDB 2012
	331.69 (estimated)	EPISUITE
Density/ specific gravity		
Vapour pressure	$2.7x10^{-6}$ mm Hg at 25°C (estimated)	HSDB 2012
	$2.9x10^{-6}$ mm Hg at 25°C (estimated modified Grain method)	EPISUITE
Solubility	620,000 mg/L (experimental)	HSDB 2012
	202,300 mg/L (estimated)	EPISUITE
Henrys law constant	$2.78x10^{-9}$ atm-m^3/mol (estimated)	HSDB 2012
	3.248 $x10^{-12}$ atm-m^3/mol (estimated via VP/Wsol)	EPISUITE
Log organic carbon partition coefficient (log Koc)	1.206 (estimated MCI method)	EPISUITE
	0.582 (estimated Kow method)	EPISUITE
Log octanol-water partition coefficient (log Kow)	-0.62 (estimated)	HSDB 2012

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation	N/A	
Aerobic BOD	N/A	
Anaerobic BOD	N/A	
Ready Biodegradability Prediction	No	EPISUITE
Fugacity		
Air %	0.0596	EPISUITE
Water %	28	EPISUITE
Soil %	71.9	EPISUITE
Sediment %	0.0701	EPISUITE
Bioconcentration factor (BCF)	0.2 (estimated)	HSDB
	3.162 L/kg (estimated)	EPISUITE
Biotransformation half-life	0.03485 days	EPISUITE

Notes: 1 EPI Suite™ v4.0, United States Environmental Protection Agency.

3. Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line 5 June 2012

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Estimated acute toxicity data							
Common name	**Species name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Concentration (g/m^3)**	**Reference**
Guppy	Poecilia reticulate	NR	Accumulation	Accumulation General	0-9 days	2.91	ECOTOX

Estimated chronic toxicity data
Data not available

Media Type: freshwater

IMBL: immobile

ABND: abundance

ITX : Intoxicated

MOR/MORT: Mortality

POP: Population

REP: Reproduction

PROG : Progeny Counts

SEXR : Sex ratio

FCND: Fecundity

HTCH : Hatch

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

ECOTOX, US Environmental Protection Agency ECOTOX database contained over 500 test results, data selected as LC50 and NOEC from common species used for toxicity testing with non-physiological end points; data presented as [1] geometric mean (range) N=3; [2] geometric mean (range) N=11; [3] geometric mean (range) N=5; [4] geometric mean (range) N=7.
ECOSAR US Environmental Protection Agency ECOSAR Class Program.

NA = not assessed.

ATTACHMENT 4
Chemical Information Sheet - Hexamethylenetetramine

Name	Hexamethylenetetramine
Synonyms	Hexamine; Methenamine; Urotropine; 1,3,5,7-tetraazaadamantane, Formin, Aminoform
CAS number	100-97-0
Molecular formula	C6H12N4
Product name	Hexamethylenetetramine

Physical Properties	Value	Reference
Phase/state	White, crystalline powder or colorless, lustrous crystals	3
Molecular weight	140.19 g/mol	3
Melting point	65.06 °C	1
	>250 °C	2
	280°C sublimes	4
Boiling point	208.59 °C	1
	sublimes	2
Density/ specific gravity	1.331 at -5°C	3
	1.7 at 25°C	3
Vapour pressure	4.0X10-3 mmHg at 25 °C (experimental)	3
Solubility	76.7 g/m^3 at 25°C	1
	1g soluble in 1.5ml water, 12.5ml alcohol, 320ml ether, 10ml chloroform	3
Henrys law constant	1.6X10-9 atm m^3/mole (derived)	3
Log organic carbon partition coefficient (log Koc)	1.74 (based on Koc 55 (SRC))	3
Log octanol-water partition coefficient (log Kow)	-4.15 (estimated)	3

Persistence/ Bioaccumulation	Value	Reference
Aquatic biodegradation		
Aerobic BOD	In a 5-day BOD test using a sewage seed, methenamine reached 2.02% of its theoretical BOD	3
Anaerobic BOD	No data found	
Biowin1 (Linear Model Prediction)	-0.1402	1 estimate
Biowin2 (Non-Linear Model Prediction)	0.0004	1 estimate
Biowin3 (Ultimate Biodegradation Timeframe)	months	1 estimate
Biowin4 (Primary Biodegradation Timeframe)	Weeks-months	1 estimate
Biowin5 (MITI Linear Model Prediction)	0.0741	1 estimate
Biowin6 (MITI Non-Linear Model Prediction)	0.0304	1 estimate
Biowin7 (Anaerobic Model Prediction)	-4.1834	1 estimate
Ready Biodegradability Prediction	No	1 estimate
Fugacity		
Air %	0.0102	1 estimate
Water %	39.5	1 estimate
Soil %	60.4	1 estimate
Sediment %	0.0957	1 estimate

Bioconcentration factor (BCF)	3.162 L/kg	1 estimate
Biotransformation half-life	8.324E-06 days	1 estimate
Soil adsorption coefficient	10L/kg	MCI method, 1 estimate
	0.02334 L/kg	Kow method, 1 estimate

Notes: 1 EPI Suite™ v4.0, United States Environmental Protection Agency.

2 CRC Handbook of Chemistry and Physics 1913 – 1995 75th Edition, 1994 CRC Press Inc

3. Hazardous Substances Data Bank (HSDB) National library of Medicine accessed on line 1 February 2012

4. Merck

NA - not available

Aquatic toxicity guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ANZECC	2000	Aquatic toxicity	NA	
USEPA	2006	Aquatic toxicity	NA	
Other water quality guidelines				
Guideline	**Year**	**Type**	**Value (g/m^3)**	**Notes**
ADWG	2004	Drinking water	NA	
NZDWS	2008	Drinking water	NA	
WHO	2006	Drinking water	NA	
USEPA	2006	Human Health	NA	
IARC	2006	Carcinogen risk	NA	
ANZECC	2000	Stock water	NA	

Estimated acute toxicity data							
Common name	**Species name**	**Endpoint**	**Effect**	**Effect measure**	**Test time (days)**	**Concentration (g/m^3)**	**Reference**
Fish		LC50				49800	ECOSAR
Water Flea	Daphnia magna	EC50*	ITX	IMBL	1	35589000	ECOTOX
Water Flea	Daphnia magna	EC50*	ITX	IMBL	2	29868000	ECOTOX
Fathead Minnow	Pimephales promelas	LC50	MOR	MORT	4	44600000	ECOTOX
Minnow,Carp Family	Cyprinidae	NR-LETH	MOR	MORT	3	200000	ECOTOX
Estimated chronic toxicity data							
Data not available							

Notes: ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council.

USEPA, 2006: National recommended water quality criteria: 2006. EPA-822-R-02-047. Office of Water and Office of Science and Technology, United States Environmental Protection Agency.

ADWG, 2004: Australian drinking water guidelines . Endorsed by NHMRC 10 – 11 April 2003. National Health and Medical Research Council, Natural Resource Management Ministerial Council.

NZDWS, 2008: Drinking-water standards for New Zealand 2005 (Revised 2008). Ministry of Health, Wellington.

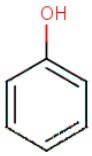
WHO, 2006: Guidelines for Drinking-water Quality 2006.

IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation. Classification: Group 1: Carcinogenic to humans; Group 2A: Probably carcinogenic to humans; Group 2B: Possibly carcinogenic to humans; Group 3: Not classifiable as to carcinogenicity to humans; Group 4: Probably not carcinogenic to humans.

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ECOSAR US Environmental Protection Agency ECOSAR Class Program.

NA = not assessed.

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Name	Phenol
Synonyms	Numerous synonyms including, benzenol, carbolic acid, hydroxybenzene, monohydroxybenzene, monophenol, oxybenzene, phenic acid, phenyl hydrate, phenyl hydroxide, phenylic acid, phylic alcohol
CAS number	108-95-2
Molecular formula	C_6H_6O
Molecular Structure	

Overview	References
Phenol is used ubiquitously and can be found in industrial, professional and consumer products. It is used as a general disinfectant and antiseptic, for the manufacture of colourless or light coloured artificial resins, in medical and industrial compounds and dyes and as a reagent in chemical analysis. Phenol is bactericidal in concentrations above 1% and fungicidal above 1.3%. Phenol is released into the environment by wood stoves, vehicle exhaust and other combustion processes. It is also naturally produced in decaying organic matter. Phenol in its crystalline form is colourless to light pink. It has a sweet and acrid odour and a sweet and sharp burning taste in its natural form (crystals). Phenol is caustic both as crystals and in solution.	1

Human Health Toxicity Summary	Reference
Inhalation Mortality was observed in human babies exposed to phenol via inhalation when it was used as a cleaner and disinfectant in nurseries. The cause of death was hyper-bilirubinaemia (jaundice). Other symptoms in humans exposed via inhalation include pulmonary irritation and oedema, coughing, stridor and aromatic odour of the breath. In animal species, inhalation has often resulted in stimulation of the central nervous system (CNS), severe CNS depression, hyperaemia (increased blood flow) of the lungs, bronchopneumonia, purulent bronchitis and hyperplasia of the peri-bronchial tissues. Guinea pigs exposed to concentrations up to 50 ppm for 20 days presented signs of toxicity in post-mortem examination of the lung, heart, liver and kidneys. Rats exposed to 25 ppm continuously for 15 days showed signs of neurological impairment including muscle twitching, disturbed walking rhythm and posture	1

although these symptoms were reversible on cessation of exposure.	
Irritancy The substance is irritating to the eyes and the skin. In humans, dermal exposure can result in exfoliation, cauterization and discolouration of the skin. Eye exposure may result in complete recovery, blindness and loss of an eye. In animals, dermal exposure has resulted in eczema, inflammation, discolouration, necrosis, sloughing and gangrene and exposure of the eyes has caused irritation, visual effects and glaucoma in some species. No signs of increased sensitivity, after prolonged or repeated exposures was reported in human or animal studies. Oral ingestion in humans and animals can result in muco-cutaneous and gastrointestinal corrosions and necrosis and mouth sores.	1
Carcinogenicity Phenol has not been reported by IARC or US EPA to have carcinogenic effects on humans or research animals.	1
Developmental In developmental studies with rats and mice, phenol reduced litter survival in rats at a concentration of 5000 ppm. In mice it was found to not be a developmental toxicant, except perhaps at maternally toxic concentrations.	1
Mutagenicity/genotoxicity No evidence of mutagenicity/genotoxicity has been reported for humans. In animal studies however exposure has resulted in induction of skin tumours in mice and mutagenicity in Salmonella, *E. Coli* and Drosophila.	1
Systemic toxicity/Organ effects Effects noted in both human and animal studies have included muscle spasms, weak and rapid pulse, accelerated respiration, tachycardia, seizures, collapse, unconsciousness, renal, kidney and liver damage with failure and death. Ingestion in humans has resulted in mouth sores, vomiting, diarrhea, oral and gastric ulcers and dark urine. Systemic complaints from acute exposure include CNS stimulation and depression, seizures, coma, tachycardia, ventricular dysrhythmias, hypotension, hypothermia, metabolic acidosis, and acute tubular necrosis. Neurotoxic effects include damage to nerve cells resulting in vasometer centre depression, cardiac arrest, vascular failure, coma and death.	1

Toxicity Values	Value	Reference
Animal Studies	**LD50**	
Rat oral	530 mg/kg	1
Rat oral	317 mg/kg	1, 2
Cat oral	100 mg/kg	1
Dog oral	500 mg/kg	1
Mouse oral	270 mg/kg	1, 2
Mouse inhalation	177 mg/kg	2
Mouse intra-peritoneal	180 mg/kg	2
Mouse subcutaneous	344 mg/kg	2
Rat dermal	669 mg/kg	1, 2
Rabbit dermal	850 mg/kg	1
Rabbit skin	630 mg/kg	2
Rat subcutaneous	460 mg/kg	1, 2
Rat inhalation	316 mg/kg	2
Rat intra-peritoneal	127 mg/kg	2
Mouse intravenous	112 mg/kg	1, 2

Footnotes:
LD50 – lethal dose for 50 % of experimental population

Human Health Toxicity Ranking		
	Hazard Category	**Number**
Carcinogenicity	L	1
Mutagenicity/genotoxicity	M	2
Reproductive toxicity	No data	-

Developmental toxicity	M	2
Endocrine disruption	No data	-
Neurotoxicity	No data	-
Acute toxicity (oral, dermal or inhalation)	M	2
Corrosion/irritation of the skin or eye	H	3
Sensitisation of the skin or respiratory system	L	1
Immune system effects	No data	-
Systemic toxicity/Organ effects	H	3
Explosive potential	H	3
Flammable potential	H	3
Sum		**20**
Number of points		**9**
Toxicity Score		**2.2**

Concluding Summary Comments

Phenol in its pure form exhibits a range of toxicity which is predominantly associated with acute exposure. Phenol is irritant and corrosive with a degree of volatility that warrants evaluation of atmospheric exposures. The latter may be flammable and explosive thus compounding the risks associated with chemical effects. All pathways require evaluation with an emphasis on inhalation and dermal exposures due to the potent necrotic action on skin, mucous membranes and respiratory tract. While these effects are based on the pure substance in the hydraulic fracturing scenario the phenol is a component of a granular (phenol-formaldehyde) resin with a “mild odour” with the latter representing emissions from the solid form of the volatile components – both phenol and formaldehyde. Residual phenol concentrations are reported as less than 1.5%. Taking this information into consideration the phenol represents a low order of concern relative to the moderate to high level of concern from the hazard ranking. This, however, requires evaluation in terms of mass exposure, i.e. where there are large masses or stockpiles of the resin in confined or enclosed environments or where a large-scale spill scenario occurs. These occupational and environmental settings would then require appropriate risk management measures to mitigate exposures.

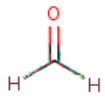
References and Notes

1. HSDB (2010) Phenol. Hazardous Substances DataBank . Toxicology Data Network (TOXNET). cAvailable at http://toxnet.nlm.nih.gov/cgi-bin/sis/search. [Accessed 16 June 2012].
2. ChemIDPlus (2012) Phenol. ChemIDPlus database. Toxicology Data Network (TOXNET) Available at www.toxnet.nlm.nih.gov/cgi-bin/sis/search. [Accessed 12 June 2012].

NA No information available

Created by:	NLC	23/04/2012
Reviewed and Edited by:	LT	30/06/2012

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Name	Formaldehyde
Synonyms	Numerous synonyms including, formalin, formic acid, karsan, lysoform, methyl aldehyde, methylene oxide, oxomethane and paraform.
CAS number	50-00-0
Molecular formula	CH_2O
Molecular Structure	

Overview	References
Formaldehyde can be found in industrial, professional and consumer products. Formaldehyde has many uses including as a pesticide, in histological labs, as a germicide, textile finish, preservative, stabilizer, disinfectant and antibacterial food additive. It is also used in the production of resins, wood products, plastics, fertilizers and foam insulation. Formaldehyde is a nearly colourless gas with a pungent suffocating odour.	1, 2

Human Health Toxicity Summary	Reference
Inhalation In both human and animal studies, effects following inhalation have included irritation of the throat and respiratory tract with resultant cough, chest tightness and wheezing. Other symptoms include headaches, weakness and heart palpitations.	2
Irritancy/Hypersensitivity Formaldehyde is irritating to the eyes, skin, respiratory and gastrointestinal tracts. Symptoms include conjunctivitis and corneal burns, skin discoloration, dermatitis and increased sensitization, burning in the mouth and throat, nausea and vomiting. Formaldehyde is a respiratory sensitiser.	2
Carcinogenicity There is sufficient evidence in humans and experimental animals for the carcinogenicity of **formaldehyde**. **Formaldehyde** is considered carcinogenic to humans (Group 1) by the IARC (International Agency for Research on Cancer) and a probable human carcinogen by the US EPA (United States Environmental Protection Agency - Group B1). These findings are based on human data from nine studies that show statistically significant associations between site-specific respiratory neoplasms and exposure to **formaldehyde** or **formaldehyde**-containing products. An increased incidence of nasal squamous cell carcinomas was observed in long-term inhalation studies in rats and in mice. The classification is supported by in vitro genotoxicity data and **formaldehyde's** structural relationships to other carcinogenic aldehydes such as acetaldehyde.	2
Systemic Local effects on the eyes and skin include conjunctivitis, corneal burns, brownish discoloration of skin, dermatitis, hives, and pustule-vesicular eruption. Effects from inhalation exposure include rhinitis and anosmia (loss of sense of smell), pharyngitis, laryngospasm, tracheitis and bronchitis, pulmonary eodema, cough, constriction in the chest, dypsnea (difficulty in breathing), headache, weakness, palpitation (rapid heartbeat), gastro-enteritis (inflammation of the stomach and intestines). Following ingestion, effects include burning in mouth and eosophagus, nausea and vomiting, abdominal pain, diarrhea, vertigo (dizziness), unconsciousness, jaundice, albuminuria, hematuria, anuria, acidosis, convulsions.	2

F**ormaldehyde once absorbed,** depresses the CNS and symptoms equivalent to alcohol intoxication are noted, consisting of vertigo, depression, and coma. Rarely convulsions are observed.	
Reproductive/Developmental An investigation of reproductive function in female workers exposed to **formaldehyde** in the garment industry revealed increased incidence of menstrual disorders, inflammatory disease of the reproductive tract, sterility, anaemia, and low birth weights among offspring. In animal studies no side effects were noted in rat embryos following exposure to formaldehyde.	2
Mutagenicity/genotoxicity **Formaldehyde is a genotoxin as it has been observed to** induce gene mutation in bacteria, fungi, yeast, and *Drosophila* larvae as well as in cultured rodent and human cells. In part, these mutations appear to be the consequence of DNA damage. A second mechanism by which **formaldehyde** may damage the genome is considered to be through inhibition of DNA repair.	2
Systemic toxicity/Organ effects **Exposure to formaldehyde has resulted in liver toxicity in a number of animal studies. Limited information was available on organ effects in humans.**	2

Toxicity Values	Value	Reference
Animal Studies	**LD50**	
Mouse intra-peritoneal	1548 mg/kg	3
Mouse oral	1590-5627 mg/kg	2, 3
Mouse inhalation	3907 mg/kg/6 hours	2
Rabbit skin	>1700 mg/kg	3
Rabbit dermal	43 mg/kg	2
Rat inhalation	5000-6350 mg/kg/4 hours	2, 3
Rat intra-peritoneal	2459 mg/kg	3
Rat oral	3523-8600 mg/kg	2, 3
Rat subcutaneous	1700 mg/kg	3

Footnotes:
LD50 – lethal dose for 50 % of experimental population

Human Health Toxicity Ranking		
	Hazard Category	**Number**
Carcinogenicity	H	3
Mutagenicity/genotoxicity	H	3
Reproductive toxicity	H	3
Developmental toxicity	L	1
Endocrine disruption	No data	-
Neurotoxicity	H	3
Acute toxicity (oral, dermal or inhalation)	H	3
Corrosion/irritation of the skin or eye	H	3
Sensitisation of the skin or respiratory system	H	3
Immune system effects	No data	-
Systemic toxicity/Organ effects	M	2
Explosive potential	H	3
Flammable potential	H	3
Sum		**30**
Number of points		11
Toxicity Score		**2.7**

Concluding Summary Comments

Formaldehyde in its pure form has been associated with a range of acute and chronic hazards varying from the ability to produce nasal carcinomas to local and systemic effects over all exposure pathways with an emphasis on the inhalation pathway. Its volatility may result in elevated atmospheric concentrations which if confined could result in eye, nose and throat irritation and hypersensitivity responses. The latter are of particular concern due to the respiratory sensitising nature of formaldehyde that may then result in adverse effects at markedly low atmospheric concentrations. This, combined with its flammable and explosive nature indicated that pure formaldehyde is a substance of significant health concern and hazard warranting attention and evaluation of any potential exposures.

In the current hydraulic fracturing scenario this substance has been reviewed on the basis of a monomer within a polymerisation reaction that yields a phenol-formaldehyde resin. This resin subsequently coats a cellulose substrate and has the appearance of a "brown, granular solid with a mild odour". The resultant residual formaldehyde concentrations are reported below 1% in the polymer. The resultant "mild odour" associated with the polymer would reflect off-gassing of the volatile residual monomers, including formaldehyde. While this does not necessarily reflect a serious hazard concern compared with the use of the pure substance, caution is required where occupational exposures may result due to the presence of large quantities of the polymer, particularly in confined settings where atmospheric concentrations may be elevated. On an equivalent basis large scale accidental release of the polymer in environmental settings may result in short-term-exposures to sensitive subgroups such as asthmatics and this hazard should be recognised. Dermal and inhalation pathways are the critical pathways with the irritant respiratory sensitising properties a key determinant.

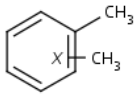
References and Notes

1. ATSDR (2012) Toxicological Profile for Formaldehyde. Agency for Toxic Substance and Disease Registry , US Department of Health and Human Services. Available at www.atsdr.cdc.gov/toxfaq.html. [Accessed 16 June 2012].
2. HSDB (2010) Formaldehyde. Hazardous Substances DataBank . Toxicology Data Network (TOXNET). cAvailable at http://toxnet.nlm.nih.gov/cgi-bin/sis/search. [Accessed 16 June 2012].
3. ChemIDPlus (2012) Formaldehyde. ChemIDPlus database. Toxicology Data Network (TOXNET) Available at www.toxnet.nlm.nih.gov/cgi-bin/sis/search. [Accessed 12 June 2012].

NA No information available

Created by:	NLC	16/06/2012
Reviewed and edited by:	LT	29/06/2012

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Name	Xylene
Synonyms	Numerous synonyms including, benzene dimethyl, dimethylbenzene, kyslen, methyl toluene, xylenen, xylol, xylole.
CAS number	1330-20-7
Molecular formula	C_8H_{10}
Molecular Structure	

Overview	References
Xylene can be found in industrial, professional and consumer products. Xylene has many uses including as an aquatic herbicide, a pesticide, in histological labs, in the manufacture of fibres, dyes, resins, paints, coatings/varnishes and inks. It is also added to gasoline to improve octane ratings. Xylene is a clear colourless liquid with a distinctive sweet smell.	1, 2

Human Health Toxicity Summary	Reference
Inhalation In both human and animal inhalation studies, effects have included irritation of the throat and respiratory tract. Central nervous system effects in both animals and humans are also common at high concentrations (systemic effects).	1, 2
Irritant Xylene is irritating to the eyes of both humans and animals. In mild cases it can cause slight irritation and redness but at higher concentrations and/or longer exposure durations, conjunctivitis and eye lesions have been reported. Multiple exposures to xylene may lead to effects on the skin in humans including flaking to moderate dermatitis, rashes, irritation, dryness and cracking.	2
Carcinogenicity IARC report that there is inadequate evidence for the carcinogenicity of xylene in humans. There is evidence suggesting lack of carcinogenicity in experimental animals and therefore not classifiable as to its carcinogenicity to humans.	2

Systemic General human health effects include central nervous system effects such as dizziness, headaches, short term memory loss, decreases in reaction time, confusion, slurred speech, tremors, and loss of consciousness. Other effects include eye, skin and respiratory tract irritation and vomiting. Animal studies have reported laboured breathing and pulmonary inflammation, congestion of cells in the liver, spleen and kidneys, decreased white blood cell counts, and weight loss. Most of these effects have occurred at high exposure levels.	2
Developmental No development effects were observed in humans exposed to xylene. Studies in hamsters have reported decreased foetal size and bodyweight and an increased incidence of prenatal deaths following exposure to xylene. Chickens exposed *in ovo* had increased incidences of malformations. In rats, studies have observed an increased incidence of bone retardation and extra ribs, and increased effects on the brain, liver and heart.	2
Mutagenicity/genotoxicity There is no indication based on available reported research and case studies that xylene has genotoxic effects on humans or animals.	2
Systemic toxicity/Organ effects **The critical target organ following xylene exposure to high concentrations in animals is the central nervous system and to a lesser extent the liver, kidneys and spleen. Most of the effects observed were reversible following cessation of exposure.**	1, 2

Toxicity Values	Value	Reference
Animal Studies	**LD50**	
Mouse intra-peritoneal	1548 mg/kg	3
Mouse oral	1590-5627 mg/kg	2, 3
Mouse inhalation	3907 mg/kg/6 hours	2
Rabbit skin	>1700 mg/kg	3
Rabbit dermal	43 mg/kg	2
Rat inhalation	5000-6350 mg/kg/4 hours	2, 3
Rat intra-peritoneal	2459 mg/kg	3
Rat oral	3523-8600 mg/kg	2, 3
Rat subcutaneous	1700 mg/kg	3

Footnotes:
LD50 – lethal dose for 50 % of experimental population

Human Health Toxicity Ranking		
	Hazard Category	**Number**
Carcinogenicity	No data	-
Mutagenicity/genotoxicity	L	1
Reproductive toxicity	No data	-
Developmental toxicity	M	2
Endocrine disruption	No data	-
Neurotoxicity	H	3
Acute toxicity (oral, dermal or inhalation)	H	3
Corrosion/irritation of the skin or eye	M	2
Sensitisation of the skin or respiratory system	No data	-
Immune system effects	No data	-
Systemic toxicity/Organ effects	H	3
Explosive potential	H	3
Flammable potential	H	3
Sum		**20**
Number of points		**8**
Toxicity Score		**2.5**

Concluding Summary Comments

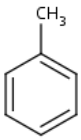
The hazard ranking of moderate to high concern reflects pure xylene and its respective isomers. This needs to be considered in light of the low potential for limited exposure associated with a residual level of less than 1% in the Mod Acid which comprises a very low percentage of the LiteProp 125. Once baked and cured it is unlikely to contain xylene levels of sufficient magnitude to warrant a health concern should small amounts of resin be used. If there are particular settings where large masses of resin are confined within enclosed areas where occupational exposures may result, consideration of residual off-gassing and suitable mitigation measures may be required.

References and Notes

1. ATSDR (2012) Toxicological Profile for Xylene. Agency for Toxic Substance and Disease Registry , US Department of Health and Human Services. Available at www.atsdr.cdc.gov/toxfaq.html. [Accessed 16 June 2012].
2. HSDB (2010) Xylene. Hazardous Substances DataBank . Toxicology Data Network (TOXNET). Available at http://toxnet.nlm.nih.gov/cgi-bin/sis/search. [Accessed 16 June 2012].
3. ChemIDPlus (2012) Xylene. ChemIDPlus database. Toxicology Data Network (TOXNET) Available at www.toxnet.nlm.nih.gov/cgi-bin/sis/search. [Accessed 12 June 2012].

NA No information available

Created by:	NLC	12/06/2012
Reviewed and edited by:	LT	02/07/2012

Name	Toluene
Synonyms	Numerous synonyms including, methacide, methylbenzene, methylbenzol, toluol, phenylmethane
CAS number	108-88-3
Molecular formula	C_7H_8
Molecular Structure	

Overview	References
Toluene can be found in a range of industrial, professional and consumer products. It occurs naturally in crude oil and in the tolu tree. Toluene is produced in the process of making gasoline and other fuels from crude oil and in the making of coke from coal. Toluene is used in making paints, paint thinners, fingernail polish, lacquers, explosives, dyes, adhesives, solvents, cosmetics, antifreeze, inks, rubber and in some printing and leather tanning processes. Toluene is a clear colourless liquid with a distinctive sweet smell. Toluene is highly flammable.	1, 2

Human Health Toxicity Summary	Reference
Inhalation Adverse inhalation effects in exposed humans are both time and concentration dependent. General effects include headaches, blurred vision, dizziness, anaesthesia, and with high level exposures, respiratory arrest. Sudden death among people who deliberately inhale toluene in other products has been observed to be a result of cardiac arrest. In one study of 2 children sniffing toluene containing glue, adverse effects included reduced appetite, nightmares, incoordination and loss of consciousness. A 27-year-old male developed cerebral and cerebellar atrophy over a period of five years of extensive glue sniffing. He also developed bilateral optic atrophy with blindness and severe hearing loss.	1 and 2
Irritant Toluene vapours irritate both the eyes and upper respiratory tract in humans and liquid toluene also irritates the eyes. If aspirated, coughing, gagging, distress, and rapidly developing pulmonary	2

oedema may result. If ingested, toluene causes vomiting, griping, diarrhoea, and depressed respiration. Kidney and liver damage may follow ingestion. Toluene has been shown to cause defatting of skin which can lead to dryness, fissuring and secondary infections.	
Carcinogenicity IARC report that there is inadequate evidence for the carcinogenicity of toluene in humans. There is evidence suggesting lack of carcinogenicity in experimental animals. Toluene is therefore considered by IARC to be not classifiable as to its carcinogenicity to humans. In an animal study exposing mouse skin to painting with toluene there was negative tumour development.	2
Systemic General health effects following human exposure include dizziness, headaches, sore throats, eye irritation and difficulty in sleeping. Systemic effects include growth retardation, liver and kidney damage and miscellaneous effects. High level exposure may lead to death. Epidemiological and clinical reports have recorded neurobehavioral effects such as activity and sleep changes, performance and learning impacts and electro-physiological effects. Studies of women exposed to solvents such as benzene, **toluene**, and xylene have shown menstrual disturbances, principally associated with abnormal bleeding. In animals exposed to toluene, effects have included muscle weakness (rats), reduced coordination and muscle tremors (puppies, kittens and calves), lung and spleen inflammation (dogs and goats) and mild tremors/CNS effects (dogs and cats).	2
Developmental/Reproductive/Teratogenicity Exposure to toluene via maternal spray paint or glue sniffing has been observed to lead to maternal complications including renal tubular acidosis, hypokalaemia, hypocalcaemia, cardiac arrhythmias, rhabdomyolysis, and premature labour. Premature **toluene** exposure leads to a characteristic pattern of anomalies similar to findings in infants exposed to alcohol in utero, consisting of an increased incidence of malformations, poor growth, and developmental delays. In other studies children born to mothers who abused toluene by inhalation during pregnancy had adverse effects including microcephaly, minor craniofacial and limb anomalies, central nervous system defects, attention disorders, developmental delay, learning disorders, and language deficits. The pregnancies of four of five women associated with gross **toluene** abuse (0.5 to 2 cans of spray paint/day for 6 months to 11 years) resulted in evidence of renal toxicity (as evidenced by severe renal tubular acidosis), foetal toxicity (manifested as intrauterine growth retardation), and teratogenicity (e.g. deformed external ears, ventricular septal defect). Women workers exposed to high air concentrations of **toluene** (50-150 ppm) appeared to have a higher incidence of spontaneous abortion than a similar group of women with no occupational exposure to **toluene**. The offspring of mice exposed to toluene had an increased incidence of soft palates. Fertile chicken eggs exposed to increasing doses of toluene had decreasing hatchability. There were no teratogenic effects in rats exposed to toluene via inhalation throughout gestation although there	2

was some growth retardation of the offspring.	
Mutagenicity/genotoxicity In experiments in vitro, toluene did not change the number of sister-chromatid exchanges or the number of chromosomal aberrations in human lymphocytes. In 32 male workers there was no significant difference from controls in the frequency of chromosome aberrations and sister chromatid exchanges following exposure to toluene. Toluene did not induce gene mutations in Salmonella typhimurium, however chromosomal aberrations were observed in the bone marrow cells of male albino rats after chronic inhalation exposure.	2
Systemic toxicity/Organ effects **The most significant effects following exposure to toluene is on the cardiovascular (heart and blood vessels) and nervous systems.** **In humans, toluene** abuse (exposure to 10,000 ppm) has been linked with kidney disease as evidenced by blood (haematuria), protein (proteinuria), albumin (albuminuria), and pus (pyuria) in the urine, accompanied by elevated serum creatinine, decreased urinary output, and metabolic and renal tubular acidosis. **Toluene** appears to produce reversible effects upon liver, renal, and nervous systems. The nervous system appears to be the most sensitive to the effects of **toluene** with high level **toluene** exposures producing in-coordination, ataxia, unconsciousness and eventually, death. Lower level acute exposures in people can produce dizziness, exhilaration and confusion.	1, 2

Toxicity Values	Value	Reference
Animal Studies	**LD50**	
Rat oral	636 mg/kg	3
Rat intravenous	1960 mg/kg	2, 3
Rat intraperitoneal	1332 mg/kg	2, 3
Rat inhalation	49 g/m^3/4 hours	3
Rabbit skin	14.1 mL/kg	2, 3
Mouse inhalation	400 mg/kg/24 hours	2, 3
Mouse intraperitoneal	115 mg/kg	2, 3

Mouse subcutaneous	2250 mg/kg	2, 3
Guinea Pig intraperitoneal	500 mg/kg	3

Footnotes:
LD50 – lethal dose for 50 % of experimental population

Human Health Toxicity Ranking		
	Hazard Category	**Number**
Carcinogenicity	No data	-
Mutagenicity/genotoxicity	L	1
Reproductive toxicity	H	3
Developmental toxicity	H	3
Endocrine disruption	No data	-
Neurotoxicity	H	3
Acute toxicity (oral, dermal or inhalation)	H	3
Corrosion/irritation of the skin or eye	M	2
Sensitisation of the skin or respiratory system	No data	-
Immune system effects	No data	-
Systemic toxicity/Organ effects	H	3
Explosive potential	H	3
Flammable potential	H	3
Sum		**24**
Number of points		**9**
Toxicity Score		**2.7**

Concluding Summary Comments

The hazard ranking of moderate to high concern is based on the pure substance and reflects a range of acute and chronic toxicities combined with flammable and explosive properties. This should be assessed against the low exposure potential associated with residual toluene in the Mod Acid used in the resin mixture. This represents less than 1% of a very low percentage of Mod Acid in the final LiteProp 125 mixture. As a consequence exposure to toluene from resin off-gassing is considered unlikely. Should there be large masses of resin within confined settings where the residual toluene composition is elevated risk mitigation measures may be required.

References and Notes

1. ATSDR (2012) Toxicological Profile for Toluene. Agency for Toxic Substance and Disease Registry , US Department of Health and Human Services. Available at www.atsdr.cdc.gov/toxfaq.html. [Accessed 16 June 2012].

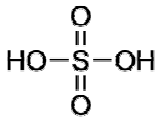
2. HSDB (2010) Toluene. Hazardous Substances DataBank . Toxicology Data Network (TOXNET). Available at http://toxnet.nlm.nih.gov/cgi-bin/sis/search. [Accessed 16 June 2012].

3. ChemIDPlus (2012) Toluene. ChemIDPlus database. Toxicology Data Network (TOXNET) Available at www.toxnet.nlm.nih.gov/cgi-bin/sis/search. [Accessed 12 June 2012].

NA No information available

Created by:	NLC	12/06/2012
Reviewed and edited by:	LT	03/07/2012

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Name	Sulphuric acid
Synonyms	Sulfuric acid, dihydrogen sulphate, oil of vitriol
CAS number	7664-93-9
Molecular formula	H_2SO_4
Molecular Structure	

Overview	References
Sulphuric acid is a strong acid used as a chemical ingredient in a range of industrial applications such as chemical synthesis and manufacture, electrical engineering, mining and metal extraction, and in cleaning supplies. Sulphuric acid occurs as a colourless and odourless dense viscous liquid with a high melting point. It is stable at room temperature and is corrosive and highly irritating.	1

Human Health Toxicity Summary	Reference
Inhalation Human and animal inhalation studies report that sulphuric acid is corrosive to the eyes, skin and mucous membranes but is not considered an allergen following skin contact by humans. Acute inhalation in humans causes a range of adverse respiratory effects. Reports of accidental human skin burns from acute and prolonged exposure are well documented. Inhalation LC50 values in the rat, mouse and rabbit are 0.375-0.425 mg/L, 0.600-0.850 mg/L and 1.470 mg/L-1.610 mg/L, respectively, depending on the exposure time. Guinea pigs appear to be the most sensitive to acute inhalation effects.	1,2
Irritant Sulphuric acid was irritating to the skin in concentrations over 10% in rabbit, guinea pig, and human studies. Results of eye irritation studies are inconsistent, reporting both irritating and severely irritating reactions. In animal studies oral exposure resulted in irritation/corrosion of the gastrointestinal tract. It is toxic to tissue, resulting in rapid destruction of tissue, causing severe burns. No data are available on the acute toxicity by other routes. It is not considered a skin allergen by contact.	2,3
Carcinogenicity IARC has concluded that "occupational exposure to strong inorganic mists containing **sulfuric acid** is carcinogenic for humans (Group 1)."	4

Developmental/Reproductive/Teratogenicity No information is available regarding developmental effects following exposure to sulphuric acid to humans or animals. No evidence of foetotoxicity or teratogenicity was seen in an inhalation study on mice and rabbits.	1, 2
Mutagenicity/genotoxicity **In vitro bacterial** genetic toxicity studies did not show toxic effects however in an *in vitro* non-bacterial test, chromosomal aberrations were observed and assumed to be caused by reduced pH (strong acid). There are no data from *in-vivo* mutagenicity studies available.	2
Systemic toxicity/Organ effects Lungs and tooth enamel may be affected by repeated or prolonged exposure to an aerosol of this substance. Repeated dose inhalation tests in rat, guinea pig, rabbit, monkey, hamster and dog studies consistently showed adverse effects such as altered respiratory function; histopathology of the larynx and changes in the clearance of particles from the tracheobronchial/respiratory system. Repeat dose toxicity via oral or dermal routes has not been investigated.	1,5

Toxicity Values	Value	Reference
Animal Studies	**LD50**	
Rat oral	2140 mg/kg	6

Footnotes:
LD50 – lethal dose for 50 % of experimental population

Human Health Toxicity Ranking		
	Hazard Category	**Number**
Carcinogenicity	H	3
Mutagenicity/genotoxicity	M	2
Reproductive toxicity	No data	-
Developmental toxicity	No data	-
Endocrine disruption	No data	-
Neurotoxicity	No data	-
Acute toxicity (oral, dermal or inhalation)	H	3
Corrosion/irritation of the skin or eye	H	3

Sensitisation of the skin or respiratory system	L	1
Immune system effects	No data	-
Systemic toxicity/Organ effects	H	3
Explosive potential	L	1
Flammable potential	L	1
Sum		**17**
Number of points		**8**
Toxicity Score		**2.1**

Concluding Summary Comments

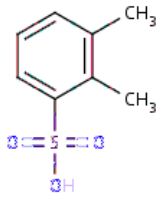
Sulphuric acid is a highly corrosive inorganic acid with a moderate to high toxicity hazard ranking reflecting its irritant and corrosive properties on biological matter. This reflects its pure or highly concentrated form which presents with elevated acute exposure concerns. In cases where it is used in dilute solutions or as an acid catalyst in polymerisation reactions the level of hazard is significantly reduced as a consequence of markedly reduced corrosive potential.

References and Notes

1. NICNAS (2003) Existing Chemicals Information Sheet: Sulfuric Acid. Sydney, NSW.
2. OECD (2001); SIDS Initial Assessment Reports for Sulfuric Acid (CAS No: 7664-93-9). Available from, as of July 3, 2011: http://www.inchem.org/documents/sids/sids/7664939.pdf. [Accessed 04/07/2012]
3. Lewis, R.J. Sr (2004). *Sax's Dangerous Properties of Industrial Materials. 11th Edition*. Wiley-Interscience, Wiley & Sons, Inc. Hoboken, NJ. p. 3331.
4. IARC (1992). Occupational Exposures to Mists and vapours from Strong Inorganic Acids; and other Industrial Chemicals. Lyon, France. World Health Organizsation pp 336 (IARC Monographs on the Evaluation of Carcinogenic Risks to Humans Vol 54)
5. International Program on Chemical Safety/Commission of the European Communities (2000). *International Chemical Safety Card on Sulfuric Acid*.
6. ChemIDPlus - Toxicology Data Network (TOXNET) www.toxnet.nlm.nih.gov/cgi-bin/sis/search. Accessed 03 July 2012.

NA No information available

Created by:	MER	03/07/2012
Reviewed and edited by:	LT	04/07/2012

Name	o,p-toluenesulfonic acid/xylene sulfonic acid
Synonyms	Numerous synonyms including, benzenesulfonic acid, dimethyl; dimethylbenzenesulfonic acid; xylene sulfonic acid, sodium salt; conco sxs, cylophil sxs30, eltesol sx30, naxonate g, richonate sxs and stephanate x.
CAS number	25321-41-9
Molecular formula	$C_8H_{10}O_3S$
Molecular Structure	

Overview	References
The major use of xylene sulfonic acid is as a hydrotrope in liquid household detergents and shampoos. It is also used as a degreasing compound; in printing pastes in the textile industry and as an additive in glue in the leather industry. It is used in detergents, handwashing, dishwashing and laundering and in many cleaning products, where high concentrations of organic surfactants need to be kept in homogenous solution. The general structure of these compounds is a hydrocarbon chain linked to an ionic group (anionic or cationic) or an alcohol group (non-ionic). Soaps are salts of a fatty acid made by the action of alkali or natural fats and oils.	1

Human Health Toxicity Summary	Reference
Inhalation Aspiration can cause upper airway irritation, upper airway oedema and respiratory distress.	1
Irritancy/Hypersensitivity Detergents dissolve lipid layers in tissues and can produce local irritation and injury. The most common effects are skin, mucosal and eye irritation. Skin irritation, dryness and contact dermatitis can result from skin exposure. If eyes are exposed there can be momentary irritation although no permanent damage has been observed. Ingestion can cause gastric injury and oral, pharyngeal and oesophageal burns. Clinical signs observed in acute dermal exposure have included erythema with additional	1

desquamation of the treated skin. Sodium xylene sulfonate is not a skin irritant and there is no indication that hydrotopes cause skin sensitisation in animal studies. There are no reliable human data for sensitisation.	
Carcinogenicity There is inadequate evidence for the carcinogenicity of xylene sulfonic acid in humans and animals. Rats and mice exposed via their skin had no increased evidence of carcinogenic effects.	1
Systemic Clinical signs following acute oral toxicity studies included decreased activity, weakness, prostration, increased salivation, diarrhoea and anogenital staining. No significant systemic toxicity has been observed in dermal studies with test durations from 17 days up to 2 years and exposure doses from 6 to 2000 mg a.i./kg bodyweight by the dermal route. Local effects were reported in one of six dermal studies and a LOAEL for sodium xylene sulfonate calculated of 1300 mg a.i./kg bodyweight per day and NOAEL of 440 mg a.i./kg bodyweight per day.	3
Developmental/Reproductive There is no evidence from repeat dose animal studies to suggest hydrotropes have adverse effects on reproductive organs.	3
Mutagenicity/genotoxicity The hydrotropes category has been assessed for mutagenic potential in a variety of *in vivo* and *in vitro* assays and no positive results were observed in any of the studies.	3
Systemic toxicity/Organ effects Necropsy data from acute animal studies reported slight pulmonary inflammation, gastrointestinal inflammation and haemorrhage, mild liver changes, congestion of the liver, kidneys, adrenal glands and gastrointestinal tract and redness of the stomach mucosa in animals that died.	3

Toxicity Values	Value	Reference
Animal Studies	**LD50**	
Rat, oral (sodium salt, toluene)	6500 mg/kg bodyweight	3
Rat, oral (sodium salt, xylene)	7200 mg/kg bodyweight	3

	LC50	
Rabbit, dermal (sodium salt), toluene	> 557 mg/L (g/m^3)	3

Footnotes:
LD50 – lethal dose for 50 % of experimental population
LC50 – lethal concentration for 50% of experimental population

Human Health Toxicity Ranking		
	Hazard Category	**Number**
Carcinogenicity	L	1
Mutagenicity/genotoxicity	L	1
Reproductive toxicity	L	1
Developmental toxicity	No data	-
Endocrine disruption	No data	-
Neurotoxicity	No data	-
Acute toxicity (oral, dermal or inhalation)	L	1
Corrosion/irritation of the skin or eye	M	2
Sensitisation of the skin or respiratory system	L	1
Immune system effects	No data	-
Systemic toxicity/Organ effects	M	2
Explosive potential	L	1
Flammable potential	L	1
Sum		**11**
Number of points		**9**
Toxicity Score		**1.2**

Concluding Summary Comments

Hydrotropes in general exhibit a close consistency in their structure, use, fate and health and environmental effects. They exhibit a low order of acute and chronic toxicity and hazard to human health. Their major adverse health effects are limited to irritant effects on skin, eyes and mucous membranes and systemic effects at high doses. These reflect the pure or high concentration solutions. At final use concentrations in the order of a few percent the low hazard ranking is further reduced.

References and Notes

1. HSDB (2010) Dimethylbenzene sulfonic acid. Hazardous Substances DataBank . Toxicology Data Network (TOXNET). Available at http://toxnet.nlm.nih.gov/cgi-bin/sis/search. [Accessed 16 June 2012].
2. ChemIDPlus (2012) Dimethylbenzene sulfonic acid. ChemIDPlus database. Toxicology Data Network (TOXNET) Available at www.toxnet.nlm.nih.gov/cgi-bin/sis/search. [Accessed 12 June 2012].
3. UNEP (2005) Hydrotropes. CAS No. 1300-72-7; 12068-03-0; 26447-10-9; 28348-53-0; 32073-22-6; 37475-88-0. SIDS Initial Assessment Report for SIAM 21. United Nations Environment Program, Washington, D.C.

NA No information available

Created by:	NLC	12/06/2012
Reviewed and edited by:	LT	04/07/2012

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Santos

APPENDIX H.4 RADIOACTIVE TRACER AND PERFORATION BALL

MEMO

To: Andrew Stannard

From: Tom Biksey and Chris Bevan

CC: Nigel Goulding

Date: 2 July 2013

Re: **Radioactive Tracer and Perforation Ball Environmental Hazard and Dosage Assessment**

Introduction

Santos GLNG (Santos) is looking to trial and if successful, implement a new multi-zone hydraulic fracturing process called Just In Time Perforating (JITP). This process uses an Exxon Mobil patented process to streamline the entry and exit of equipment out of the casing, and saving considerable time in execution of hydraulic fracturing.

Unlike the approach currently used by Santos, which uses a coil tubing rig and associated zonal isolation packers (above and below the perforation intervals), the approach simply uses perforation balls to provide isolation. Identical to the methodology outlined in the hydraulic fracturing risk assessment, hydraulic fracturing is conducted from the bottom upwards; but unlike the previous methodology, the process is more streamlined with equipment not moved in and out of the casing hole. In the process, perforation balls are used to provide the required zone isolation in the previous perforated and hydraulically fractured intervals. The perforation balls are added at the end of each hydraulic fracturing injection cycle to temporarily clog the perforations, and to provide isolation so the interval above can be hydraulically fractured.

As a traditional packer is not utilised in this process, complete isolation between individual treatment stages is harder to achieve. Hence, it is important to utilise alternative tools to evaluate which seams have been treated, and to evaluate the effectiveness of the treatment itself and the treatment process. To facilitate the use of diagnostic techniques to assess the efficacy of the isolation and fracturing, radioactive tracers are added to the proppant to facilitate tracing of the placement of sands. These tracers are mix with the sand during the injection cycle with different tracers used for every stage.

The following products were evaluated in this assessment for environmental hazards and, in the case of the radioactive tracer, for determining the dosage from exposure. **Attachment 1** includes the Material Safety Data Sheets (MSDSs) for the radioactive tracers and one performance ball, and **Attachment 2** includes manufactures information on the radioactive tracers and the other performance ball.

Tom Biksey • 311 Crabapple Drive, Washington, PA 15301
724.884.6724 • tom.biksey@ehs-support.com • www.ehs-support.com

Product	Description
J144 Perforation Balls	Rubber-coated phenolic high temperature, high pressure ball sealers
Associated Research Development LTD (ARD) Thermoset polyurethane sealer balls	Polyurethane sealer balls
ProTechnics Iridium ZeroWash® bead tracers	Ceramic beads embedded with radionuclide Iridium-192 (as iridium oxide)
ProTechnics Scandium ZeroWash® bead tracers	Ceramic beads embedded with radionuclide Scandium-46 (as scandium oxide)
ProTechnics Antimony ZeroWash® bead tracers	Ceramic beads embedded with radionuclide Antimony-124 (as antimony oxide)

To address the proposed use of perforation balls and radioactive tracers in future hydraulic fracturing events, the following environmental hazard and dosage assessment was conducted to ensure compliance with Conditions of Santos' Gas Field Environmental Authorities (e.g., the Roma Shallow Gas Project Area East Environmental Authority PEN103814911).

As part of this assessment, EHS Support obtained additional physical, chemical and toxicological data on the radioactive tracers in accordance with the previous risk assessment methodologies, as detailed in the *GLNG Coal Seam Hydraulic Fracturing Quantitative Risk Assessment for Schlumberger Chemistry Report* (EHS Support, October 2012). In addition, radiation dose studies on potential human exposure to the radionuclide bead tracers were sought from the manufacturers and summarised in the dosage assessment as part of this study (see **Attachment 3**).

For the environmental hazard assessment, a PBT (persistence, bioaccumulative, toxic) assessment was conducted in accordance with the guidance developed by Department of the Environment, Water, Heritage, and the Arts (DEWHA, 2009). The PBT assessment is conducted because of specific concerns for substances that can be shown to persist for long periods in the environment, to bioaccumulate in food chains, and can give rise to toxic effects after a longer time and over a greater spatial scale than chemicals without these properties. These effects may be difficult to detect at an early stage because of long-term exposures at normally low concentration levels and long life-cycles of species at the top of the food chain.

PBT Assessment

Perforation Balls (J144)

J144 perforation balls are rubber-coated phenolic high temperature, high pressure ball sealers. These balls are covered with an oil and temperature resistant black rubber (composition not provided). Information from the supplier states that no degradation is expected at temperatures less than 375^{o}C.

Persistence

Biodegradation of the J144 perforation balls under operational and field conditions is unlikely. Elastomers, such as nitrile rubber, by their nature are generally not considered to be biodegradable (Boethling and Nabholz, 1997). Therefore, J144 perforation balls are considered persistent in the environment.

Bioaccumulation

J144 perforation balls are not bioavailable due to their physical size and resistance to biodegradation (Boethling and Nabholz, 1997). Thus, J144 perforation balls do not have the ability to bioaccumulate.

Toxicity

No toxicity studies have been conducted on J144. However, J144 perforation balls are insoluble in water, and their physical size and resistance to biodegradation limits their bioavailability (Boethling and Nabholz, 1997). Thus, J144 perforation balls are not expected to be harmful to aquatic organisms.

Conclusion

J144 perforation balls are not PBT substances. These balls are not expected to degrade or breakdown in the environment by microorganisms. Their size (similar to shotgun pellets) and their insolubility in water will prevent their uptake of these balls by aquatic organisms and thus J144 perforation balls will not be harmful to aquatic organisms. If ingested, J144 perforation balls will also not be toxic to humans.

ARD Thermoset Polyurethane Sealer Balls

Persistence

Biodegradation of ARD Thermoset polyurethane sealer balls under operational and field conditions are unlikely. Polymers, such as polyurethane, by their nature are generally not considered to be biodegradable (Boethling and Nabholz, 1997). Therefore, ARD Thermoset polyurethane sealer balls are considered persistent in the environment.

Bioaccumulation

ARD Thermoset polyurethane sealer balls are not bioavailable due to their physical size and their resistance to biodegradation (Boethling and Nabholz, 1997). Thus, ARD Thermoset polyurethane sealer balls do not have the ability to bioaccumulate.

Toxicity

No toxicity studies were found on ARD Thermoset plastic sealer balls. However, these balls are insoluble in water, and their physical size and resistance to biodegradation limits their bioavailability (Boethling and Nabholz, 1997). Thus, ARD Thermoset polyurethane sealer balls are not expected to be harmful to aquatic organisms.

Conclusion

ARD Thermoset polyurethane sealer balls are not PBT substances. These balls are not expected to degrade or breakdown in the environment by microorganisms. Their size (similar to shotgun pellets) and their insolubility in water will prevent their uptake of these balls by aquatic organisms and thus ARD polyurethane sealer balls will not be harmful to aquatic organisms. If ingested, these balls will also not be toxic to humans.

ZeroWash bead tracers

The ProTechnics ZeroWash® bead tracers are manufactured using a patented process that prevents the radioisotope from being washed off the proppant-emulating carrier particle (ProTechnics, undated). This process fixes non-water soluble metals in a ceramic matrix. After the resulting ceramic beads are kiln fired and sieved, they are activated by neutron bombardment in a nuclear reactor. In the United States, ProTechnics ZeroWash® bead tracers are approved for burial by the United States Nuclear Regulatory Commission (NRC).

The following ProTechnics ZeroWash® bead tracers were included in the PBT Assessment:

- Iridium ZeroWash® Bead Tracer (radionuclide: [Iridium-192] iridium oxide)
- Antimony ZeroWash® Bead Tracer (radionuclide: [Antimony-124] antimony oxide)
- Scandium ZeroWash® Bead Tracer (radionuclide: [Scandium-46] scandium oxide)

Persistence

The ceramic beads are not expected to biodegrade, and the metal oxides embedded in the ceramic beads are naturally occurring minerals so that biodegradation does not apply. Biodegradation also does not apply to the radionuclide component of these tracer beads. Nevertheless, the radionuclides are relatively short-lived: the half-lives of iridium-192 (Ir-192), antimony-124 (Sb-124) and scandium-46 (Sc-46) are 74, 60.2 and 83.8 days, respectively. Thus, ProTechnics ZeroWash® bead tracers are expected to be persistent in the environment based on its chemical composition, whereas the radioactivity associated with these bead tracers will not be persistent because of the short half-lives of the radionuclides.

Bioaccumulation

No specific data on bioaccumulation were located on the ProTechnics ZeroWash® bead tracers. These tracer beads, given their chemical composition and physico-chemical properties, are not expected to be bioavailable by any route of exposure. They are non-water soluble metals in a ceramic matrix bead, with mesh sizes of 40 to 70 (approximately 200 to 400 microns). Because these tracer beads are not bioavailable (not absorbed into the body), they do not have the ability to bioaccumulate.

Toxicity

Aquatic

ProTechnic ZeroWash® bead tracers are not expected to be toxic to aquatic organisms based on the chemical composition; these bead tracers are not likely to be bioavailable because of their insolubility and particle size. The radiation effects of the radioisotopes to aquatic organisms is unknown.

Mammalian

Exposure to these radionuclides can increase the risk for human cancer because of their high-energy gamma radiation. Gamma radiation is high-energy electromagnetic radiation emitted by certain radionuclides when their nuclei transition from a higher to a lower energy state. These rays have high energy and a short wave length. Gamma rays penetrate tissue farther than beta or alpha particles, but leave a lower concentration of ions in their path to potentially cause cell damage. Gamma rays are very similar to x-rays.

Conclusion

ProTechnic ZeroWash® bead tracers containing the radioisotopes Ir-192, Sb-124 and Sc-46 (as oxides) are not considered to be PBT substances. These bead tracers are not expected to degrade or breakdown in the environment by microorganisms. Their size (similar to sand) and their insolubility in water will prevent these bead tracers from being taken by aquatic organisms. For the radionuclides present in these beads, they have very short half-lives (less than 84 days), meaning that they will decay rapidly. Whereas the radioactivity from the bead tracers may pose a potential human health concern (discussed more fully below), the tracer bead itself is an inert particle and is not expected to be harmful to aquatic organisms, wildlife or humans.

Dosage Assessment

Perforation Balls (J144) and ARD Thermoset Polyurethane Sealer Balls

As the J144 Perforation Balls and ARD Thermoset Polyurethane Seal Balls are inert substances, no potential routes of exposures to the compounds within these materials were identified. The J144 Perforation Balls and ARD Thermoset Polyurethane Seal Balls have been determined to pose no potential adverse impacts on human health and the environment and introduce no additional environmental hazards of risks. On this basis, no further assessment of this product is recommended.

ProTechnic ZeroWash® Bead Tracers

ProTechnic ZeroWash® bead tracers consist of water-insoluble metals embedded in a ceramic matrix bead, with mesh sizes of 40 to 70 (ProTechnics, undated), which is approximately 200 to 400 microns in diameter. The metal is an integral part of the bead, and thus it cannot be washed off or stripped away. Furthermore, these bead tracers, unlike sand, are not easily crushed, having crush strength greater than 8,000 pounds per square inch (psi) (ProTechnics, undated). The metals are oxides of iridium, scandium and antimony, which are activated by neutron bombardment in a nuclear reactor, resulting in the formation of iridium-192 (Ir-192), scandium (Sc-46) and antimony-124 (Sb-124).

The ProTechnic ZeroWash® tracer beads are mixed in with injection proppant for the fracturing operations. It is not known what the concentration of the tracer isotope in the injection proppant will be, that is planned specifically for each of the fracturing operations. However, ProTechnic documents from the literature review have stated that the tracer isotope injection concentration in operations in the United States and in Canada is approximately 1.0 microcurie (μCi) of tracer per kilogram (kg) of proppant (ProTechnics, undated; ProTechnics (Canada), undated; Baker Botts LLP, 2012). Thus, a concentration of 1.0 μCi/kg proppant will be used for this dosage assessment. It will also be assumed that the concentration of tracer beads in the proppant does not change during the operation; therefore, the specific activity of the isotopes in the flowback will be 1.0 μCi/kg. The actual concentration of the tracer isotope will actually be less than 1.0 μCi/kg proppant because of radioactive decay (the half-lives of these radionuclides are less than 84 days). Because of the unique properties of ProTechnics ZeroWash® tracer beads, only the solid proppant in a flowback (not the fluid) are treated as though they contain radioactive material.

Potential Health Effects

The risk for human cancer can increase through human exposure to Ir-192, Sc-46, or Sb-124 due to their high-energy gamma radiation. Gamma radiation is high-energy electromagnetic radiation emitted by certain radioisotopes when their nuclei transition from a higher to a lower energy state. These rays have high energy and a short wave length. Gamma rays penetrate tissue farther than do beta or alpha particles, but leave a lower concentration of ions in their path to potentially cause cell damage.

Radioactive materials are quantified by units of activity: how many atoms are disintegrating in a unit of time (disintegrations per second or minute) A curie (Ci), for instance, is equivalent to 3.7×10^{10} disintegrations per second (dps) or 2.22×10^{12} disintegrations per minute (dpm). The absorbed dose is the amount of energy that ionizing radiation imparts to a given mass of matter, with the units being the gray (Gy) or the rad. Because different materials that receive the same exposure may not absorb the same amount of radiation, the dose equivalent relates the absorbed dose to the biological effect of that dose. The rem (R) or sievert (Sv) is the derived unit of equivalent radiation dose, effective dose, and committed dose. Quantities that are measured in rems or sieverts are designed to quantify the stochastic biological effects of radionuclides, primarily radiation-induced cancer. These units are a complex weighted average of absorbed dose (a physical quantity measured in rads). Rems and sieverts are used primarily in occupational settings where the regulatory concern is risk management; for example, the risk of future cancer induction. Regulatory limits and chronic doses are often given in units of mSv/a or Sv/a, where they are understood to represent an average over the entire year.

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) have set dose limits for ionizing radiation from both occupational and public exposure (ARPANSA, 2002). The effective radiation dose limit for occupationally-exposed humans is 20 mSv (2 rems) per year averaged over a period of five (5) consecutive years. The effective dose is not to exceed 50 mSv (5 rems) in any given year. For the public, the effective dose limit for radiation is 1 mSv (0.1 rem) per year; a higher value of effective dose could be allowed in a single year, provided that the average over five (5) years does not exceed 1 mSv (0.1 rem) per year. The effective dose equivalent is a weighted sum of doses to all irradiated organs or tissues.

In the United States, where the annual limit for a total effective dose equivalent is 50 mSv or 5 rems, there are also annual limit on intake (ALI) for radionuclides, which are regulatory limits for internal contamination. It is the amount of radioactive material, that if taken into the body, results in an annual regulatory dose limit being met. The ALIs for Ir-192, Sb-124, and Sc-46 are 900, 500 to 600, and 900 μCi, respectively. These ALI values would be applicable to Australia since the ARPANSA has set the annual effect dose limit for occupational exposure to not exceed 50 mSv (5 rems) in a year.

Human exposure to radioactivity from the ProTechnic ZeroWash® beads in the flowback material can occur by two routes: external and internal.

The internal exposure would be from ingestion of the tracer beads present in the solids of the flowback. The particle size (200 to 400 microns) of these beads is too large for these beads to be respirable. Because the tracer beads are not soluble in water, and the radionuclides are bound in the bead, radioactivity exposure by ingestion is limited to the resident time in the body. Based on the tracer isotope injection concentration of 1 μCi/kg, an individual would have to ingest at least 900, 500 to 600, or 900 kg of flowback solid material containing Ir-192, Sb-124, or Sc-46 to reach the ALI. It is unrealistic to consider that humans could ingest these large quantities of flowback material in order to meet the regulatory annual limits of these radionuclides. Thus, it can be assumed that the presence of these tracer beads in flowback material would result in a negligible cancer risk to humans from ingestion.

Exposure to radioactivity from the tracer beads in flowback material can also occur from external exposure. This may occur from exposure of workers and trespassers to flowback material, in the transport of the flowback material to a waste disposal site, and at the disposal site.

Transportation

The Santos D&PE Hazard Analysis and Risk Control Form (MOC D&PE 107, 16 Sep 2011) evaluated the transport, storage, use and removal of radioactive tracers during the Moomba fracturing campaign. It was estimated that a person would need to be within one (1) metre of 1,000 pounds (454

kg) of contaminated flowback material in the typical quantities for 177 days to receive the yearly legal dose limit for a radiation worker. This estimate is highly conservative as sand containing the radioactive tracers in most cases will not come back to ground surface and in the event that sand 'blow out' is to occurring during hydraulic fracturing, the sand materials will be excavated and either buried and/or transported off-site for disposal. The estimate given in the Santos D&PE Hazard Analysis and Risk Control Form indicates that the flowback material containing ProTechnic ZeroWash® bead tracers would pose a negligible risk to trespassers.

ProTechnics has estimated that the maximum radiation effective dose rate, at a distance of 1-foot (0.3m) from a vehicle transporting flowback waste containing ProTechnic ZeroWash® bead tracers, would be on the order of 0.1 mR/hour. The radiation effective dose rate in the cab of the transport vehicle would be on the order of 0.004 mR/hour. Using an average transport time of 1-hour, and assuming the same driver was used for all of the expected disposals (10 per year), the effective dose to the driver of the vehicle would be 0.04 mR. Due to its low radiation level and radioactive concentration, an accident causing the release of the waste returns from the transport vehicle would result in a low effective dose to workers or members of the public during the subsequent clean-up efforts (Federal Register, 2003).

Disposal

ProTechnics requested that the Texas Commission on Environmental Quality (TCEQ) adopt a rule that would conditionally exempt minimal amounts of properly disposed radioactive proppant tracers in hydraulic fracturing flowback from TCEQ low level radioactive waste licensing and disposal requirements (Baker Botts LLP, 2012; see **Attachment 3**). In this petition, ProTechnics has estimated that tracer injection operations at the disposal pit are automated to minimise the time require for personnel to be in the immediate area of the injected material. Assuming an injection time of 4 hours per disposal, and an individual within 1-foot (0.3m) of the radioactive material during the injection operation, the total effective dose per year would not be expected to exceed 4 mR from this operation (Federal Register, 2003).

The earthen pit disposal of ProTechnics ZeroWash® tracer beads is not expected to result in harm to public health and safety (Baker Botts LLP, 2012). Doses were calculated for varying amounts of flowback (from 500 to 23,000 pounds) containing the maximum 1 μCi/kg ProTechnics ZeroWash® tracer concentration of Sc-46. Dose was also calculated over a range of possible physical geometries. A worst-case scenario was chosen in which an individual standing on top of a covered earthen pit and standing next to an uncovered pit for a year to determine maximum exposure to ProTechnics ZeroWash® tracer flowback. The results showed that a person standing on a covered earthen pit for twenty-four hours a day for an entire year would accumulate only 5.56 mrems. This value is roughly 18 times lower than the annual dose limit for the public of 0.1 rems. No elevated readings have ever been measured above one of ProTechnics' covered earthen pits (Baker Botts LLP, 2012). These earthen pits are covered with at least two feet of overburden soil. For a person standing next to an uncovered earthen pit for four hours/day for an entire year, the effective dose is still only 66 mrem per year (Baker Botts LLP, 2012), which is lower than the regulatory annual dose limit for the public of 0.1 rem.

The following table compares some radiation dosages from sources that people are exposed to in everyday life with those dosages that may occur from exposure to ProTechnics ZeroWash® bead tracers in flowback material. The radiation dose from short-term exposures to flowback material containing these radioactive bead tracers are similar in magnitude (or even lower) to radiation doses that people may receive from medical and dental x-rays, and even from natural background radiation found all around us. Long-term exposure to these bead tracers that may occur when disposed of in pits would result in radiation doses that are well below the yearly doses that people receive from natural background radiation.

A Comparison of Typical Effective Radiation Doses from Various Sources [a, b] to Doses from Exposure to Radioactive Tracers in Flowback Materials

mrem	Description of Source
0.1-1.0	Hourly cosmic dose to a commercial flight
1	**Approximate daily dose from natural radiation, including radon**
2-4	Chest X-ray exam (single exposure)
2-9	Dental X-ray exam (single exposure)
3.5	Hourly dose for a worker standing within 1 metre of 454 kg of containing flowback material with radioactive tracer beads
5	Yearly dose for a person standing next to covered pit with flowback material containing radioactive tracer beads (4 hours per day)
40-70	Spinal X-ray exam (single exposure)
66	Yearly dose for a person standing next to uncovered pit with flowback material containing radioactive tracer beads (4 hours per day)
120	Abdominal X-ray exam (single exposure)
300	**Yearly dose to people in the United States from natural background radiation**

[a]Sources and Effects of Ionizing Radiation, Volume 1, Annex B. United Nations Scientific Committee on the Effects of Atomic Radiation UNSCEAR 2000 Report to the General Assembly, with Scientific Annexes (http://www.unscear.org/unscear/en/publications/2000_1.html)
[b]Health Physics Society (http://hps.org/hpspublications/radiationfactsheets.html)

Conclusion

Human exposure to flowback material containing Technics ZeroWash® bead tracers (containing the radionuclides Ir-192, Sb-124 and Sc-46) is expected to result in radiation doses that are similar in magnitude to sources that people are exposed to in everyday life. On this basis, the existing exposure controls implemented by Santos for hydraulic fracturing activities and management of flowback water are considered sufficient for management of potential impacts on human health and the environment.

Reference

ARPANSA (2002). Recommendations for Limiting Exposure to Ionizing Radiation (1995) (Guidance Note [NOHSC:2022(1995)]) and National Standard for Limiting Occupational Exposure to Ionizing Radiation [NOHSC:1013(1995)]. Radiation Protection Series No.1, Australian Radiation Protection and Nuclear Safety Agency, National Occupational Health and Safety Commission, Commonwealth of Australia, Republished March 2002.

Baker Botts LLP. 2012. Petition for Rulemaking under Tex. Health & Safety Code 401.106(a). Letter to Mr. Zak Covar, Executive Director, Texas Commission on Environmental Quality, dated October 8, 2012 (**Attachment 3**).

Boethling, R.S. and Nabholz, J.V. (1997). Environmental assessment of polymers under the U.S. Toxic Substances Control Act. In: Ecological Assessment of Polymers Strategies for Product Stewardship and Regulatory Programs (Hamilton, J.D. and Sutcliffe, R. eds.), pp. 187-234, Van Nostrand Reinhold.

DEWHA. 2009.Environmental risk assessment guidance manual for industrial chemicals, Department of the Environment, Water, Heritage and the Arts, Commonwealth of Australia.

EHS Support LLC. 2012. GLNG Coal Seam Hydraulic Fracturing Quantitative Risk Assessment for Schlumberger Chemistry Report.

Federal Register. 2003. Environmental Assessment and Finding of No Significant Impact Related to Materials License No. 42-26928-01, Core Laboratories, Inc. (dba Protechnics) of Houston, TX, License Amendment Request for Approval of an Alternate Disposal Method, Federal Register 68 (208): 61472-61474, October 28, 2003.

ProTechnics Canada Undated. Flowback Procedures Involving the Use of Radioactive Materials.

ProTechnics. Undated. Marketing brochure for SPECTRASTIM™ and ZeroWash® tracers, http://www.corelab.com/protechnics/cms/docs/brochure/SPECTRASTIM.pdf (**Attachment 2**)

ATTACHMENT 1 MSDS FOR RADIOACTIVE TRACERS AND PERFORMANCE BALLS

MANUFACTURER

Date-Issued: 9/24/2011
MSDS Ref. No: IR-192

SPECTRATEK SERVICES
2726 AZTEC N.E. BUILDING B
ALBUQUERQUE, NM 87107
PHONE : (505) 888-0144
24 HOUR EMERGENCY RESPONSE:
(Within US) 1 800 535 5053 (Outside US) 1 352 323 3500 Collect

MATERIAL SAFETY DATA SHEET

1. PRODUCT IDENTIFICATION

PRODUCT NAME:	IRIDIUM ZERO WASH® BEAD TRACER
RADIONUCLIDE:	IRIDIUM-192 (IR-192)
CHEMICAL FORM:	IRIDIUM OXIDE
PHYSICAL FORM:	SOLID

2. MATERIAL COMPOSITION

Hazardous Components:	Radioactive Iridium-192
Type of Hazard:	• (beta), • (gamma)

3. HAZARD IDENTIFICATION

Inhalation: Due to the bead size, inhalation is not a potential health hazard.

Ingestion: Bead is not soluble in the human body. May cause mechanical irritation in digestive tract.

Skin Contact: If in contact with skin, bead may cause mechanical skin irritation.

Eye Contact: The bead may cause mechanical eye irritation.

Lower exposure limits apply for pregnant women working in the restricted area.

4. FIRST AID MEASURES

Inhalation: Irrigate nose with saline solution to remove any beads in the nose.

Ingestion: If swallowed, obtain competent medical attention immediately. Beads will be removed during the normal digestive tract elimination process.

Skin Contact: In case of skin contact, wash area with water and mild detergent. Survey area with radiation instrument equipped with end window Geiger-Mueller probe to determine cleaning effectiveness. If bead is on clothing, use adhesive tape to remove the bead. Treat tape and cleaning fluid as radioactive waste and place in proper storage container.

Eye Contact: In case of contact with eye, flush with copious amounts of water for at least 15 minutes. Survey and place any beads removed from the eye into a radioactive waste container.

5. FIRE FIGHTING MEASURES

Fire and Explosion Hazard is Negligible

Autoignition Temperature is not applicable

Extinguishing Media: Carbon Dioxide or Halon. This reduces the spread of the radioactive beads.

Special Hazards: No special hazards. Normal fire-fighting PPE is sufficient protection.

6. ACCIDENTAL RELEASE MESURES

Control the area. Do not move personnel from the area until they have been surveyed with a G-M survey instrument. If radioactive beads are not present, the personnel may leave the area. Wear protective clothing, safety eyewear, impervious boots and rubber gloves. Clean up area by scooping up spilled material and transfer to a container. It may be necessary to remove some soil or other items indicating the presence of radioactive material. If clothing indicates the presence of radioactive material, remove the bead with adhesive tape, hold tape containing the bead for decay in proper storage area and treat as radioactive waste per regulatory requirements.

7. HANDLING AND STORAGE

The package should be appropriately shielded and handled minimally. Store the package away from fire hazards. The handling, storage and disposal of the radioactive material should be performed with compliance to local, federal or state government agency license for the use of the material. The material should be handled only by qualified personnel.

8. PERSONNEL EXPOSURE CONTROLS

When the packaging and interior of the container are in good condition, the risk of exposure is minimized.

Respiratory Protection: Not required.

Skin Protection: Plastic, latex or rubber gloves are recommended.

Eye Protection: Safety goggles or safety glasses should be worn to protect the eyes.

Other Protective Measures: Personnel should survey frequently to determine if contamination is present. There should be no smoking, eating or drinking in the restricted area.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance: Gray to beige beads

Odor: No odor

Solubility: Insoluble in most fluids

Boling point: Not applicable

Melting point: Not applicable

Half-life: 74 days

10. STABILITY AND REACTIVITY

Stable under most conditions and hazardous polymerization will not occur. The source is considered to be stable when exposed to ignition sources and excessive heat.

11. TOXICOLOGICAL INFORMATION

Exposure to large amounts of radiation can cause biological effects. Acute exposure is not anticipated but the committed annual external whole body exposure is 50 mSv. The annual limit of external skin exposure is 500 mSv.

12. ECOLOGICAL INFORMATION

No information found.

13 DISPOSAL CONSIDERATION

Waste can be held for decay or disposed by a licensed waste disposal company. Follow local, federal and state government regulations for proper disposal of waste.

14. TRANSPORTATION INFORMATION

Shipping Name: Radioactive Material, Type A Package

Hazard Class: 7

Identification Number: UN 2915

15. REGULATORY INFORMATION

UN 2915 Radioactive Material, Type A Package, Class 7

16. **OTHER INFORMATION**

No other paperwork required by Regulation

The material presented above is believed to be correct, but does not purport to be all inclusive and shall be used as a guide only. SpectraTek shall not be liable for any damage resulting from the use of this information.

MANUFACTURER

Date-Issued: 9/24/2011
MSDS Ref. No: SB-124

SPECTRATEK SERVICES
2726 AZTEC N.E. BUILDING B
ALBUQUERQUE, NM 87107
PHONE : (505) 888-0144
24 HOUR EMERGENCY RESPONSE:
(Within US) 1 800 535 5053 (Outside US) 1 352 323 3500 Collect

MATERIAL SAFETY DATA SHEET

1. PRODUCT IDENTIFICATION

PRODUCT NAME:	ANTIMONY ZERO WASH® BEAD TRACER
RADIONUCLIDE:	ANTIMONY-124 (SB-124)
CHEMICAL FORM:	ANTIMONY OXIDE
PHYSICAL FORM:	SOLID

2. MATERIAL COMPOSITION

Hazardous Components:	Radioactive Antimony-124
Type of Hazard:	• (beta), • (gamma)

3. HAZARD IDENTIFICATION

Inhalation: Due to the bead size, inhalation is not a potential health hazard.

Ingestion: Bead is not soluble in the human body. May cause mechanical irritation in digestive tract.

Skin Contact: If in contact with skin, bead may cause mechanical skin irritation.

Eye Contact: The bead may cause mechanical eye irritation.

Lower exposure limits apply for pregnant women working in the restricted area.

4. FIRST AID MEASURES

Inhalation: Irrigate nose with saline solution to remove any beads in the nose.

Ingestion: If swallowed, obtain competent medical attention immediately. Beads will be removed during the normal digestive tract elimination process.

Skin Contact: In case of skin contact, wash area with water and mild detergent. Survey area with radiation instrument equipped with end window Geiger-Mueller probe to determine cleaning effectiveness. If bead is on clothing, use adhesive tape to remove the bead. Treat tape and cleaning fluid as radioactive waste and place in proper storage container.

Eye Contact: In case of contact with eye, flush with copious amounts of water for at least 15 minutes. Survey and place any beads removed from the eye into a radioactive waste container.

5. FIRE FIGHTING MEASURES

Fire and Explosion Hazard is Negligible

Autoignition Temperature is not applicable

Extinguishing Media: Carbon Dioxide or Halon. This reduces the spread of the radioactive beads.

Special Hazards: No special hazards. Normal fire-fighting PPE is sufficient protection.

6. ACCIDENTAL RELEASE MESURES

Control the area. Do not move personnel from the area until they have been surveyed with a G-M survey instrument. If radioactive beads are not present, the personnel may leave the area. Wear protective clothing, safety eyewear, impervious boots and rubber gloves. Clean up area by scooping up spilled material and transfer to a container. It may be necessary to remove some soil or other items indicating the presence of radioactive material. If clothing indicates the presence of radioactive material, remove the bead with adhesive tape, hold tape containing the bead for decay in proper storage area and treat as radioactive waste per regulatory requirements.

7. HANDLING AND STORAGE

The package should be appropriately shielded and handled minimally. Store the package away from fire hazards. The handling, storage and disposal of the radioactive material should be performed with compliance to local, federal or state government agency license for the use of the material. The material should be handled only by qualified personnel.

8. PERSONNEL EXPOSURE CONTROLS

When the packaging and interior of the container are in good condition, the risk of exposure is minimized.

Respiratory Protection: Not required.

Skin Protection: Plastic, latex or rubber gloves are recommended.

Eye Protection: Safety goggles or safety glasses should be worn to protect the eyes.

Other Protective Measures: Personnel should survey frequently to determine if contamination is present. There should be no smoking, eating or drinking in the restricted area.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance: Gray to beige beads

Odor: No odor

Solubility: Insoluble in most fluids

Boling point: Not applicable

Melting point: Not applicable

Half-life: 60 days

10. STABILITY AND REACTIVITY

Stable under most conditions and hazardous polymerization will not occur. The source is considered to be stable when exposed to ignition sources and excessive heat.

11. TOXICOLOGICAL INFORMATION

Exposure to large amounts of radiation can cause biological effects. Acute exposure is not anticipated but the committed annual external whole body exposure is 50 mSv. The annual limit of external skin exposure is 500 mSv.

12. ECOLOGICAL INFORMATION

No information found.

13 DISPOSAL CONSIDERATION

Waste can be held for decay or disposed by a licensed waste disposal company. Follow local, federal and state government regulations for proper disposal of waste.

14. TRANSPORTATION INFORMATION

Shipping Name: Radioactive Material, Type A Package

Hazard Class: 7

Identification Number: UN 2915

15 REGULATORY INFORMATION

USA DOT – UN 2915 Radioactive Material, Type A Package, Class 7

no other paperwork required -

CANADA -

AUSTRALIA -

IATA – UN 2915 Radioactive Material, Type A Package, Class 7
no other paperwork required

16. **OTHER INFORMATION**

The material presented above is believed to be correct, but does not purport to be all inclusive and shall be used as a guide only. SpectraTek shall not be liable for any damage resulting from the use of this information.

MANUFACTURER

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(Within US) 1 800 535 5053 (Outside US) 1 352 323 3500 Collect

Date-Issued: 9/24/2011
MSDS Ref. No: SC-46

MATERIAL SAFETY DATA SHEET

1. PRODUCT IDENTIFICATION

PRODUCT NAME:	SCANDIUM ZERO WASH® BEAD TRACER
RADIONUCLIDE:	SCANDIUM-46 (SC-46)
CHEMICAL FORM:	SCANDIUM OXIDE
PHYSICAL FORM:	SOLID

2. MATERIAL COMPOSITION

Hazardous Components:	Radioactive Scandium-46
Type of Hazard:	• (beta), • (gamma)

3. HAZARD IDENTIFICATION

Inhalation: Due to the bead size, inhalation is not a potential health hazard.

Ingestion: Bead is not soluble in the human body. May cause mechanical irritation in digestive tract.

Skin Contact: If in contact with skin, bead may cause mechanical skin irritation.

Eye Contact: The bead may cause mechanical eye irritation.

Lower exposure limits apply for pregnant women working in the restricted area.

4. FIRST AID MEASURES

Inhalation: Irrigate nose with saline solution to remove any beads in the nose.

Ingestion: If swallowed, obtain competent medical attention immediately. Beads will be removed during the normal digestive tract elimination process.

Skin Contact: In case of skin contact, wash area with water and mild detergent. Survey area with radiation instrument equipped with end window Geiger-Mueller probe to determine cleaning effectiveness. If bead is on clothing, use adhesive tape to remove the bead. Treat tape and cleaning fluid as radioactive waste and place in proper storage container.

Eye Contact: In case of contact with eye, flush with copious amounts of water for at least 15 minutes. Survey and place any beads removed from the eye into a radioactive waste container.

5. FIRE FIGHTING MEASURES

Fire and Explosion Hazard is Negligible

Autoignition Temperature is not applicable

Extinguishing Media: Carbon Dioxide or Halon. This reduces the spread of the radioactive beads.

Special Hazards: No special hazards. Normal fire-fighting PPE is sufficient protection.

6. ACCIDENTAL RELEASE MESURES

Control the area. Do not move personnel from the area until they have been surveyed with a G-M survey instrument. If radioactive beads are not present, the personnel may leave the area. Wear protective clothing, safety eyewear, impervious boots and rubber gloves. Clean up area by scooping up spilled material and transfer to a container. It may be necessary to remove some soil or other items indicating the presence of radioactive material. If clothing indicates the presence of radioactive material, remove the bead with adhesive tape, hold tape containing the bead for decay in proper storage area and treat as radioactive waste per regulatory requirements.

7. HANDLING AND STORAGE

The package should be appropriately shielded and handled minimally. Store the package away from fire hazards. The handling, storage and disposal of the radioactive material should be performed with compliance to local, federal or state government agency license for the use of the material. The material should be handled only by qualified personnel.

8. PERSONNEL EXPOSURE CONTROLS

When the packaging and interior of the container are in good condition, the risk of exposure is minimized.

Respiratory Protection: Not required.

Skin Protection: Plastic, latex or rubber gloves are recommended.

Eye Protection: Safety goggles or safety glasses should be worn to protect the eyes.

Other Protective Measures: Personnel should survey frequently to determine if contamination is present. There should be no smoking, eating or drinking in the restricted area.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance: Gray to beige beads

Odor: No odor

Solubility: Insoluble in most fluids

Boling point: Not applicable

Melting point: Not applicable

Half-life: 84 days

10. STABILITY AND REACTIVITY

Stable under most conditions and hazardous polymerization will not occur. The source is considered to be stable when exposed to ignition sources and excessive heat.

11. TOXICOLOGICAL INFORMATION

Exposure to large amounts of radiation can cause biological effects. Acute exposure is not anticipated but the committed annual external whole body exposure is 50 mSv. The annual limit of external skin exposure is 500 mSv.

12. ECOLOGICAL INFORMATION

No information found.

13 DISPOSAL CONSIDERATION

Waste can be held for decay or disposed by a licensed waste disposal company. Follow local, federal and state government regulations for proper disposal of waste.

14. TRANSPORTATION INFORMATION

Shipping Name: Radioactive Material, Type A Package

Hazard Class: 7

Identification Number: UN 2915

15 REGULATORY INFORMATION

USA DOT – UN 2915 Radioactive Material, Type A Package, Class 7

no other paperwork required -

CANADA -

AUSTRALIA -

IATA – UN 2915 Radioactive Material, Type A Package, Class 7
no other paperwork required

16. **OTHER INFORMATION**

The material presented above is believed to be correct, but does not purport to be all inclusive and shall be used as a guide only. SpectraTek shall not be liable for any damage resulting from the use of this information.

Material Safety Data Sheet

Cured polyurethane

Version: 1.0 | Revision Date: 10/07/2011 | Print Date: 06/08/2012

SECTION 1. PRODUCT AND COMPANY IDENTIFICATION

Product name: *Cured polyurethane*

Company: Chemtura Corporation
199 Benson Road
Middlebury, CT
06749
United States of America

Telephone: 866-430-2775

Emergency telephone number: CHEMTREC: (24 hours) 800-424-9300
:
Chemtura Corporation Emergency Response: CHEMTURA : 800-292-5898

For additional emergency telephone numbers see section 16 of the Safety Data Sheet.

Prepared by: Product Safety Department
(US) +1 866-430-2775

10/07/2011

+011-886-2-2712-5668 MSDSRequest@chemtura.com

SECTION 2. HAZARDS IDENTIFICATION

Emergency Overview

Form: solid
Hazard Summary : No information available.

Potential Health Effects

Symptoms of Overexposure : No information available.

SECTION 3. COMPOSITION/INFORMATION ON INGREDIENTS

Hazardous components

No dangerous ingredients according to Regulation (EC) No. 1907/2006

SECTION 4. FIRST AID MEASURES

First aid procedures

General advice	:	No hazards which require special first aid measures.
Inhalation	:	Move to fresh air in case of accidental inhalation of dust or fumes from overheating or combustion. If symptoms persist, call a physician.
Skin contact	:	Wash off with soap and plenty of water.
Eye contact	:	Flush eyes with water as a precaution. Remove contact lenses. Protect unharmed eye. Keep eye wide open while rinsing.
Ingestion	:	Clean mouth with water and drink afterwards plenty of water. Do not give milk or alcoholic beverages. Never give anything by mouth to an unconscious person.

Notes to physician

Symptoms	:	No information available.
Risks	:	No information available.
Treatment	:	No information available.

SECTION 5. FIRE-FIGHTING MEASURES

Flammable properties

Ignition temperature	:	> 392 °F (> 200 °C)

Fire fighting

Suitable extinguishing media	:	Use extinguishing measures that are appropriate to local circumstances and the surrounding environment.
Further information	:	Standard procedure for chemical fires.

Protective equipment and precautions for firefighters

Specific hazards during fire fighting	:	No information available.
Special protective equipment for fire-fighters	:	In the event of fire, wear self-contained breathing apparatus.

SECTION 6. ACCIDENTAL RELEASE MEASURES

Personal precautions	:	Not expected to present a significant inhalation hazard under anticipated conditions of normal use.
Environmental precautions	:	No special environmental precautions required.
Methods for containment /	:	Sweep up and shovel.

Methods for cleaning up	Keep in suitable, closed containers for disposal.

SECTION 7. HANDLING AND STORAGE

Handling

Handling procedures	:	For personal protection see section 8. No special handling advice required.
Advice on protection against fire and explosion	:	Avoid dust formation. Provide appropriate exhaust ventilation at places where dust is formed.

Storage

Requirements for storage areas and containers	:	Keep in a dry, cool and well-ventilated place.
Advice on common storage	:	No special restrictions on storage with other products.
Other data	:	No decomposition if stored and applied as directed.

SECTION 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Exposure Guidelines

Engineering measures

Personal protective equipment

Eye protection	:	Safety glasses
Hand protection	:	For prolonged or repeated contact use protective gloves.
Skin and body protection	:	Protective suit
Respiratory protection	:	No personal respiratory protective equipment normally required.
Hygiene measures	:	General industrial hygiene practice.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance

Form	:	solid

Safety data

Ignition temperature	:	> 392 °F (> 200 °C)
Density	:	1.2 g/cm3

Specific Gravity	:	1.2 at
Water solubility	:	Note: insoluble

SECTION 10. STABILITY AND REACTIVITY

Conditions to avoid	:	Remarks: no data available
Materials to avoid	:	Remarks: None known.
Hazardous decomposition products	:	Note: Carbon monoxide, carbon dioxide and unburned hydrocarbons (smoke). Hydrocarbons Hydrogen cyanide

SECTION 11. TOXICOLOGICAL INFORMATION

Skin irritation	:	Remarks: According to the classification criteria of the European Union, the product is not considered as being a skin irritant.
Eye irritation	:	Remarks: According to the classification criteria of the European Union, the product is not considered as being an eye irritant.
Sensitisation	:	Remarks: no data available
Further information	:	no data available

12. ECOLOGICAL INFORMATION

Ecotoxicity effects
Elimination information (persistence and degradability)

Bioaccumulation	:	Remarks: no data available
Mobility	:	Remarks: no data available
Biodegradability	:	Remarks: no data available

Further information on ecology

Additional ecological information	:	There is no data available for this product.

SECTION 13. DISPOSAL CONSIDERATIONS

Further information : Offer surplus and non-recyclable solutions to a licensed disposal company.

Contaminated packaging : Empty remaining contents.
Empty containers should be taken to an approved waste handling site for recycling or disposal.

SECTION 14. TRANSPORT INFORMATION

DOT
Not dangerous goods

TDG
Not dangerous goods

IATA
Not dangerous goods

IMDG
Not dangerous goods

RID
Not dangerous goods

SECTION 15. REGULATORY INFORMATION

SECTION 16. OTHER INFORMATION

Further information

Other Emergency Phone Number

Latin America:	Brazil	+55 113 711 9144
	All other countries	+44 (0) 1235 239 670
Mexico:		+52 555 004 8763

The information provided in this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as a guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text.

ATTACHMENT 2 MANUFACTURER INFORMATION FOR RADIOACTIVE TRACERS AND PERFORMANCE BALLS

SEALER BALLS

Associated Research Developments Ltd. (ARD) is Canada's largest sealer ball manufacturer.
ARD has been producing high quality sealer balls for international and domestic markets for nearly 40 years.

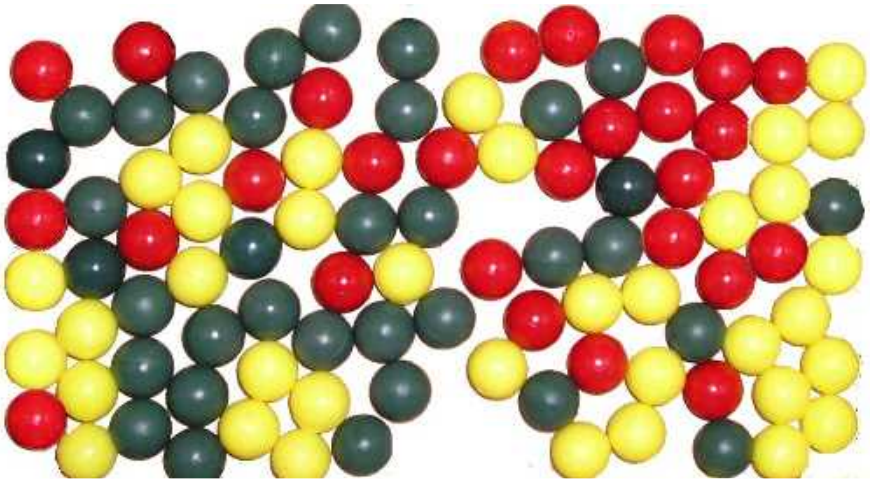


Polyurethane

ARD Thermoset polyurethane balls are hand cast, hand trimmed and individually inspected. The polyurethane balls have proved to have excellent performance under a combined state of high pressure and temperature. These balls are produced in a variety of sizes ranging from 5/8" (16mm) to 1-1/2" (38mm). Thermoset polyurethane sealer balls are also offered in three different, color-coded specific gravities: 0.9 (yellow), 1.1 (red) and 1.3 (green). All three specific gravities are available in all the different sizes offered.

Thermo Plastic

ARD Thermo plastic sealer balls perform well under a combined state of high pressure and temperature. These balls are a more recent addition to our product line. There is currently a limited range of sizes (7/8" or 22mm only) and specific gravities but we will continue to add new ones as the R&D is completed. The performance of the thermoplastic balls is excellent and the cost is lower.



Associated Research Developments Ltd. - 1235 H 40 Ave NE, Calgary AB T2E 6M9 CANADA
Ph: (403) 250-1977 Email: info@associatedrd.com www.associatedrd.com

ProTechnics

SPECTRA™ **STIM** ZeroWash®

ZeroWash® has been awarded the Meritorious Award for Engineering Innovation
Hart's Petroleum Engineer INTERNATIONAL

SPECTRA**STIM**™ is a proppant tracing technology that involves the precise injection of uniquely identifiable Zero**Wash**® tracers. Engineered for maximum diagnostic value, SPECTRA**STIM** tracers are designed to target specific stages or segments and different proppant or fluid types in hydraulic fracture and other completion operations.

Zero**Wash** tracers are the only means to accurately pinpoint completion placement. A post-stimulation spectral gamma ray log is run to precisely identify and quantify the Zero**Wash** tracer placement in the completion operation.

SPECTRA**STIM** provides direct measurements to develop and refine completion procedures and processes to optimize production.

SPECTRA**STIM** is a proven diagnostic tool in the following applications:

- **Hydraulic Fracturing Treatments**
- **Acid Treatments**
- **Cementing** (Channel Identification, Squeeze Coverage, Top of Cement)
- **Horizontal Well Completions**
- **Mechanical Integrity Tests**
- **Conformance Control**
- **Polymer Treatments**
- **Gravel and Frac Pack Treatments**
- **Pre-Frac Diagnostic Testing**

SPECTRA**STIM** is essential in determining:

- **Fracture Height**
- **Staging Performance and Efficiency**
- **Mechanical Integrity (Internal and External)**
- **Wellbore/Fracture Connectivity**
- **Fracture Orientation Signature** (Transverse/Longitudinal)
- **Perforation Cluster Strategy and Effectiveness**
- **Interwell/Offset Fracture Communication**

Zero**Wash** tracers are manufactured using a patented process that fixes the non-water-soluble tracer metal into the matrix of a high strength ceramic particle. Independently tested and certified to perform in the most extreme downhole environments.

Zero**Wash** tracers are so effectively formed with no potential for wash-off they are:

- **Client HSE Preferred**
- **US Nuclear Regulatory Commission (NRC) Approved**
- **Safe to Transport, Handle, Store and Dispose**

Zero**Wash**®
CERAMIC PROPPANT BEAD



Isotope Table

Isotope	Symbol	Form	Half Life Days	Energy Spectrum (million electron volts)	Maximum Permissible Concentration	Disposal Method
Iridium 192	Ir-192	ZW, ZWLD	74 days	0.311, 0.468, 0.609	10	ID, OD, CII
Scandium 46	Sc-46	ZW, ZWLD	83.8 days	0.889, 1,121	10	ID, OD, CII
Antimony 124	Sb-124	ZW	60.2 days	0.603, 0.720, 1.691	7	ID, CII

ID= In-Situ Decay OD= Offshore Disposal CII= Class II Disposal

Tracer Properties and Usage

Tracer Form	Description	Mesh Size	Specific Gravity	Crush Strength (psi)	Color	Application	Concentration (mCi)
Zero Wash (ZW)	Intermediate strength ceramic bead imbedded with oxideform of the isotope	40/70 mesh	2.65	>8,000	Various shades of gray	Designed to emulate particulate materials. Primarily used to trace proppants	.35 to .6 mCi per 1,000 gal or 1,000 lb
Zero Wash LD (ZWLD)	Low density ceramic bead imbedded with oxide form of the isotope	40/70 mesh	1.3 -1.48	1,500 - 2,000	Dark green to brown	Designed to emulate fluid and low density materials. Used to trace pad fluids and acids at matrix rate.	.5 to 1 mCi per 1,000 gal or 1,000 lb
Cobalt Wire	1/4 in. wire approximately 2 cm long	N/A	N/A	N/A	N/A	Depth control, cement hardware, non-ferrous tubulars, compaction	1 microcurrie

ATTACHMENT 3 TCEQ RISK ASSESSMENT FOR RADIOACTIVE TRACERS WITH CONFIDENTIAL INFORMATION REDACTED.

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October 8, 2012

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34597
DLS
cc-Stephanie

Via Hand Delivery

Mr. Zak Covar
Executive Director
Texas Commission on Environmental Quality
12100 Park 35 Circle, Building F
Austin, Texas 78753

Re: Petition for Rulemaking under TEX. HEALTH & SAFETY CODE § 401.106(a)

Dear Mr. Covar:

This rulemaking petition is submitted on behalf of the ProTechnics Division of Core Laboratories LP, 6510 W. Sam Houston Parkway N., Houston, Texas 77041 ("ProTechnics") pursuant to TEX. HEALTH & SAFETY CODE § 401.106(a) and 30 TEX. ADMIN. CODE § 20.15. ProTechnics specifically requests that the Texas Commission on Environmental Quality ("TCEQ") adopt a rule that would conditionally exempt minimal amounts of properly disposed radioactive proppant tracers in hydraulic fracturing flowback from TCEQ low level radioactive waste licensing and disposal requirements.

BACKGROUND

Since May 12, 1992, ProTechnics has overseen the management and disposal of flowback containing proppant with ZeroWash® tracers in earthen pits. These earthen pits are, and have been managed by oil and gas well operators under the jurisdiction of the Railroad Commission. For two decades, this method of management and disposal has been authorized by the Department of State Health Services (*see* Attachment 1) and the Nuclear Regulatory Commission (*see* Attachment 2) through a license exemption. In fact, the Nuclear Regulatory Commission recently confirmed ProTechnics' method of management and disposal of ZeroWash® tracers via a license amendment issued on August 30, 2012. With the passage of S.B. 1604 (80th Leg., 2007) and subsequent TCEQ rulemakings under that act, it appears that a licensing exemption from TCEQ may now be required so that this product can continue to be managed in the same manner going forward.

1. FACTUAL BACKGROUND

For over two decades, ProTechnics has been an innovator in "completion diagnostic" services that enable oil and gas companies to optimize reservoir performance and maximize hydrocarbon recovery from producing fields. A key feature of the services provided

by ProTechnics to its clients over the last twenty years involves the established use of ZeroWash® proppant tracer beads in hydraulic fracturing operations. These tracers are introduced at low concentrations into hydraulic fracturing fluid containing proppant during hydraulic fracturing operations. The tracers provide a small signal above background that enables well operators taking subsequent well log measurements to identify the interval(s) where the proppant and tracers were placed, allowing well operators to increase recoverable reserves by identifying and recovering bypassed pay and providing information that identifies opportunities to optimize well completion processes.

This use of ZeroWash® tracers takes place at various drilling sites across the world. In Texas, it is authorized by Department of State Health Services License No. L03835 (the "DSHS License"). Historically, when ZeroWash® tracer material was released during a "sandout" or returned to the surface in flowback, the DSHS License authorized the diversion of the released and/or returned material to earthen pits subject to the jurisdiction of the Railroad Commission and the subsequent covering of that material with two feet of clean soil. ZeroWash® tracer flowback has been disposed of in this manner for the last twenty years.

The Department of State Health Services previously authorized this method of disposal, as did the Nuclear Regulatory Commission, because it does not result in a significant risk to public health and safety or the environment, and because it complies with the "as low as reasonably achievable" ("ALARA") principle for exposure to radiation. Critical in both agencies' decision-making was the unique properties of ProTechnics' tracers—ProTechnics uses ZeroWash® proppant tracer beads consisting of an insoluble material that ensures by its design that radioactivity will not migrate or leach into groundwater (*see* Attachments 3 & 6).

2. BRIEF EXPLANATION OF PROPOSED RULE

ProTechnics markets and sells its ZeroWash® tracers to oil and gas companies across the world. Current regulatory uncertainty regarding the management of flowback in Texas hampers ProTechnics' business goals and threatens the viability of a valuable service used in various shale plays across the United States. ProTechnics and its customers need certainty regarding acceptable management and disposal of ZeroWash® tracer flowback. ProTechnics believes that pursuant to TEX. HEALTH & SAFETY CODE § 401.106(a), the Commission should reach the same conclusion that the Department of State Health Services and the Nuclear Regulatory Commission have reached—that this long-standing disposal practice does not result in a significant risk to public health and safety or the environment, and thus should be conditionally exempt from TCEQ licensing and disposal requirements. ProTechnics also believes that the long standing management and disposal practices previously approved by Department of State Health Services and the Nuclear Regulatory Commission should continue to be available in lieu of, or in addition to the State's otherwise applicable disposal rules.

3. INJURY AND INEQUITY THAT COULD RESULT FROM THE FAILURE TO ADOPT THE PROPOSED RULE

Without a rule from TCEQ, the regulated community is left with serious uncertainty regarding the acceptability of a longstanding, safe, sound and economical management practice for disposing of such wastes, a practice approved by the Texas Department of State Health Services (*see* Attachment 1) and the Nuclear Regulatory Commission (*see* Attachment 2). The conditional exemption would apply only if disposal of the flowback material is conducted in accordance with the proposed TCEQ rule requirements.

TECHNICAL ANALYSIS

Adoption of a rule conditionally exempting disposal of ZeroWash® tracer flowback from licensing and disposal requirements will not pose a significant risk to public health and safety or the environment. This is a sound conclusion from a technical perspective for three reasons.

First, ZeroWash® tracer flowback has been disposed of in earthen pits since May 12, 1992, without any reported or known harm to public health and safety or the environment. Not only do the typical isotopes ProTechnics is licensed to use by the Department of State Health Services have a half-life of less than 90 days, but only a very small amount of tracer material is used to log a well—a 20-mCi vial containing 15 ccs of ZeroWash® tracer material traces 50,000 pounds of proppant (*see* Attachment 4). Further, the concentration of any tracers brought to the surface in flowback will always be relatively low because the tracer material is mixed into fracturing proppant prior to being injected into a well, meaning that only a small fraction of the proppant tracer returns to the surface. Additionally, although flowback sometimes occurs in fracturing operations, based on experience, flowback of ZeroWash® tracer only occurs in approximately one in ten applications.

Second, ProTechnics has undertaken calculations—computed over a broad and systematic range of possible scenarios with worst-case conditions of exposure time, isotope energy and half-life—to demonstrate that earthen pit disposal of ZeroWash® tracer flowback will not result in harm to public health and safety. For purposes of the calculations, dose was calculated for varying amounts of flowback (from 500 pounds to 23,000 pounds), containing the maximum 1,000 pCi/g ZeroWash® tracer concentration of Scandium-46. Dose was also calculated over a range of possible physical geometries. To be conservative, ProTechnics used worst case scenarios of an individual standing on top of a covered earthen pit and standing next to an uncovered pit for a year to determine maximum exposure to ZeroWash® tracer flowback.

The results of the calculations demonstrate that a rule which conditionally exempts from licensing and disposal flowback containing ZeroWash® tracer and similar products will not result in a significant risk to public health and safety. A person standing on a covered earthen pit for twenty-four hours a day for an entire year would accumulate only 5.56 mrem (*see*

Attachment 5).[1] To put this in context, a similar amount of radiation could be expected in a roundtrip flight from New York to Los Angeles (0.5 mrem/Hr). In addition, without any half-life decay, the first day calculates an activity above background at the surface of only 0.0057 mrem/Hr. No elevated readings have ever been measured above one of ProTechnics' covered earthen pits.[2] The parameters for the above calculations reflect *worst-case scenarios*, and when more realistic exposure times and distances are used, the dose is *essentially negligible*. All worst case scenarios clearly exhibit that exposure levels to the general public will be well below the 100 mrem limit allowed per year under TCEQ rules.

Third, the unique characteristics of ProTechnics' patented ZeroWash® tracer material protect against any dangers of leaching or migration into groundwater. Testing performed by scientists at Texas A&M University confirm that there is no appreciable "wash-off" from ProTechnics' ZeroWash® tracer material (*see* Attachment 6). This means that the tracer material will not contaminate any other materials it contacts, thereby leaving fluids and solids free of contamination from the tracer material so that there is no danger of transfer to a water table and no significant risk to the environment. Because of the unique properties of the ZeroWash® tracer material, regulatory agencies of the United States and Canada have approved elevated release limits.

The characteristics of ProTechnics' ZeroWash® tracers ensure that flowback disposal in earthen pits regulated by the Railroad Commission will not result in a significant risk to public health and safety or the environment. And because any alternative method of disposal would require pre-disposal transportation, disposal on-site in earthen pits is at least as protective, if not more protective, of public health, safety and the environment than other waste disposal methods. As such, disposal on-site in earthen pits complies with the "as low as reasonably achievable" ALARA principle for exposure to radiation.

STATUTORY AUTHORITY FOR PROPOSED RULEMAKING

The Texas Radiation Control Act grants TCEQ the general power and authority to adopt rules relating to control of sources of radiation. *See* TEX. HEALTH & SAFETY CODE § 401.051. The TCEQ has general jurisdiction to regulate and license the disposal of radioactive substances. *See id.* at § 401.011(b). Pursuant to TEX. HEALTH & SAFETY CODE § 401.106(a), the TCEQ has specific authority to exempt flowback containing ZeroWash® tracer from licensing and disposal requirements. Texas Health and Safety Code Section 401.106(a) provides:

---

[1] Attachment 5 is confidential under Texas Public Information Act § 552.110, and is being submitted separately.

[2] Because the ZeroWash® tracer flowback is always covered with at least 2 feet of overburden soil, and that is the requirement for the conditional exemption in the proposed rule to apply, this is the calculation that is most useful for purposes of showing protectiveness. However, even if you assume that a person stands next to an uncovered earthen pit for four hours a day for an entire year, the exposure is still only 66 mrem per year.

> The board or commission[3] by rule may exempt a source of radiation or a kind of use or user from the licensing or registration requirements provided by this chapter and under the agency's jurisdiction if the board or commission finds that the exemption of that source of radiation or kind of use or user will not constitute a significant risk to the public health and safety and the environment.

Id. at § 401.106(a).

The Memorandum of Understanding ("MOU") between the TCEQ, the State Department of Health Services, and the Railroad Commission, which is codified in the Texas Administrative Code, specifically contemplates that disposal of radioactive tracer material will qualify for an exemption under Section 401.106(a). The applicable sections of the MOU provide:

> (f) Radioactive material.
>
> ...
>
> (4) Management of radioactive tracer material.
>
> > (A) Radioactive tracer material is subject to the definition of low-level radioactive waste under Texas Health and Safety Code, §401.004, and must be handled and disposed of in accordance with the rules of the TCEQ and the Department of State Health Services.
> >
> > (B) Exemption. Under Texas Health and Safety Code, §401.106, the TCEQ may grant an exemption by rule from a licensing requirement if the TCEQ finds that the exemption will not constitute a significant risk to the public health and safety and the environment.

16 TEX. ADMIN. CODE § 3.30(f)(4).

The TCEQ is also specifically authorized to provide exemptions from records relating to the disposal of a source of radiation by rule. *See id.* at § 401.057(b).

TEXT OF PROPOSED RULE

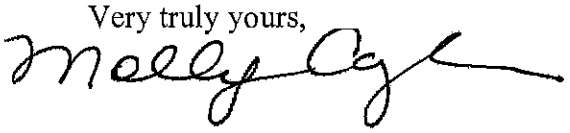
The proposed text of the rule is enclosed and has been included electronically on CD.

* * * * *

[3] "Commission" means the Texas Commission on Environmental Quality. TEX. HEALTH & SAFETY CODE § 401.003(2).

We appreciate your consideration of this rulemaking petition. Should you have any questions about the petition or the draft rule, please do not hesitate to contact me at 512.322.2535 or molly.cagle@bakerbotts.com.

Very truly yours,



Molly Cagle

cc: Charles Maguire, TCEQ (via U.S. mail)
Patricia Duron, TCEQ (via U.S. mail)
Tom Hampton, Core Lab (via U.S. mail)
Carlos Romo, Baker Botts L.L.P.

TEXT OF PROPOSED RULE

Texas Administrative Code

TITLE 30	ENVIRONMENTAL QUALITY
PART 1	TEXAS COMMISSION ON ENVIRONMENTAL QUALITY
CHAPTER 336	RADIOACTIVE SUBSTANCE RULES
SUBCHAPTER C	GENERAL LICENSING REQUIREMENTS
RULE §336.230	**Disposal of Radioactive Tracer Material Used in Oil and Gas Exploration or Production Operations**

(a) Purpose. The purpose of this Section is to conditionally exempt the on-site disposal of qualified tracer materials used in oil and gas operations pursuant to 30 TAC §336.203 and Texas Health & Safety Code §401.106(a).

(b) Eligibility and Qualification for the conditional exemption. Only Radioactive Materials License Holders may apply for the conditional exemption provided by this Section. In order for the disposal of solid tracer material used in oil and gas exploration and/or production operations to qualify for the conditional exemption from general licensing and disposal requirements provided by this Section, the following requirements must all be met:

(1) The Radioactive Materials License Holder seeking the conditional exemption must file an administratively complete registration with the Executive Director in accordance with this Section, and the Executive Director must confirm that the registration is accepted and that tracer materials are qualified tracer materials.;

(2) The tracer materials for which the conditional exemption is sought must meet the following criteria:

(A) The tracer materials are short half-life isotopes Iridium (Ir)-192, Scandium (Sc)-46 or Antimony (Sb)-124;

(B) The tracer materials are mixed with a combination of inorganic earthen material in the form of metal oxides and sintered at up to 500° C to form a strong ceramic structure incorporating a small amount of isotopes Ir, Sc, or Sb;

(C) The Ir, Sc or Sb isotopes are in a form that is non-water soluble; and

(D) The total radioactive concentration of all Ir, Sc or Sb isotopes is 1,000 picocuries/gram or less, and the physical half life of the qualified tracer materials is less than 90 days; and

(3) The qualified tracer materials are disposed of in accordance with the Registration, Disposal, Closure, and Annual Certification requirements of this Section.

(c) Definitions. The following words and terms when used in this section shall have the following meanings:

(1) "Closure" means the amount of time needed to return a pit to unrestricted release levels.

(2) "Flowback" means the process of allowing fluids to flow from the oil and gas well following a treatment, either in preparation for a subsequent phase of treatment or in preparation for cleanup and returning the well to production.

(3) "Job Site Survey Form" means a form signed by the Operator or Well Owner and Logging/Tracer Supervisor with survey information indicating that the pit where qualified tracer materials are disposed is at unrestricted release levels.

(4) "Logging/Tracer Supervisor" means an individual trained in a training program for the handling and disposal of qualified tracer materials including 25 TAC §289.253(o) requirements.

(5) "Operator" means the person responsible for managing oil and gas exploration and production activities and flowback at an oil and gas well site.

(6) "Pit" means earthen barrier used to dispose of qualified tracer material used in oil and gas exploration and/or production operations and permitted under applicable Railroad Commission rules.

(7) "Proppant" means sand or any natural or man-made material that is used in a hydraulic fracturing treatment to prop open the artificially created or enhanced fractures once the treatment is completed.

(8) "Qualified Tracer Materials" means radioactive tracer materials that meet all the criteria under Subsection (b)(2) of this Section.

(9) "Radioactive Materials License Holder" means a person issued a license by the Texas Department of State Health Services authorizing the licensee to receive, acquire, store, possess and transfer radioactive material listed in the license.

(10) "Tracer Material" means radioactive material with half-lives less than 90 days used in subsurface oil and gas exploration and production operations.

(11) "Well Owner," if different from the Operator, means the oil and gas lessee responsible for contracting with the Operator for oil and gas exploration and production activities and flowback at an oil and gas well site.

(12) "Well reversal material" means solid material, such as sand and other proppants used in hydraulic fracturing, flowing from the well following a treatment.

(13) "Well Site Agreement" means an agreement signed by the Operator or Well Owner and Radioactive Materials License Holder providing for each person's respective responsibilities in handling and disposing of qualified tracer materials.

(d) Registration. A Radioactive Materials License Holder seeking the conditional exemption from licensing and disposal requirements under this Section shall submit a registration, on a form prepared by the Executive Director. The registration shall include:

(1) A demonstration that tracer materials are qualified tracer materials;

(2) A complete description of the qualified tracer materials for which the conditional exemption is sought, including the identity, form and estimate of the typical total radioactive concentration of the qualified tracer material used per well in oil and gas exploration and/or production operations;

(3) a description of how qualified tracer materials are used in oil and gas exploration and/or production operations;

(4) information related to the training of a Logging/Tracer Supervisor;

(5) a description of the procedures a Logging/Tracer Supervisor will use to monitor and otherwise confirm and prepare a record to document closure of pits where qualified tracer materials are disposed; and

(6) a description of how and where the Radioactive Materials License Holder will maintain records showing compliance with this Section.

(e) Disposal. All of the following disposal procedures must be followed for qualified tracer materials to be conditionally exempt from Chapter 336 licensing and disposal requirements:

(1) A Radioactive Materials License Holder and Operator or Well Owner shall sign a Well Site Agreement indicating that the Operator or Well Owner has been informed of disposal procedures for on-site disposal of qualified tracer materials in a pit in accordance with this Subsection.

(2) An Operator or Well Owner disposing of qualified tracer materials must:

(A) Direct well reversal material (including any proppant or sand screened out of flowback fluid) to an on-site pit; and

(B) Backfill the pit with two (2) feet of clean soil within 30 days of final well clean up.

(f) Closure. The Radioactive Materials License Holder must:

(1) Maintain as part of the Well Site Agreement, an agreement with the Operator or Well Owner to control access to the pit until the radioactivity has decayed to unrestricted release levels, subject to inspection by representatives of the Executive Director; and

(2) Complete a Job Site Survey Form within 30 days of receipt of notice of closure of the pit documenting that a Logging/Tracer Supervisor has surveyed the pit with an End Window Geiger Muller Detector or equivalent device and found radioactivity at unrestricted release levels and identifying all information on which that documentation is based; and

(3) Maintain for a period of two years after closure the Well Site Agreement and Job Site Survey Form (including back-up documentation) associated with each pit where qualified tracer materials are disposed in lieu of any other recordkeeping requirements under Texas Health & Safety Code §401.057 relating to disposal of tracer materials under this Section. Records must include information regarding the date of disposal, the survey instrument used, the background radiation level, the radiation level measured at the surface of each disposal area, and the name of the Logging/Tracer Supervisor who completed the Job Site Survey Form. Records shall be kept readily available for inspection by representatives of the Executive Director.

(g) Annual certification. To maintain its eligibility for the conditional exemption provided by this Section, a Radioactive Materials License Holder shall submit a certification to the TCEQ on an annual basis confirming the accuracy or otherwise demonstrating compliance with the registration information and requirements under Subsection (d).

Attachment 1

Department of State Health Services

RADIOACTIVE MATERIAL LICENSE

Pursuant to the Texas Radiation Control Act and Texas Department of State Health Services (Agency) regulations on radiation, and in reliance on statements and representations heretofore made by the licensee, a license is hereby issued authorizing the licensee to receive, acquire, possess and transfer radioactive material listed below; and to use such radioactive material for the purpose(s) and at the place(s) designated below. This license is subject to all applicable rules, regulations and orders of the Agency now or hereafter in effect and to any conditions specified below.

LICENSEE	
1. Name	PROTECHNICS DIVISION OF CORE LABORATORIES LP ATTN WILL C WILLIAMS
2. Address	6510 WEST SAM HOUSTON PKWY STE 100 HOUSTON TX 77041

This license is issued in response to a letter

Dated: November 14, 2011

Signed by: Will Williams

3. License Number	Amendment Number
L03835	59

PREVIOUS AMENDMENTS ARE VOID

4. Expiration Date: August 31, 2015

RADIOACTIVE MATERIAL AUTHORIZED

5. Radioisotope	6. Form of Material	7. Maximum Activity	8. Authorized Use
A. Any radioactive material with atomic number less than 83 (except Se-75) and with a half-life less than 120 days	A. Any (except sealed sources)	A. No single unit quantity to exceed 40 millicuries Total activity of any single radioisotope not to exceed 100 millicuries	A. Tracer studies in oil, gas and geothermal wells. Field flood studies and inter-well tracer studies.
B. Ir-192, Ir-194	B. Any (except sealed sources)	B. No tracer single unit quantity to exceed 40 millicuries of either isotope. Markers not to exceed 50 microcuries each Total: 15 curies	B. Tracer studies in oil, gas and geothermal wells. Field flood studies and inter-well tracer studies and radioactive markers.
C. Sc-46	C. Any (except sealed sources)	C. No tracer single unit quantity to exceed 40 millicuries of either isotope. Markers not to exceed 50 microcuries each Total: 4000 millicuries	C. Tracer studies in oil, gas and geothermal wells. Field flood studies and inter-well tracer studies and radioactive markers.

Department of State Health Services

RADIOACTIVE MATERIAL LICENSE

LICENSE NUMBER	AMENDMENT NUMBER
L03835	59

5. Radioisotope (Continued...)	6. Form of Material (Continued...)	7. Maximum Activity (Continued...)	8. Authorized Use (Continued...)
L. Xe-133	L. Any (except sealed sources)	L. No single unit quantity to exceed 100 millicuries Total: 2 curies	L. Casing integrity tests on injection wells in gas storage fields.

9. Radioactive material shall only be stored at:

Site Number	Location
007	Midland - 2001 Commerce Street
009	Fort Worth – 518 Aviator Drive
010	Houston – 6510 West Sam Houston Pkwy, Ste. 100
011	Alice – 5038 South Highway 281
012	Kilgore – **183 Old Post Oak Road**

10. The authorized place of use is at temporary sites, in areas not under exclusive Federal jurisdiction, throughout Texas.

11. Radioactive material shall not be stored or used at a permanent site unless that site is specifically authorized on this license. A site is considered permanent if radioactive material is stored and/or used at that location for more than 90 days in any twelve-month period.

12. The licensee shall limit storage of Ir-192 and Ir-194 to 5000 millicuries at all storage locations except the Kilgore, Texas facility which is authorized to maintain no more than 15 curies of Ir-192 and Ir-194 total. This condition does not supersede the maximum allowable activity authorized in Part B of Condition 7.

13. The individual designated to perform the functions of Radiation Safety Officer (RSO) for activities covered by this license and Site 010 is Will C. Williams. The Site Radiation Safety Officer (SRSO) for Site 007 is Roberto Sanchez. The SRSO for Site 009 is David R. Jackson. The SRSO for Site 011 is Frank Garcia. The SRSO for Site 012 is Todd Sasche.

14. The licensee shall comply with the provisions (as amended) of Title 25 Texas Administrative Code (TAC) §289.201, §289.202, §289.203, §289.204, §289.205, §289.251, §289.252, §289.253 and §289.257.

15. Radioactive material shall be used by, or under the direct supervision of, individuals designated by the RSO only after each worker has successfully completed an Agency accepted training course. Documentation verifying the successful completion of the training for each worker shall be maintained by the licensee for inspection by the Agency.

Department of State Health Services

RADIOACTIVE MATERIAL LICENSE

LICENSE NUMBER	AMENDMENT NUMBER
L03835	59

20. The licensee is exempted from the requirements of 25 TAC §289.253(o)(1)(D) only for users of radioactive material authorized in Part I of Conditions 5, 6, 7 and 8. The licensee shall maintain a separate utilization log containing, as a minimum, the make and model number and/or serial number (or if absent, a unique description) of each sealed source authorized by Part I of Conditions 5, 6, 7 and 8 removed from storage, the identity of the logging supervisor receiving the sources of radiation, the locations where used and dates of use. These utilization logs shall be kept available for inspection by the Agency for five years from the date of the recorded event.

21. Except as specifically provided otherwise by this license, the licensee shall possess and use the radioactive material authorized by this license in accordance with statements, representations, and procedures contained in the following:

application dated July 22, 2005,
letters dated October 6, 2006, January 8, 2008, February 5, 2008, July 29, 2010, August 13, 2010, September 21, 2010, February 19, 2011, March 7, 2011.
facsimiles received January 23, 2007 and February 28, 2007.

Title 25 TAC §289 shall prevail over statements contained in the above documents unless such statements are more restrictive than the regulations.

SEG:seg

FOR THE DEPARTMENT OF STATE HEALTH SERVICES

Date November 17, 2011

Ray Fleming, Program Coordinator
Industrial Licensing Program

Attachment 2

UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION IV
1600 EAST LAMAR BOULEVARD
ARLINGTON, TEXAS 76011-4511

August 30, 2012

Core Laboratories, Inc.
dba ProTechnics Division of Core Laboratories
ATTN: Will C. Williams
Radiation Safety Officer
6316 Windfern Road
Houston, Texas 77040

SUBJECT: LICENSE AMENDMENT

Please find enclosed copy of Amendment Number 44 to NRC License Number 42-26928-01. **As a result of your July 30, 2012 letter, the NRC has created a new license condition 18 reinstating an alternate disposal method that was previously approved, by means of tie-down conditions, on February 21, 1996, with the issuance of Amendment No. 18 to this license. The new license condition 18 makes it easier to the reader to understand what authorization is being granted as opposed to an authorization granted by tie-down conditions. Other license conditions were also updated. For your benefit, these changes are identified in boldface. In addition, I have included copies of the tie-down letters referenced in conditions 20.A. through 20.G. for your review.**

An environmental assessment for this action is not required, since this action is categorically excluded under 10 CFR 51.22(c)(14)(xi). You should review the enclosed document carefully and be sure that you understand all conditions. You can contact me at 817-200-1189 if you have any questions about this license.

The NRC's Safety Culture Policy Statement became effective in June 2011. While a policy statement and not a regulation, it sets forth the agency's expectations for individuals and organizations to establish and maintain a positive safety culture. You can access the policy statement and supporting material that may benefit your organization on NRC's safety culture Web site at http://www.nrc.gov/about-nrc/regulatory/enforcement/safety-culture.html. We strongly encourage you to review this material and adapt it to your particular needs in order to develop and maintain a positive safety culture as you engage in NRC-regulated activities.

NRC's Regulatory Issue Summary (RIS) 2005-31, provides criteria to identify security-related sensitive information and guidance for handling and marking of such documents. This ensures that potentially sensitive information is not made publicly available through ADAMS. The RIS may be located on the NRC Web site at: http://www.nrc.gov/reading-rm/doc-collections/gen-comm/reg-issues/2005/. Pursuant to NRC's RIS 2005-31, the enclosed materials license will not be made publicly available.

NRC expects licensees to conduct their programs with meticulous attention to detail and a high standard of compliance. Because of the serious consequences to employees and the public that can result from failure to comply with NRC requirements, you must conduct your radiation safety program according to the conditions of your NRC license, representations made in your license application, and NRC regulations. In particular, note that you must:

1. Operate by NRC regulations 10 CFR Part 19, "Notices, Instructions and Reports to Workers: Inspection and Investigations," 10 CFR Part 20, "Standards for Protection Against Radiation," and other applicable regulations.

2. Notify NRC in writing of any change in mailing address.

3. By 10 CFR 30.36(d) and/or license condition, notify NRC, promptly, in writing, and request termination of the license:

    a. When you decide to terminate all activities involving materials authorized under the license whether at the entire site or any separate building or outdoor area;

    b. If you decide not to acquire or possess and use authorized material; or

    c. When no principal activities under the license have been conducted for a period of 24 months.

4. Request and obtain a license amendment before you:

    a. Change Radiation Safety Officers;

    b. Order byproduct material in excess of the amount, radionuclide or form authorized on the license;

    c. Add or change the areas or address(es) of use identified in the license application or on the license; or

    d. Change the name or ownership of your organization.

5. Submit a complete renewal application or termination request at least 30 days before the expiration date on your license. You will receive a reminder notice approximately 90 days before the expiration date. Possession of radioactive material after your license expires is a violation of NRC regulations.

NRC will periodically inspect your radiation safety program. Failure to conduct your program according to NRC regulations, license conditions, and representations made in your license application and supplemental correspondence with NRC may result in enforcement action against you. This could include issuance of a notice of violation; imposition of a civil penalty; or an order suspending, modifying, or revoking your license as specified in the NRC Enforcement Policy. The NRC Enforcement Policy is available on the following internet address: http://www.nrc.gov/about-nrc/regulatory/enforcement/enforce-pol.html.

In accordance with 10 CFR 2.390 of the NRC's "Rules of Practice," a copy of this letter will be available electronically for public inspection in the NRC Public Document Room or from the NRC's document system (ADAMS). ADAMS is accessible from the NRC Web site at http://www.nrc.gov/reading-rm/adams.html.

Thank you for your cooperation.

Sincerely,

Roberto J. Torres, Senior Health Physicist
Nuclear Materials Safety Branch B

Docket: 030-30429
License: 42-26928-01
Control: 578115

Enclosure: As stated

NRC FORM 374 PAGE 1 OF 6 PAGES

U.S. NUCLEAR REGULATORY COMMISSION Amendment No. 44

MATERIALS LICENSE

Pursuant to the Atomic Energy Act of 1954, as amended, the Energy Reorganization Act of 1974 (Public Law 93-438), and Title 10, Code of Federal Regulations, Chapter I, Parts 30, 31, 32, 33, 34, 35, 36, 39, 40, and 70, and in reliance on statements and representations heretofore made by the licensee, a license is hereby issued authorizing the licensee to receive, acquire, possess, and transfer byproduct, source, and special nuclear material designated below; to use such material for the purpose(s) and at the place(s) designated below; to deliver or transfer such material to persons authorized to receive it in accordance with the regulations of the applicable Part(s). This license shall be deemed to contain the conditions specified in Section 183 of the Atomic Energy Act of 1954, as amended, and is subject to all applicable rules, regulations, and orders of the Nuclear Regulatory Commission now or hereafter in effect and to any conditions specified below.

Licensee	In accordance with letter dated July 30, 2012
1. Core Laboratories, Inc. dba ProTechnics Division of Core Laboratories 2. 6316 Windfern Road Houston, Texas 77040	3. License number 42-26928-01 is amended in its entirety to read as follows: 4. Expiration date February 28, 2016 5. Docket No. 030-30429 Reference No.

6. Byproduct, source, and/or special nuclear material	7. Chemical and/or physical form	8. Maximum amount that licensee may possess at any one time under this license
A. Hydrogen-3	A. Any	A. Not to exceed 999 millicuries total and 100 millicuries per injection
B. Scandium-46	B. Any	B. Not to exceed 8,000 millicuries total and 40 millicuries per injection
C. Bromine-82	C. Any	C. Not to exceed 3,000 millicuries total and 400 millicuries per injection
D. Zirconium-95	D. Any	D. Not to exceed 750 millicuries total and 40 millicuries per injection
E. Antimony-124	E. Any	E. Not to exceed 8,000 millicuries total and 40 millicuries per injection
F. Iodine-131	F. Any	F. Not to exceed 200 millicuries total and 50 millicuries per injection
G. Iridium-192	G. Any	G. Not to exceed 12,000 millicuries total and 40 millicuries per injection
H. Gold-198	H. Any	H. Not to exceed 1,000 millicuries total and 200 millicuries per injection
I. Bromine-82	I. Any	I. Not to exceed 3,000 millicuries total and 400 millicuries per injection
J. Barium-133	J. Sealed Source (Isotope Products Labs. Model HEG-133 Series, Capsule A-3015)	J. No single source to exceed 2 millicuries; total possession 40 millicuries

NRC FORM 374A U.S. NUCLEAR REGULATORY COMMISSION

MATERIALS LICENSE
SUPPLEMENTARY SHEET

License Number
42-26928-01

Docket or Reference Number
030-30429

Amendment No. 44

6. Byproduct, source, and/or special nuclear material	7. Chemical and/or physical form	8. Maximum amount that licensee may possess at any one time under this license
K. Cesium-137	K. Sealed Source (Isotope Products Model HEG-137 Series, Capsule A-3015)	K. No single source to exceed 500 millicuries; total possession 10 curies
L. Americium-241	L. Sealed Source (Gammatron AN-H, Gulf Nuclear VL-1)	L. No single source to exceed 500 microcuries; 10 millicuries total
M. Americium-241	M. Sealed Source (IPL HEG-241 Series, Capsule A-3015)	M. No single source to exceed 500 microcuries; 10 millicuries total
N. Scandium-46	N. Solid	N. No single marker to exceed 50 microcuries
O. Cobalt-60	O. Solid	O. No single marker to exceed 50 microcuries
P. Antimony-124	P. Solid	P. No single marker to exceed 50 microcuries
Q. Cesium-137	Q. Solid	Q. No single marker to exceed 100 microcuries
R. Iridium-192	R. Solid	R. No single marker to exceed 50 microcuries

9. Authorized use:

A. through H. For use in tracer studies in oil, gas, and geothermal wells.

I. For use in above ground tracer studies in process equipment and pipelines.

J. and K. For use in Cedar Bluff Group Fluid Identification logging tool.

L. and M. For use as a calibration/stabilization source in Halliburton Model TSCAN logging tool.

N. through R. For use in pipe collar markers in oil and gas wells.

NRC FORM 374A U.S. NUCLEAR REGULATORY COMMISSION	PAGE 3 of 6 PAGES
MATERIALS LICENSE **SUPPLEMENTARY SHEET**	License Number 42-26928-01
	Docket or Reference Number 030-30429
	Amendment No. 44

CONDITIONS

10. Licensed material shall be stored or used only at the following:

    A. i. Alaska Department of Natural Resources, Deadhorse Tract 57, Spine Road, Prudhoe Bay, Alaska
    ii. 1701 Old St. Mary's Pike, Parkersburg, West Virginia
    iii. 570 Jonah Drive, Rock Springs, Wyoming, and
    iv. 1030 Silurian Lane, Sidney, Montana

    B. Licensed material may be stored at Shell Offshore, Inc. Gas Well: OSG-C 11553, Well No. 2, Field: Garden Banks Block 602, Offshore Louisiana, in accordance with letter December 16, 1999, pending final abandonment

    C. Licensed material identified in letter dated March 02, 2006, may be stored at Exxon Mobil Production Company's Gas Well: Tip Top T65-30G2, Section 30 Township 29N Range 113W, Sublette County Wyoming, API #49-035-2389, in accordance with letter dated March 02, 2006, pending final abandonment.

    D. Licensed material identified in letter dated May 08, 2006, may be stored at Anadarko Petroleum Company's Well: Green Canyon 518#1 St00BP2, Offshore Gulf of Mexico, OCS-G21801, API#60-811-40377-02, in accordance with letter dated May 08, 2006, pending final abandonment.

    E. Temporary job sites anywhere in the United States where the U.S. Regulatory Commission maintains jurisdiction for regulating the use of licensed material, including areas of exclusive Federal jurisdiction within Agreement States.

    If the jurisdiction status of a Federal facility within an Agreement State is unknown, the licensee should contact the federal agency controlling the job site in question to determine whether the proposed job site is an area of exclusive Federal jurisdiction. Authorization for use of radioactive materials at job sites in Agreement States no under exclusive Federal jurisdiction shall be obtained from the appropriate state regulatory agency.

11. A. Licensed materials shall be used by or under the supervision and in the physical presence of, or individuals who have been trained as specified in letters dated December 16, 2005 and February 21, 2006.

    B. The Radiation Safety Officer for this license is Will C. Williams.

12. The licensee shall not vacate or release to unrestricted use a field office or storage location whose address is identified in Condition 10, without prior U.S. Nuclear Regulatory Commission approval.

13. The licensee is authorized to transport licensed material only in accordance with the provisions of 10 CFR Part 71, "Packaging and Transport of Radioactive Material."

NRC FORM 374A U.S. NUCLEAR REGULATORY COMMISSION	PAGE 4 of 6 PAGES
MATERIALS LICENSE **SUPPLEMENTARY SHEET**	License Number 42-26928-01
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14. Pursuant to 10 CFR 39.91, the licensee is exempted from the requirements of 10 CFR 39.63(b) for use of remote handling tools. This exemption will remain in effect until formally withdrawn by the U.S. Nuclear Regulatory Commission.

15. Notwithstanding the periodic leak test required by 10 CFR 39.35, the requirement does not apply to sources, except sources containing plutonium, that are stored and not being used. The sources exempted from this periodic test shall be tested for leakage before use or transfer to another person. No sealed source shall be stored for a period of more than 10 years without being tested for leakage and/or contamination.

16. Notwithstanding the requirements of 10 CFR 39.47 and pursuant to 10 CFR 39.91, and in accordance with the statements, representations and procedures contained in letters dated July 14, 1997 **(ML003724357)**, **November 14, 1997 (ML003724675)**, **January 20, 1998 (ML003724684)**, February 4, 1998 **(ML003724694)**, and February 27, 2004 **(ML040580735)**, the licensee may use radioactive markers with activities of 50 microcuries or less of iridium-192, scandium-46, antimony-124, and cobalt-60, and 100 microcuries or less of cesium-137 as pipe collar markers in oil and gas wells.

17. The licensee is authorized to hold byproduct material with a physical half-life of less than or equal to 120 days for decay-in-storage before disposal without regard to its activity if the licensee:

    A. Monitors byproduct material at the surface before disposal and determines that its radioactivity cannot be distinguished from the background radiation level with an appropriate radiation detection survey meter set on its most sensitive scale and with no interposed shielding; and

    B. Removes or obliterates all radiation labels, except for radiation labels on materials that are within containers and that will be managed as biomedical waste after they have been released from the licensee; and

    C. Maintains records of the disposal of licensed materials for up to 3 years. The record must include the date of disposal, the survey instrument used, the background radiation level measured at the surface of each waste container, and the name of the individual who performed the disposal.

18. **Notwithstanding the requirements of 10 CFR 20.2007, pursuant to 10 CFR 20.2002, and in accordance with the statements, representations, and procedures contained in correspondence dated May 4, 1993 (ML12243A227), April 20, 1994 (ML12243A209), January 17, 1996 (ML12243A188), February 13, 1996 (ML12243A188), and December 16, 2005 (ML060260462), the licensee may release well-logging sandouts and well returns, containing residual radioactive materials, into on-site shallow earthen pit provided that:**

    A. **The total radioactive concentration of all isotopes is 1,000 picocuries/gram or less, and the physical half-life of the radioactive material is 120 days or less.**

    B. **The residual radioactive tracer material (scandium-46, bromine-82, zirconium-95, antimony-124, iodine-131, iridium-192, or gold-198) being disposed of will be in the form of the patented "Zero-Wash" product in sandouts or well returns.**

NRC FORM 374A U.S. NUCLEAR REGULATORY COMMISSION	PAGE 5 of 6 PAGES
MATERIALS LICENSE SUPPLEMENTARY SHEET	License Number 42-26928-01
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C. The licensee is required to use well logging beads known as "Zero-Wash", which are insoluble where the radioactivity will not migrate or leach into groundwater, as described in letter dated July 11, 1991 (ML033040193).

D. The on-site shallow earthen pit disposal method has been permitted by the State, Territory, or Federal jurisdiction regardless of whether the job site is in an area where the U.S. Nuclear Regulatory Commission maintains jurisdiction for regulating licensed material, including areas of exclusive Federal jurisdiction within Agreement States.

E. The licensee is required to maintain access control over the on-site shallow earthen pit until the radioactivity has decayed to unrestricted release levels.

F. The licensee maintains an agreement with the owner or operator to control access to the on-site shallow earthen pit until the radioactivity has decayed to unrestricted release levels.

G. The licensee is required to maintain records of disposal in accordance with 10 CFR 20.2108.

19. Notwithstanding the requirements of 10 CFR 20.2007, pursuant to 10 CFR 20.2002, and in accordance with the statements, representations, and procedures contained in correspondence dated August 23, 2000 **(ML003758270)**, January 23, 2002 **(ML033070068)**, and October 30,2003 **(ML033070340)**, the licensee may release well-logging sandouts and well returns containing residual radioactive materials, into Class II Disposal Wells provided that:

A. The total radioactive concentration of all isotopes is 1,000 picocuries/gram or less, and the physical half-life of the radioactive material is 120 days or less.

B. The residual radioactive trace material (scandium-46, **bromine-82**, **zirconium-95**, antimony-124, **iodine-131**, iridium-192, or gold-198) being disposed of will be in the form of the patented "Zero-Wash" product in sandouts or well returns.

C. The licensee is required to use well logging beads known as "Zero-Wash", which are insoluble where the radioactivity will not migrate or leach into groundwater, as described in letter dated July 11, 1991 (ML033040193).

D. The well has been permitted by the State, Territory, or Federal jurisdiction to accept non-hazardous oil and gas waste regardless of whether the job site is in an area where the U.S. Nuclear Regulatory Commission maintains jurisdiction for regulating licensed material, including areas of exclusive Federal jurisdiction within Agreement States.

E. The licensee is required to maintain access control over the Class II Disposal Well until the radioactivity has decayed to unrestricted release levels.

F. The licensee maintains an agreement with the owner or operator to control access to the Class II Disposal Well until the radioactivity has decayed to unrestricted release levels.

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MATERIALS LICENSE SUPPLEMENTARY SHEET	License Number 42-26928-01
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G. The licensee is required to maintain records of disposal in accordance with 10 CFR 20.2108.

20. Except as specifically provided otherwise in this license, the licensee shall conduct its program in accordance with the statements, representations, and procedures contained in the documents, including any enclosures, listed below. The U.S. Nuclear Regulatory Commission's regulations shall govern unless the statements, representations, and procedures in the licensee's application and correspondence are more restrictive than the regulations.

A.	**Letter dated May 4, 1993**	**[ML12243A227, ML12243A209]**
B.	**Letter dated April 20, 1994 with procedures**	**[ML12243A209]**
C.	**Letter dated January 17, 1996**	**[ML12243A188, ML12235A437]**
D.	**Letter dated February 13, 1996**	**[ML12243A188, ML12235A437]**
E.	**Letter dated July 14, 1997**	**[ML003724357]**
F.	**Letter dated November 14, 1997**	**[ML003724675]**
G.	**Letter dated January 20, 1998**	**[ML003724684]**
H.	Letter dated February 4, 1998	[ML003724694]
I.	Letter dated December 16,1999	[ML003703009]
J.	Letter dated August 28, 2000	[ML003758270]
K.	Letter dated January 23, 2002	[ML033070068]
L.	Letter dated October 30, 2003	[ML033070340]
M.	Letter dated February 27, 2004	[ML040580735]
N.	Letter dated December 16, 2005 (renewal)	[ML060260462]
O.	Letter dated January 7, 2006 (renewal)	[ML060080505]
P.	Letter dated February 21, 2006	[ML060620583]
Q.	Letter dated March 7, 2006	[ML060620583]
R.	Letter dated January 27, 2006	[ML060410348]
S.	Letter dated May 8, 2006	[ML061290405]
T.	Letter dated February 27, 2008	[ML080740236]
U.	Letter dated June 7, 2011 with enclosures	[ML111720084]

FOR THE U.S. NUCLEAR REGULATORY COMMISSION

Date August 30, 2012

By _____
Roberto J. Torres, Senior Health Physicist
Nuclear Materials Safety Branch B
Region IV
Arlington, Texas 76011-4511

Attachment 3

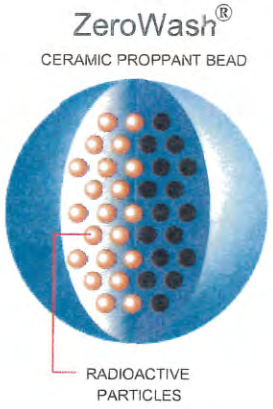
ZeroWash®
Isotope Tracer Technology

ZeroWash® tracers are manufactured using a patented process that prevents the isotope from being washed off the proppant-emulating carrier particle.This process fixes non-water-soluble metals in a ceramic matrix. After the resulting ceramic beads are kiln fired and sieved, they are activated by neutron bombardment in a nuclear reactor.

Because the resulting tracer particles are so effectively formed with no potential for wash off, ZeroWash® tracers provide unsurpassed environmental stewardship. They are HSE preferred and U.S. Nuclear Regulatory Commission (NRC) approved for burial.

ZeroWash® tracers, available in three primary isotopes, are produced in two forms:

- ZeroWash® ZW – an intermediate strength ceramic particle
- ZeroWash® ZWLD – a low-density ceramic particle



ISOTOPE TABLE

Isotope	Symbol	Form	Half Life Days	Energy Spectrum (million electron volts)
Iridium 192	Ir-192	ZW, ZWLD	74 days	0.315, 0.470, 0.605
Scandium 46	Sc-46	ZW, ZWLD	83.8 days	0.889, 1.121
Antimony 124	Sb-124	ZW, ZWLD	60.2 days	0.603, 0.722, 1.69

TRACER PROPERTIES AND USAGE

Tracer Form	Description	Mesh Size	Specific Gravity	Crush Strength (psi)	Color	Application
ZeroWash® (ZW)	Intermediate strength ceramic bead imbedded with oxide form of the isotpe	40/70 16 - 80 mesh available	2.65	>8,000	Various shades of gray	Designed to emulate particulate materials. Primarily used to trace pad fluids and acids at matrix rate
ZeroWash® (ZWLD)	Low density ceramic bead imbeded with oxide form of the isotope	40/70 30-100 mesh available	1.3 - 1.48	1,500 - 2,000	Dark green to brown	Designed to emulate fluid and low density materials. Used to trace pad fluids and acids at matrix rate

Attachment 4

Visual of Low Concentration



A 20-mCi vial of ZeroWash® traces 50,000 pounds of proppant

This low concentration is what allows us to operate without potential for exposure to the public.

Attachment 5

BAKER BOTTS LLP

FROM _____

ATTACHMENT 5

CONFIDENTIAL

CONFIDENTIAL

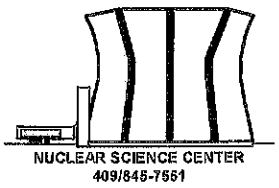
Attachment 6

TEXAS ENGINEERING EXPERIMENT STA

TEXAS A&M UNIVERSITY

COLLEGE STATION TEXAS 77843-3575

11 July 1991



ProTechnics International
14760 Memorial Drive, Suite 206
Houston, Texas 77079

We have completed the wash test on your patent pending radioactive carrier PTI-ZW under the testing criteria that you included in your guidelines and our input that we discussed. The test was performed and completed on June 19, 1991. Listed below are the test results.

Sincerely,

John L. Krohn
Assistant Director

RECEIVED 13 JUL 1991

JLK/ym

Radioactive Wash Test Results
(PTI-ZW)

	Temp	KCL Water	15% HCL
Washoff	80° F	12/1000 of 1%	17/1000 of 1 %
Washoff	180° F	40/1000 of 1%	41/1000 of 1 %

Note : These washoff amounts could be considered negligible in view of the probability of filter washby of production fines.

Santos

APPENDIX H.5 HALLIBURTON – CARBONRT

MEMO

To: Monique Harrison

From: Tom Biksey and Chris Bevan

CC: Nigel Goulding

Date: June 23, 2015

Re: **CARBONRT® ECONO Fluid System PBT Assessment and Comparison to Previous Hydraulic Fracturing Fluid**

Introduction

Santos GLNG (Santos) is looking to use a new proppant called CARBONRT® ECONO (CarboNRT), developed by CARBO Ceramics Inc., in their hydraulic fracturing process. CarboNRT is a non-radioactive tracer that can help measure fracture height and proppant location. The new proppant will be used in a Halliburton fluid system in conjunction with sand, water, bactericides, breakers, clay control, gelling agents, and pH control. **Attachment 1** provides the *Santos Prejob CarboNRT* disclosure for three concentration alternatives including a listing of the chemical constituents, CAS number and percent of total volume in the fluid system. The fluid system components provided in Attachment 1, with the exception of CarboNRT, were addressed previously as part of the Hydraulic Fracturing Risk Assessment Compendium (RA Compendium) by Santos GLNG Projects (2014). Specifically, the fluid system components were addressed either in the Delta 140 fluid system (Appendix C2 and C5 of the RA Compendium), or in the CleanStimAU fluid system (Appendix C3 of the RA Compendium).

To address the proposed use of CarboNRT in the new Halliburton fluid system for future hydraulic fracturing events, the following environmental hazard assessment was conducted to ensure compliance with Conditions of Santos' Gas Field Environmental Authorities (e.g. the Roma Shallow Gas Project Area East Environmental Authority PEN103814911). As part of this assessment, EHS Support obtained physical, chemical and toxicological data on the CarboNRT constituents. In addition, the drinking water guidelines and predicted no-effects concentrations (PNECs) for aquatic life in accordance with the previous risk assessment methodologies presented in the RA Compendium were reviewed and compiled for the environmental hazard assessment. **Attachment 2** includes the detailed human health and environmental toxicological profiles for the hydraulic fracturing chemicals with the exception of CarboNRT, which is inert (see PBT Assessment section below for summary of characteristics). **Attachment 3** includes the Safety Data Sheets for the hydraulic fracturing chemicals.

For the environmental hazard assessment, a PBT (persistence, bioaccumulative, toxic) assessment was conducted in accordance with the guidance developed by DEWHA (2009), as presented in the RA Compendium. The PBT assessment is conducted because of specific concerns for substances that can be shown to persist for long periods in the environment, to bioaccumulate in food chains, and can give rise to toxic effects after a longer time and over a greater spatial scale than chemicals without these properties. These effects may be difficult to detect at an early stage because of long-term exposures at normally low concentration levels and long life-cycles of species at the top of the food chain.

PBT Assessment

The results of the PBT assessment for the chemical constituents in the CarboNRT fluid system are summarised in **Table 1**. CarboNRT is a ceramic proppant (semi-crystalline alumina silicate; sintered kaolite), and an inorganic, nonmetalllic, inert solid particle. The following summarises these characteristics:

- Human health: CarboNRT is not expected to be absorbed by the oral, dermal, or inhalation routes of exposure due to its physical size. It is expected to be stable in biological media and resistant to metabolism, and essentially acutely non-toxic by the oral, dermal, and inhalation routes of exposure. Under certain conditions, dusts may be formed, which is to be considered as a nuisance dust. It is expected to be non-irritating and not a dermal sensitiser. CarboNRT is not expected to exhibit any systemic toxicity.
- Environmental: CarboNRT is persistent in the environment. It is not expected to bioaccumulate or to be toxic to aquatic organisms because of its water insolubility and lack of bioavailability. None of the CarboNRT fluid system chemical constituents was classified as a PBT chemical, and is therefore not considered to be inherently hazardous chemicals.

Comparison to Previous Assessed System Fluid

As described above, the previous stimulation fluid systems were assessed through the risk assessment processes developed in the RA Compendium. Through this assessment process, it was demonstrated that the operational controls and properties of the stimulation fluids would ensure that the chemicals were contained within the target sequences and would not exhibit long-term mobility. As detailed in the PBT assessment and the discussion presented below, the new proppant CarboNRT and the pre-existing fluid system does not introduce any new environmental risks, and has similar physical properties to the fluid systems previously assessed.

Table 2 and **Table 3** presents the drinking water guidelines and PNECs for aquatic life for the CarboNRT fluid system, **Table 4** compares the chemical constituents in the CarboNRT fluid system to the previous Halliburton fluid systems assessed as either Delta 140 or CleanStimAU. The following summarises the key findings of this comparison:

- The chemicals used in the CarboNRT fluid system are no more mobile than those assessed for Delta 140 or CleanStimAU fluid systems in the RA Compendium. Therefore, the chemicals are anticipated to be contained to the immediate vicinity of the fracture zone with many of the soluble organics (e.g., alcohols) rapidly biodegrading in the subsurface or being extracted in the flowback water.
- The CarboNRT fluid system does not contain BTEX (benzene, toluene, ethylbenzene, xylenes) or polycyclic aromatic hydrocarbons (PAHs); **Attachment 4** presents the Australian Government's National Measurement Institute (NATA) reports of analyses that document this finding.
- There were no carcinogenic chemicals identified in the CarboNRT fluid system.

Overall, the potential hazard to human health and the environment are less in the CarboNRT system fluid when compared to the previous Halliburton Delta 140 and CleanStimAU system fluid. In general, there are fewer constituents in the CarboNRT system fluid than in the previous Halliburton fluid system, including fewer solvents.

Based on the assessment presented, the potential risks to human health and the environment presented in the RA Compendium for Delta 140 and CleanStimAU would be expected to be similar or greater than the potential risks from CarboNRT, and a quantitative risk assessment is not required for CarboNRT. The existing combination of management and operational controls that were being implemented to eliminate and control the potential for exposures outlined in the quantitative risk assessment for the previous system fluids would also serve to eliminate and control any potential for

exposures from the CarboNRT system fluid. The potential risks would be within the acceptable range for implementation of management and operational controls. These include:

- Worker training and hazard identification
- Use of appropriate personal protective equipment (gloves, etc.)
- Flowback storage pond fencing to prevent entry of livestock and minimise trespassing
- Installation of dam liners and routine dam inspections to prevent releases from flowback storage ponds
- Routine operational and security patrols to prevent trespassing.

Reference

DEWHA. 2009. Environmental risk assessment guidance manual for industrial chemicals, Department of the Environment, Water, Heritage and the Arts, Commonwealth of Australia.

National Environmental Protection (Assessment of Site Contamination) Measure 1999. (National Environment Protection Council); and Monitoring and Sampling Manual 2009, Environmental Protection (Water) Policy 2009, DERM, Version 1, September 2009.

Santos GLNG Projects. 2014. Santos GLNG. Upstream Hydraulic Fracturing Risk Assessment Compendium of Assessed Fluid Systems

Tables

Table 1: PBT Assessment of the CarboNRT Fluid System

Substance	P/vP criteria fulfilled?	B/vB criteria fulfilled?	T criteria fulfilled?	Overall conclusion
Acetic acid (64-19-7)	No (screening data available)	No (screening data available)	No (experimental data available)	Not PBT (based on screening and experimental data)
Ceramic materials & wares, chemicals (66402-68-4)	Yes (inorganic, nonmetallic inert solid)	No (inorganic, nonmetallic inert solid)	No (inorganic, nonmetallic solid)	Not PBT (based on physic-chemical properties)
Guar Gum (9000-30-0)	No (screening data estimated)	No (screening data available)	No (screening data available)	Not PBT (based on screening and measured data)
Hemicellulase enzyme (9012-54-8)	No (screening data available)	No (screening data available)	No (screening data available)	Not PBT (based on screening data)
Lactose (63-42-3)	No (screening data using QSAR)	No (screening data using QSAR)	No (screening data using QSAR)	Not PBT (based on screening data using QSAR)
Monoethanolamine borate (26038-87-9, read-across from CAS No. 68512-53-8)	No (screening data available)	No (screening data available)	No (screening data available)	Not PBT (based on screening data)
Sodium hydroxide (1310-72-2)	Not applicable (ionic species ubiquitous in environment)	No (essential ions to biological systems; actively regulated)	No (screening data available)	Not PBT (based screening data and ubiquitous inorganic salt)
Tributyl tetradecyl phosphonium chloride (81741-28-8)	Yes (screening data available)	No (screening data available)	Yes (screening data available)	Not PBT (based on screening data)

Table 2: CarboNRT Oral Reference Doses and Drinking Water Guidelines Derived for Hydraulic Fracturing Chemicals

Constituent (CAS No.)	Study	Critical Effect/Target Organ(s)	NOAEL (mg/kg-day)	Uncertainty Factors	Oral Reference Dose (mg/kg-day)	Drinking Water Guideline (ppm)
Ceramic materials & wares, chemicals[1] (66402-68-4)	ND[2]	ND	ND	ND	ND	ND
Guar Gum (9000-30-0)	Rat 2-yr drinking water	General toxicity	1,250	100	12.5	44
Hemicellulase enzyme (9012-54-8)	13-week rat dietary	Reduced body weight gain	600	1,000	0.6	2
Lactose (63-42-3)	Combined reproductive/ chronic rat dietary	Cecum and fecal changes; ↑calcium uptake and excretion; kidney; adrenal effects and tumors	1,000	1,000	1.0	3.5
Monoethanolamine borate (26038-87-9, read-across from CAS No. 68512-53-8)	28-day rat oral gavage	None	1,000	1,000	1.0	3.5
Tributyl tetradecyl phosphonium chloride[3] (81741-28-8)	ND[1]	ND	ND	ND	ND	ND

[1]Biologically inert.

[2]Not determined.

[3]No available data.

Australian Drinking Water Screening Values for Hydraulic Fracturing Chemicals

Constituent (CAS No.)	Drinking Water Screening Guideline	Drinking Water Screening Value
Acetic acid (64-19-7)	pH	6.5 to 8.5
Sodium hydroxide (1310-72-2)	Sodium; pH	180 (aesthetic); 6.5 to 8.5

Table 3: CarboNRT Aquatic Toxicity Values

Constituents	Endpoint	E(L)C50 or NOEC (mg/L)	Assessment Factor	$PNEC_{aquatic}$ (mg/L)
Acetic acid (64-19-7)	Chronic Daphnia	23	50	0.46
Ceramic materials & wares, chemicals[1] (66402-68-4)	ND[2]	ND	ND	ND
Guar Gum (9000-30-0)	48-hr EC50 (Daphnia)	42	1,000	0.042
Hemicellulase enzyme (9012-54-8)	96-hr LC50 (fish)	330	1,000	0.33
Lactose (63-42-3)	Acute fish (QSAR)	81,045	1,000	81
Monoethanolamine borate (26038-87-9, read-across from CAS No. 68512-53-8)	72-hr EC50 (algae)	13	1,000	0.013
Sodium hydroxide (1310-72-2)	ND	ND	ND	ND
Tributyl tetradecyl phosphonium chloride (81741-28-8)	48-hr EC50 (*Daphnia*)	0.025	1,000	2×10^{-5}

[1]Biologically inert.

[2]ND = Not Determined.

Table 4: Comparison of Halliburton Fluid Systems: CarboNRT, Delta 140, and CleanStimAU

Constituent	CarboNRT	Delta 140	Clean StimAU	Drinking water guideline (ppm)	PNECaq (mg/L)
Acetic acid	X	X		6.5 to 8.5 pH	0.46
CarboNRT	X			ND	ND
Guar Gum	X	X		44	0.042
Hemicellulase enzyme	X	X	X	2	0.33
Lactose	X		X	3.5	81
Monoethanolamine borate (read-across from CAS No. 68512-53-8)	X	X		3.5	0.013
Sodium hydroxide	X	X		180 (aesthetic)	ND
Tributyl tetradecyl phosphonium chloride	X		X	ND	2×10^{-5}
Aluminum sulfate			X	0.18 (as Al)	0.06 (as Al)
Maltodextrin		X	X	ND	ND
Sodium chloride			X	180 for Na+ and 250 for Cl- (aesthetic)	ND
Shellac, ammonium salt			X	1.8	ND
Sodium carboxymethyl cellulose			X	ND	0.5
Sodium lauryl sulfate			X	4	0.09
Sorbitan, monododecanoate, poly(oxy-1,2-diethanediyl)			X	88	0.1
Sulfuric acid			X	H; 500 (health) and 250 (aesthetic) for SO_4	0.0026
Talc			X	ND	ND

Constituent	CarboNRT	Delta 140	Clean StimAU	Drinking water guideline (ppm)	PNECaq (mg/L)
Potassium chloride			X	63.7	0.1
Alcohols, C6-C12, ethoxylated propoxylated		X		2	1.69 Range: 0.1 - 5.77
Alcohols, C10-C16, ethoxylated propoxylated		X		2	0.54 Range: 0.04 - 1.8
Choline chloride		X		248	0.6
Cocoamidopropyl betaine		X		0.19	0.0186
Ethylene glycol		X		5.3	347
Polyethylene glycol		X		66	2
Tetrakis(hydroxylmethyl) phosphonium sulfate		X		0.01	0.0002

Attachment 1 - Santos Prejob CarboNRT Disclosure

HALLIBURTON

HALLIBURTON CONFIDENTIAL INFORMATION - ONLY TO BE USED FOR REGULATOR NOTIFICATION (QLD FORMAT)

Comments:
Santos PreJob FV-13-09-5, 6000 lb 16/30 Sand, 80000 lb 20/40 CarboNRT

Total injected fluid volume (kiloliters):	341.731

Comprising of: (Kilograms, liters or kiloliters)		
Base Fluid type (e.g. water)	**Liters**	**% of total volume**
Makeup Water	325545	95.3%

Proppant type (e.g sand)	**Proppant Size**	**Kilograms**	**Liters**	**% of total volume**
16/30 Sand	16/30	2722	1027	0.301%
20/40 CarboNRT	20/40	36287	13100	3.83%

Any wet chemical constitutes:	**Liters**	**% of total volume**
Water in Products	1054	0.309%
Guar gum	404	0.118%
Monoethanolamine borate	358	0.105%
Acetic acid	143	0.0419%
Sodium hydroxide	68	0.0199%
Lactose	20	0.00575%
Tributyl tetradecyl phosphonium chloride	9.8	0.00288%
Hemicellulase enzyme	2.0	0.00058%

HALLIBURTON

HALLIBURTON CONFIDENTIAL INFORMATION - ONLY TO BE USED FOR REGULATOR NOTIFICATION (QLD FORMAT)

Comments:
Santos PreJob FV-13-09-5, 6000 lb 16/30 Sand, 80000 lb 20/40 CarboNRT

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20/40 CarboNRT	20/40	36287	13100	3.83%

Any wet chemical constitutes:	**Liters**	**% of total volume**	**CAS**	**Ecotoxicity Data**
Water in Products	1054	0.309%	7732-18-5	No Hazard
Guar gum	404	0.118%	9000-30-0	Product is naturally occuring and not intrinsically hazardous.
Monoethanolamine borate	358	0.105%	26038-87-9	Freshwater Acute Algae Toxicity 72h EC50: 26 mg/L (Pseudokirchneriella subcapitata) [ECHA] (similar substance); Freshwater Acute Crustacean Toxicity 48h EC50: 423 mg/L (Daphnia magna) [ECHA]; Freshwater Acute Fish Toxicity 96h LC50: > 100 mg/L (Danio rerio) [ECHA]; Freshwater Biodegradation 28d: > 60 % [ECHA] (similar substance);
Acetic acid	143	0.0419%	64-19-7	Effect concentrations in the aquatic environment are attributable to a change in pH value Freshwater Acute Crustacean Toxicity 48h EC50: 65 mg/L (Daphnia magna) [US EPA HPVIS]; Freshwater Acute Cyanobacteria Toxicity 72h EC50: 55.22 mg/L (Anabaena flos-aquae) [ECHA]; Freshwater Acute Fish Toxicity 96h LC50: 75 mg/L (Lepomis macrochirus) [US EPA HPVIS]; Bioaccumulation Log Kow: -0.17 [ECHA]; Freshwater Biodegradation 7d: 99 % [US EPA HPVIS];
Sodium hydroxide	68	0.0199%	1310-73-2	Effect concentrations in the aquatic environment are attributable to a change in pH value Freshwater Acute Crustacean Toxicity 48h EC50: 40.4 mg/L (Ceriodaphnia sp.) [ECHA]; Freshwater Acute Fish Toxicity 96h LC50: 125 mg/L (Gambusia affinis) [OECD SIDS]; Bioaccumulation: Substance is inorganic - bioaccumulation is not applicable. Biodegradation: Substance is inorganic - biodegradation is not applicable.
Lactose	20	0.00575%	63-42-3	Component is naturally occuring and not intrinsically hazardous.
Tributyl tetradecyl phosphonium chloride	9.8	0.00288%	81741-28-8	Freshwater Acute Crustacean Toxicity 48h EC50: 0.0252 mg/L (Daphnia sp.) [US EPA ECOTOX]; Freshwater Acute Fish Toxicity 96h LC50: 0.0586 mg/L (Lepomis macrochirus) [US EPA ECOTOX]; Freshwater Biodegradation 28d: 0% [Cytec SDS];
Hemicellulase enzyme	2.0	0.00058%	9012-54-8	Freshwater Acute Algae Toxicity 72h EC50: > 52.1 mg/L active enzyme protein (Pseudokirchneriella subcapitata) [ECHA]; Freshwater Acute Crustacean Toxicity 48h EC50: > 52.1 mg/L active enzyme protein (Daphnia magna) [ECHA]; Freshwater Acute Fish Toxicity 96h LC50: > 100 mg/L (Oncorhynchus mykiss) [ECHA]; Bioaccumulation Log Pow: <0.05 [ECHA] (similar substance); Freshwater Biodegradation 3d: 96% [ECHA];

HALLIBURTON

HALLIBURTON CONFIDENTIAL INFORMATION - ONLY TO BE USED FOR REGULATOR NOTIFICATION (QLD FORMAT)

Comments:
Santos PreJob FV-18-15-5, 11000 lb 16/30 Sand, 130000 lb 20/40 CarboNRT

Total injected fluid volume (kiloliters):	560.284

Comprising of: (Kilograms, liters or kiloliters)		
Base Fluid type (e.g. water)	**Liters**	**% of total volume**
Makeup Water	533743	95.3%

Proppant type (e.g sand)	**Proppant Size**	**Kilograms**	**Liters**	**% of total volume**
16/30 Sand	16/30	4990	1883	0.336%
20/40 CarboNRT	20/40	58967	21288	3.80%

Any wet chemical constitutes:	**Liters**	**% of total volume**
Water in Products	1727	0.308%
Guar gum	662	0.118%
Monoethanolamine borate	587	0.105%
Acetic acid	233	0.0416%
Sodium hydroxide	111	0.0199%
Lactose	32	0.00572%
Tributyl tetradecyl phosphonium chloride	16	0.00287%
Hemicellulase enzyme	3.2	0.00057%

HALLIBURTON

HALLIBURTON CONFIDENTIAL INFORMATION - ONLY TO BE USED FOR REGULATOR NOTIFICATION (QLD FORMAT)

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16/30 Sand	16/30	4990	1883	0.336%
20/40 CarboNRT	20/40	58967	21288	3.80%

Any wet chemical constitutes:	**Liters**	**% of total volume**	**CAS**	**Ecotoxicity Data**
Water in Products	1727	0.308%	7732-18-5	No Hazard
Guar gum	662	0.118%	9000-30-0	Product is naturally occuring and not intrinsically hazardous.
Monoethanolamine borate	587	0.105%	26038-87-9	Freshwater Acute Algae Toxicity 72h EC50: 26 mg/L (Pseudokirchneriella subcapitata) [ECHA] (similar substance); Freshwater Acute Crustacean Toxicity 48h EC50: 423 mg/L (Daphnia magna) [ECHA]; Freshwater Acute Fish Toxicity 96h LC50: > 100 mg/L (Danio rerio) [ECHA]; Freshwater Biodegradation 28d: > 60 % [ECHA] (similar substance);
Acetic acid	233	0.0416%	64-19-7	Effect concentrations in the aquatic environment are attributable to a change in pH value Freshwater Acute Crustacean Toxicity 48h EC50: 65 mg/L (Daphnia magna) [US EPA HPVIS]; Freshwater Acute Cyanobacteria Toxicity 72h EC50: 55.22 mg/L (Anabaena flos-aquae) [ECHA]; Freshwater Acute Fish Toxicity 96h LC50: 75 mg/L (Lepomis macrochirus) [US EPA HPVIS]; Bioaccumulation Log Kow: -0.17 [ECHA]; Freshwater Biodegradation 7d: 99 % [US EPA HPVIS];
Sodium hydroxide	111	0.0199%	1310-73-2	Effect concentrations in the aquatic environment are attributable to a change in pH value Freshwater Acute Crustacean Toxicity 48h EC50: 40.4 mg/L (Ceriodaphnia sp.) [ECHA]; Freshwater Acute Fish Toxicity 96h LC50: 125 mg/L (Gambusia affinis) [OECD SIDS]; Bioaccumulation: Substance is inorganic - bioaccumulation is not applicable. Biodegradation: Substance is inorganic - biodegradation is not applicable.
Lactose	32	0.00572%	63-42-3	Component is naturally occuring and not intrinsically hazardous.
Tributyl tetradecyl phosphonium chloride	16	0.00287%	81741-28-8	Freshwater Acute Crustacean Toxicity 48h EC50: 0.0252 mg/L (Daphnia sp.) [US EPA ECOTOX]; Freshwater Acute Fish Toxicity 96h LC50: 0.0586 mg/L (Lepomis macrochirus) [US EPA ECOTOX]; Freshwater Biodegradation 28d: 0% [Cytec SDS];
Hemicellulase enzyme	3.2	0.00057%	9012-54-8	Freshwater Acute Algae Toxicity 72h EC50: > 52.1 mg/L active enzyme protein (Pseudokirchneriella subcapitata) [ECHA]; Freshwater Acute Crustacean Toxicity 48h EC50: > 52.1 mg/L active enzyme protein (Daphnia magna) [ECHA]; Freshwater Acute Fish Toxicity 96h LC50: > 100 mg/L (Oncorhynchus mykiss) [ECHA]; Bioaccumulation Log Pow: <0.05 [ECHA] (similar substance); Freshwater Biodegradation 3d: 96% [ECHA];

HALLIBURTON

HALLIBURTON CONFIDENTIAL INFORMATION - ONLY TO BE USED FOR REGULATOR NOTIFICATION (QLD FORMAT)

Comments:
Santos PreJob FV-13-14-1, 12000 lb 16/30 Sand, 200000 lb 20/40 CarboNRT

Total injected fluid volume (kiloliters):	842.375

Comprising of: (Kilograms, liters or kiloliters)		
Base Fluid type (e.g. water)	**Liters**	**% of total volume**
Makeup Water	802507	95.3%

Proppant type (e.g sand)	**Proppant Size**	**Kilograms**	**Liters**	**% of total volume**
16/30 Sand	16/30	5443	2054	0.244%
20/40 CarboNRT	20/40	90719	32750	3.89%

Any wet chemical constitutes:	**Liters**	**% of total volume**
Water in Products	2593	0.308%
Guar gum	995	0.118%
Monoethanolamine borate	882	0.105%
Acetic acid	350	0.0416%
Sodium hydroxide	167	0.0199%
Lactose	48	0.00571%
Tributyl tetradecyl phosphonium chloride	24	0.00285%
Hemicellulase enzyme	4.8	0.00057%

HALLIBURTON

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20/40 CarboNRT	20/40	90719	32750	3.89%

Any wet chemical constitutes:	**Liters**	**% of total volume**	**CAS**	**Ecotoxicity Data**
Water in Products	2593	0.308%	7732-18-5	No Hazard
Guar gum	995	0.118%	9000-30-0	Product is naturally occuring and not intrinsically hazardous.
Monoethanolamine borate	882	0.105%	26038-87-9	Freshwater Acute Algae Toxicity 72h EC50: 26 mg/L (Pseudokirchneriella subcapitata) [ECHA] (similar substance); Freshwater Acute Crustacean Toxicity 48h EC50: 423 mg/L (Daphnia magna) [ECHA]; Freshwater Acute Fish Toxicity 96h LC50: > 100 mg/L (Danio rerio) [ECHA]; Freshwater Biodegradation 28d: > 60 % [ECHA] (similar substance);
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Sodium hydroxide	167	0.0199%	1310-73-2	Effect concentrations in the aquatic environment are attributable to a change in pH value Freshwater Acute Crustacean Toxicity 48h EC50: 40.4 mg/L (Ceriodaphnia sp.) [ECHA]; Freshwater Acute Fish Toxicity 96h LC50: 125 mg/L (Gambusia affinis) [OECD SIDS]; Bioaccumulation: Substance is inorganic - bioaccumulation is not applicable. Biodegradation: Substance is inorganic - biodegradation is not applicable.
Lactose	48	0.00571%	63-42-3	Component is naturally occuring and not intrinsically hazardous.
Tributyl tetradecyl phosphonium chloride	24	0.00285%	81741-28-8	Freshwater Acute Crustacean Toxicity 48h EC50: 0.0252 mg/L (Daphnia sp.) [US EPA ECOTOX]; Freshwater Acute Fish Toxicity 96h LC50: 0.0586 mg/L (Lepomis macrochirus) [US EPA ECOTOX]; Freshwater Biodegradation 28d: 0% [Cytec SDS];
Hemicellulase enzyme	4.8	0.00057%	9012-54-8	Freshwater Acute Algae Toxicity 72h EC50: > 52.1 mg/L active enzyme protein (Pseudokirchneriella subcapitata) [ECHA]; Freshwater Acute Crustacean Toxicity 48h EC50: > 52.1 mg/L active enzyme protein (Daphnia magna) [ECHA]; Freshwater Acute Fish Toxicity 96h LC50: > 100 mg/L (Oncorhynchus mykiss) [ECHA]; Bioaccumulation Log Pow: <0.05 [ECHA] (similar substance); Freshwater Biodegradation 3d: 96% [ECHA];

Attachment 2 Human health and environmental toxicological profiles

Human health toxicological profiles

Toxicity Profile

Acetic acid
(CAS No. 64-19-7)

Acetic acid dissociates in aqueous media to H^+ and the acetate anion ($CH_3CO_2^-$). It is naturally occurring as the acid in apple cider vinegar and other fruit-derived products. It and several of its salts are commonly used as food additives (*e.g.*, as flavor enhancers) and are listed as Generally Recognized as Safe (GRAS) by the U.S. Food and Drug Administration (FDA).

pH: 2.5 at 50 g/L and 20°C
pK_a: 4.76 @ 20°C

Acute Toxicity

The oral LD_{50} in rats is 4,950 mg/kg, and the dermal LD_{50} in rabbits is 1,060 mg/kg. The 4-hour LC_{50} in rats is 11.4 mg/L.

Irritation

In the EU, acetic acid is classified as a skin and eye irritant at concentrations <25%. At ≥25%, it is classified as corrosive to the skin.

Sensitization

No data are available.

Repeated Dose Toxicity

In an 8-month study, rats dosed with 60 mg/kg acetic acid (three times per week) developed hyperplasia in the esophagus and forestomach.

Genotoxicity

Acetic acid was not mutagenic to *Salmonella typhimurium* strains TA 98, TA 100, TA 1535, TA 1537, and TA 1538 in an *in vitro* bacterial mutation assay with or without metabolic activation. Acetic acid (in media adjusted to a pH of 8.5) was also not genotoxic in an *in vitro* chromosomal aberration test using Chinese Hamster Ovary cells with or without metabolic activation.

Carcinogenicity

No adequate carcinogenicity studies have been conducted on acetic acid.

Reproductive Toxicity

No studies could be located.

Developmental Toxicity

There were no effects on implantations or on maternal or fetal survival in mice, rats, or rabbits at doses up to 1,600 mg/kg.

Key Study/Critical Effect for Screening Criteria

There are no repeat dose toxicity studies that were considered adequate for human health risk assessment. The only study reported on the toxicity of acetic acid by oral gavage showed effects of irritation (probably due to the pH of acetic acid) at the site of contact in the gastrointestinal tract. No systemic effects were reported.

The Joint FAO/WHO Expert Committee on Food Additives (JECFA) has maintained a group ADI of "not limited" for acetic acid and its potassium and sodium salts.

The Australian drinking water guidance value for pH may apply to acetic acid.

References

ECHA REACH: http://apps.echa.europa.eu/registered/registered-sub.aspx

JECFA: http://apps.who.int/ipsc/database/evaluations/chemical.aspx?chemID=4785

U.S. EPA HPVIS database: http://www.epa.gov/chemrtk/hpvis/index.html

Toxicity Profile

Guar Gum
(CAS No. 9000-30-0)

Guar gum (CAS No. 9000-30-0) is the milled endosperm of the leguminous plant *Cyanopsis tetragonolobus*. Structurally, it is a galactomannan consisting of a main chain of D-mannose with a side chain of D-galactose at approximately every second mannose unit. The mannose units are β-(l-4) linked, and the single D-galactose units are joined to the main chain by α-(1-6) linkages. The estimated molecular weight of guar gum cranges from 200,000 to 300,000 daltons (Glickman, 1969).

Guar gum is approved for use as a food additive by the U.S. Food and Drug Administration and is on the list of substances "generally recognized as safe" (CFR 1974).

Acute Toxicity

The oral LD_{50} is 8,100 mg/kg for mice and 9,400 mg/kg for rats (Bailey and Morgareidge, 1948).

Irritation

No data were found.

Sensitization

There are reports of respiratory sensitization in workers exposed occupationally to guar gum dusts (Maio, 1986).

Repeat Dose Toxicity Studies

F344 rats and $B6C3F_1$ mice were given diets containing 0, 6,300, 12,500, 25,000, 50,000 or 100,000 ppm guar gum for 13 weeks (NTP, 1982). Mean body weights were decreased in male rats (100,000 ppm group) and in female mice (50,000 and 100,000 ppm). A dose-related decrease in feed consumption was observed for male and female rats; male and female mice were comparable or higher than that of controls. There were no compound-related clinical signs or histopathological effects.

F344 rats and $B6C3F_1$ mice were given diets containing 0, 25,000 ppm or 50,000 ppm guar gum for 103 weeks (NTP, 1982). Mean body weights of the high-dose females were lower than those of the controls after week 20 for mice and week 40 for rats. No compound-

related clinical signs or adverse effects on survival were observed. Feed consumption by dosed rats and mice of either sex was lower than that of controls. There were no non-neoplastic histopathological effects in either rats or mice that were treatment-related.

Genotoxicity

Guar gum was not mutagenic to *Salmonella typhimurium* TA 1530 or G-46 when tested without metabolic activation; however, it was mutagenic to *Saccharomyces cerevisiae* D-3 (Green, 1977). Guar gum also was reported to cause chromosomal aberrations in human embryonic lung cells WI-38 (Green, 1977). No *in vivo* genotoxicity studies have been conducted on guar gum.

Carcinogenicity

F344 rats and B6C3F$_1$ mice were given diets containing 0, 25,000 ppm or 50,000 ppm guar gum for 103 weeks (NTP, 1982). There were increased incidences of adenomas of the pituitary in male rats and pheochromocytomas of the adrenal in female rats that were statistically significant, but these differences were considered to be unrelated to guar gum administration. When pituitary adenomas or carcinomas and when pheochromocytomas or malignant pheochromocytomas are combined, the statistical differences disappear. Hepatocellular carcinomas occurred in treated male mice at incidences that were significantly lower than that in controls. The combined incidence of male mice with either hepatocellular adenomas or carcinomas was also significantly lower in the high-dose group. It was concluded that under conditions of this bioassay, guar gum was not carcinogenic for F344 rats or B6C3F$_1$ mice.

Reproductive Toxicity

No data were found.

Developmental Toxicity

Female rabbits were given daily (6 hours/day) dermal administration of 0, 2, 10 and 50 mg/kg guar gum during gestational days 6 through 18 (IRDC, 1988). Mortalities included 2 deaths at 50 mg/kg and 1 death at 10 mg/kg. A single animal was killed in extremis. A dose-related increase in dermal irritation (including erythema, edema, and desquamation) was observed in animals receiving 10 and 50 mg/kg. The number of early resorptions was significantly increased and the number of viable fetuses was correspondingly decreased at 50 mg/kg/day ($p<0.05$). The frequency of fetal malformations and variations in the treated groups was comparable to that of the control group at all dose levels. The NOEL for this study is 2 mg/kg/day.

Key Study/Critical Effect for Screening Criteria

The key studies for the determination of a drinking water guidance value is the NTP two-year chronic bioassays. The LOAELs are based on decreased mean body weights in female mice and rats fed 50,000 ppm guar gum in diet for 103 weeks. The NOAELs for these studies are 25,000 ppm guar gum.

Rat: NOAEL (mg/kg/day) = 25,000 ppm * 0.05 = 1,250 mg/kg/day

Mouse: NOAEL (mg/kg/day) = 25,000 ppm * 0.13 = 3,250 mg/kg/day

Where 0.05 and 0.13 are the fraction of body weight that rats and mice, respectively, consume per day as food (U.S. EPA).

The lowest NOAEL of 1,250 mg/kg/day for the rat will be used to derive a drinking water guidance value.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD = 1,250/100 = 12.5 mg/kg/day

Drinking water guideline = 44 ppm

References

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Glicksman M. (1969). Gum technology in the Food Industry, pp. 590, Academic Press, New York; cited in Yoon, S.-J., Chu, D.-C., and Juneja, L.R. (2008) Chemical and physical properties, safety and application of partially hydrolyzed guar gum as dietary fiber. J. Clin. Biochem. Nutr. 42: 1-7.

Green, S. (1977). Present and future uses of mutagenicity tests for assessment of the safety of food additives. J. Environ. Pathol. Toxicol. 1: 49-54.

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Maio, J.L., Cartier, A., L'Archevêque, J., Ghezzo, H., Soucy, F., Somers, J., and Dolovich,

J. (1990). Prevalence of occupational asthma and immunologic sensitization to guar gum among employees at a carpet-manufacturing plant. J. Allergy Clin. Immunol. 86: 562-569.

NTP (1982). NTP Technical Report on the Carcinogenesis Bioassay of Guar Gum (CAS No. 9000-30-0) in F344 Rats and B6C3F$_1$ Mice (Feed Study), National Toxicology Program, Research Triangle Park, NC

Toxicity Profile

Hemicellulase
(CAS No. 9025-56-3)

Hemicellulases are a group of enzymes that break down hemicellulose, which are polysaccharides that are present in cell walls of all terrestrial plants. These polysaccharides have a β-(1→4)-linked backbone and are composed of pentoses (xylose, arabinoses), hexoses (mannose, glucose, galactose), and sugar acids. Unlike cellulose which are polysaccharides consisting of linear chains of several hundred to over ten thousand β-(1→4) linked D-glucoses, hemicelluloses are not chemically homogeneous. The best characterized hemicellulases are the 1,4- β -D-xylanases and, in particular, those derived from fungal sources presumably because their substrates, xylans, constitute the largest proportion of hemicelluloses in pasture plants.

No toxicity information could be located on hemicellulases; however, mammalian toxicity information were found on the cellulase enzymes (HERA, 2005). Cellulases cleave the ß-1,4-glycosidic bonds in cellulose, and are used in the pulp and paper industry, the textile industry, and in detergents to remove deposits and stains.

Enzymes are catalytic proteins or polypeptides and consist of amino acid residues coupled via peptide bonds. They are primarily characterized by their biocatalytic or enzymatic activity. There is a broad range of detergent cellulases used both from fungal as well as from bacterial origin; all are characterized by ß-1,4-endoglucanase activity. For the purposes of risk assessment, the structure of hemicellulases would be expected to be similar to that of cellulases, given that hemicellulases and cellulases are both enzyme families that hydrolyze polysaccharides, although differing in their substrates. Thus, the toxicity data on cellulases will be used as read-across to hemicellulases.

Acute Toxicity

The oral LD_{50} of a cellulase enzyme was calculated to be 8,000 mg/kg for mice and >10,000 mg/kg for rats (HERA, 2005). The inhalation LC_{50} of the same cellulase enzyme in rats was >3.48 mg/L. The mass mean diameter was 7.8 μm with a geometric standard deviation of 2.1 μm (HERA, 2005).

Irritation

Cellulase enzymes are mild to non-irritating to the skin and eyes of rabbits (HERA, 2005). However, the irritation potential is dependent on the amount of protease contamination in the enzyme test preparation, particularly with regards to eye irritation.

Sensitization

A cellulase enzyme was not a skin sensitizer to guinea pigs (HERA, 2005).

Repeated Dose Toxicity

Male and female rats were dosed by oral gavage with 0, 300, 1,000 or 3,000 mg/kg of a cellulase enzyme for 4 weeks. There were no treatment-related clinical signs, but a slight dose-related increase in body weight gain (approx. 7%) was seen in the males. No treatment-related changes were noted in the hematology or clinical chemistry. There were no gross or histopathologic changes that were considered treatment-related (HERA, 2005).

Male and female rats were given in their feed concentrations of 0, 120, 600 or 3,000 mg/kg of a cellulase enzyme for 13 weeks. There were no treatment-related clinical signs. A reduction in body weight gain was seen in both sexes at the 3,000 mg/kg level (10% in males and 20% in females). A slight reduction in food consumption was also noted for the 3,000 mg/kg rats. Alkaline phosphatase was increased in the 600 and 3,000 mg/kg females in a dose-dependent manner. There were no gross or histopathologic changes that were considered treatment-related. The NOAEL for this study is 600 mg/kg/day (HERA, 2005).

Genotoxicity

In an *in vitro* bacterial mutation assay, a cellulase enzyme was not mutagenic to *Salmonella typhimurium* strains TA 1535, TA 100, TA 1537 and TA98 in the presence or absence of metabolic activation. In an *in vivo* bone marrow micronucleus assay, a cellulase enzyme was not genotoxic when given to rats by oral gavage (HERA, 2005).

Carcinogenicity

No data were found.

Reproductive Toxicity

No data were found.

Developmental Toxicity

No data were found.

Key Study/Critical Effect for Screening Criteria

In a 13-week dietary study, there was reduced body weight gain in rats given 3,000 mg/kg of a cellulase enzyme. No other adverse effects were observed. The NOAEL for this study is 600 mg/kg-day.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (subchronic to chronic)

Oral RfD = 600/1000 = 0.6 mg/kg-day

Drinking water guideline = 2 ppm

Reference

Human and Environmental Risk Assessment (HERA) on Ingredients of Household Cleaning Products: α-amylase, CAS No. 9000-90-2; Cellulase (β-(1,4)-glucanase), CAS No. 9012-54-8; Lipase, 9001-62-1, 2005. http://www.heraproject.com

Toxicity Profile

Lactose
(CAS No. 63-42-3)

Lactose is a disaccharide sugar composed of galactose and glucose. It is naturally synthesized in the mammary gland of virtually all mammals, occurring in milk at levels between 1 and 7%. Commercially, lactose is extracted from the whey of cow's milk (whey is the residual liquid of milk following cheese and casein production) and is purified extensively to remove fats, proteins, vitamins and minerals (Baldrick and Bamford, 1997; Goodhart, 1994).

Pharmacokinetics/Metabolism

Lactose *per se* is not readily absorbed by the oral route. After dietary intake, lactose is readily hydrolyzed to galactose and glucose by the enzyme lactase (Hansen, 1974; Williams, 1986). Lactase is a β-galactosidase found in the brush border of the intestinal epithelium. Once hydrolyzed, the monosaccharides are then readily absorbed. Lactose can also be hydrolyzed by other enzymes, such as acid β-galactosidase.

Acute Toxicity

The acute oral LD_{50} in rats is >10,000 mg/kg (Baldrick and Bamford, 1997).

Irritation

No data were located.

Sensitization

No data were located.

Repeated Dose Toxicity/Carcinogenicity

Wistar rats were fed 20% lactose for 12 weeks before mating, and during pregnancy and lactation. At weaning, the animals were fed the same diet and the study was terminated at week 130. There were low body weights; increased blood alkaline phosphatase and urinary calcium; decreased pH of cecum contents; enlargement/increased weight of the cecum; pelvic nephrocalcinosis of the kidneys; increased proliferation of the bile ducts; adrenal medullary hyperplasia and pheochromocytomas; and Leydig cell tumors (Sinkeldam *et al.*, 1992a).

Similar findings were also observed in another study in which rats were fed 20% lactose in their diet for 130 weeks. Findings included loose feces (week one and two only); decreased pH of the feces; low body weights; increased food and water consumption; increased blood alkaline phosphatase and decreased bicarbonate; increased calcium concentration and excretion; reduced urinary pH; increased cecum weight; mineralization of the renal pelvis; increased incidence of basophilic cell foci in the adrenal medulla; and Leydig cell hyperplasia (De Groot *et al.*, 1995).

Genotoxicity

Lactose was negative in an *in vitro* chromosomal aberration study with cultured human lymphocytes in the presence and absence of metabolic activation (Sinkeldam *et al.*, 1992a).

Reproductive/Developmental Toxicity

In a multi-generation study, rats were fed 20% lactose over three successive generations. There were no adverse effects on fertility or reproductive performance. There was a slight decrease in the number of pups born alive, litter size at birth, viability index and pup weight for F_0 and F_1 offspring. There were signs of low body weights in the parental animals, and enlargement and increased weight of the cecum (Sinkeldam *et al.*, 1992b).

Pregnant mice were given 10,000 mg/kg lactose during gestation days 8-12. No maternal toxicity was observed and there were no effects on litter size, body weight on days 1 and 3, or neonate survival (Seidenberg *et al.*, 1986).

Key Study/Critical Effect for Screening Criteria

Many of the findings from the oral studies on lactose can be related to the fact that it is poorly absorbed from the small intestine. This results in a large proportion reaching the cecum and colon where it is readily fermented by the intestinal microflora. Consequently, there is increased production of volatile fatty acids and lactic acid, and a lowering of the pH and increased osmotic pressure. These changes facilitate calcium absorption. The adrenal tumors are thought to be secondary to increased calcium absorption from the intestine. Increased Leydig cell tumors in rats are of questionable relevance to humans.

Adverse effects were noted in rats given 20% in their diet for 130 weeks. Since there was only one dose level, a NOAEL was not identified.

LOAEL (mg/kg/day) = 20,000 ppm * 0.05 = 1,000 mg/kg/day

Where 0.05 is the fraction of body weight that is consumed per day as food for the mouse (U.S. EPA).

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (LOAEL to NOAEL)

Oral Reference Dose = 1,000/1,000 = 1.0 mg/kg/day

Drinking water guideline value = 3.5 ppm

References

Baldrick, P., and Bamford, D.R. (1997). A toxicological review of lactose to support clinical administration by inhalation. Food Chem. Toxicol. 35: 719-733.

DeGroot, A.P., Lina, B.A.R., Hagenaars, A.J.M., Hollanders, V.M.H., Andringa, M., and Feron, V.J. (1995) Effects of a dietary load of acid or base on changes induced by lactos in rats. Food. Chem. Toxicol. 33: 1-14.

Goodhart, F.W. (1994). Lactose. In: handbook of Pharmaceutical Excipients, 2nd Edition, pp. 252-261, The Pharmaceutical Press, London.

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Williams, C.A. (1986) Metabolism of lactose and galactose in man. Prog. Biochem. Pharmacol. 21: 219-247.

Toxicity Profile

Monoethanolamine borate
(CAS No. 26038-87-9)

The toxicity profile includes toxicity data on boric acid, reaction products with ethanolamine and triethanolamine (CAS No. 68512-53-8), which is structurally similar to monoethanolamine borate.

Acute Toxicity

The acute oral LD_{50} in rats is >2,000 mg/kg, and the acute dermal LD_{50} of CAS 68512-53-8 in rats is >2,000 mg/kg.

Irritation

Monoethanolamine borate was slightly irritating and was not considered to be a skin irritant when tested on the skin of rabbits. Monoethanolamine (MEA) Polyborate 1:1 and MEA Polyborate 1:3 were tested for eye irritancy using the Bovine Corneal Opacity and Permeability test (BCOP test). Minimal to no ocular irritation was observed in both studies.

Sensitization

CAS No. 68512-53-8 was not a skin sensitizer to guinea pigs using the Buehler method.

Repeated Dose Toxicity

Groups of male and female rats received CAS No. 68512-53-8 by oral gavage at dose levels of 0, 62.5, 250 or 1,000 mg/kg body weight per day for a period of 28 days. No deaths occurred throughout the study. Behavior, state of health, body weight development and food consumption, were not affected by administration of the test substance. No treatment-related clinical signs were observed in all animals. No changes of the oral mucosa or impairment of dental growth was observed in all study groups. There were no substance related adverse findings either in hematological examinations, clinical chemistry or urine analyses throughout the study period. As a non-adverse finding, the test substance induced slightly lower total bilirubin, cholesterol and triglycerides in high dose group rats (1,000 mg/kg body weight) and possibly marginally lower hemoglobin and hematocrit content when compared to the controls at the end of the study period. These changes were at the lower range of the historical control data for this rat strain and age and hence, not considered to be of toxicological significance. The test substance did not influence any of

the neurotoxicological parameters. No test article related changes in organ weights were observed. Necropsy at terminal sacrifice revealed no gross pathology findings in the animals of all experimental groups. All microscopic findings sporadically observed in different organs of single animals were interpreted as not compound related. The NOAEL for this study is 1,000 mg/kg/day.

Genotoxicity

In an *in vitro* chromosomal aberration test using cultured peripheral human lymphocytes, MEA Polyborate 1:1 showed a clastogenic response in experiments where the pH of the treated cultures was above the pH of the solvent control. The clastogenicity was only observed in the first cytogenetic assay. Due to fact that the adjustment of the pH of the cultures treated with MEA Polyborate 1:1 did not show a clastogenic response in the third cytogenetic assay, it has to be assumed that the high pH is responsible for the detected clastogenic activity.

In an *in vitro* chromosomal aberration test using cultured peripheral human lymphocytes, MEA Polyborate 1:3 did not induce a statistically significant or biologically relevant increase in the number of cells with chromosome aberrations in the absence and presence of S9-mix, in either of the two independently repeated experiments. CAS No. 68512-53-8 did not induce gene mutations in an *in vitro* HPRT-test with V79 Chinese hamster lung fibroblast cells, either in the presence or in the absence of metabolic activation.

Carcinogenicity

No data are available.

Reproductive Toxicity

No data are available.

Developmental Toxicity

No data are available.

Key Study/Critical Effect for Screening Criteria

A 28-day oral toxicity study conducted was conducted in rats with CAS No. 68512-53-8 (Boric acid, reaction products with ethanolamine and triethanolamine). The NOAEL for this study is 1,000 mg/kg/day. Data from CAS No. 68512-53-8 is being used as read-across to monoethanolamine borate.

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (subacute to chronic)

Oral RfD = 1000/1000 = 1 mg/kg/day

Drinking water guideline: 3.5 ppm

Reference

ECHA REACH database: http://apps.echa.europa.eu/registered/registered-sub.aspx

Toxicity Profile

Sodium hydroxide
(CAS No. 1310-73-2)

Sodium hydroxide (NaOH) has been reviewed in the OECD-SIDS program (OECD, 2002a,b).

Sodium hydroxide (NaOH) is present in the environment as sodium (Na^+) and hydroxyl ions (OH^-). Sodium is a normal constituent of the blood and an excess is excreted in the urine. A significant amount of sodium is taken up via the food because the normal uptake of sodium via food is 3.1-6.0 g per day according to Fodor *et al.* (1999). Exposure to NaOH could potentially increase the pH of the blood. However, the pH of the blood is regulated between narrow ranges to maintain homeostasis (pH of 7.4 to 7.5) by urinary excretion of bicarbonate and via exhalation of carbon dioxide.

Acute Toxicity

An oral LD_{50} of a 1-10% solution of NaOH in rabbits was reported to be 325 mg/kg (expressed as 100% NaOH). Mortality was also observed when 1% NaOH was dosed, but in this case, the applied volume was relatively high (24 mL per kg body weight).

Irritation

A NaOH solution of 8% can be considered corrosive based on animal data. Human data indicate that concentrations of 0.5 to 4% were irritating. In two different studies a concentration of 0.5% was irritating for only 55 and 61% of the volunteers, respectively. Thus, it is assumed that a concentration, which is slightly lower than 0.5%, is the non-irritating concentration.

The available animal data on eye irritation showed that the non-irritant level was 0.2-1.0 %, while the corrosive concentration was 1.2 % or >2%.

Sensitization

Male volunteers were exposed on the back to sodium hydroxide concentrations of 0.063 – 1.0% (induction). After 7 days the volunteers were challenged to a concentration of 0.125%. The irritant response correlated well with the concentration of NaOH, but an increased response was not observed when the previously patch tested sites were re-challenged. Based on this study sodium hydroxide has no skin sensitization potential.

Repeated Dose Toxicity

No animal data are available on repeated dose toxicity studies by oral, dermal, inhalation or by other routes for NaOH. It is not useful to study the repeated dose toxicity of hydroxide via an oral study because at high concentrations the substance is corrosive or irritating, while at low concentrations the hydroxide will be neutralized in the stomach by gastric juice, which has a very low pH.

Genotoxicity

Both the *in vitro* and the *in vivo* genotoxicity tests are negative.

Carcinogenicity

No carcinogenicity studies on sodium hydroxide were identified.

Reproductive Toxicity

No valid studies were identified regarding toxicity to reproduction in animals after oral, dermal or inhalation exposure to NaOH. It is not useful to study the reproduction/developmental toxicity of hydroxide via an oral study because at high concentrations the substance is corrosive or irritating, while at low concentrations the hydroxide will be neutralized in the stomach by gastric juice, which has a very low pH.

Developmental Toxicity

No valid studies were identified regarding developmental toxicity in animals after oral, dermal or inhalation exposure to NaOH. It is not useful to study the reproduction/developmental toxicity of hydroxide via an oral study because at high concentrations the substance is corrosive or irritating, while at low concentrations the hydroxide will be neutralized in the stomach by gastric juice, which has a very low pH.

Key Study/Critical Effect for Screening Criteria

The Australian drinking water guideline value for pH may apply to sodium hydroxide.

Reference

OECD (2002). IUCLID Data Set for Sodium hydroxide (CAS No. 1310-73-2), UNEP Publications.

OECD (2002). Screening Information Dataset (SIDS) Initial Assessment Report for Sodium hydroxide (CAS No. 1310-73-2), UNEP Publications.

Toxicity Profile

Tributyl Tetradecyl Phosphonium Chloride [TTPC]
(CAS No. 81741-28-8)

Limited toxicity information was located for this alkyl phosphonium salt.

Acute Toxicity

An oral LD_{50} in rats was reported to be 1,002 mg/kg. The 4-hour LC_{50} to rats is <0.9 mg/L (aerosol).

Irritation

TTPC is corrosive to the skin and eyes.

Sensitization

TTPC is not a skin sensitizer.

Repeated Dose Toxicity

No data were found.

Genotoxicity

TTPC tested negative in an Ames test.

Carcinogenicity

No data were found.

Reproductive Toxicity

No data were found.

Developmental Toxicity

No data were found.

Key Study/Critical Effect for Screening Criteria

No data are available for determining the critical effect and the LOAEL/NOAEL for an oral reference dose.

Reference

Material Safety Data Sheet for Bellacide 350, BWA Water Additives, SDS No. 10794, Report Date: 10/03/2009.

Environmental toxicological profiles

Environmental Assessment

Acetic Acid
(CAS No. 64-19-7)

Acetic acid and its salts undergo dissociation in aqueous media into the acetate anion ($H_3C_2O_2^-$) and the respective cations (H^+, NH_4^+, Ca^{2+}, Mg^{2+}, Mn^{2+}, K^+, Na^+). The toxicity of each compound is driven by acetate, with the cations playing a minor role. The pH is 2.5 at 50 g/L and 20ºC; and the pK_a is 4.76 at 20ºC.

Environmental Transport

Level I fugacity modeling predicts that about 73% of any acetic acid released to the environment would partition to water, with the remainder partitioning into the air (U.S. HPVIS database).

Biodegradation

Acetic acid and its salts readily dissociate into their respective cations and the acetate anion; the anion acetate is readily biodegraded. In aerobic conditions using adapted wastewater from domestic sewage, degradation was 96% after 20 days (Price *et al.*, 1974). It was also shown to be readily biodegradable under anaerobic conditions using activated sludge (99% after 7 days) (Kameya *et al.*, 1995).

Aquatic Toxicity

The 96-hour LC_{50} in bluegill sunfish is 75 mg/L (Price *et al.*, 1974), and the 96-hour LC_{50} in mosquito fish is 251 mg/L (Wallen *et al.*, 1957). The 96-hour LC_{50} of 60% acetic acid in *Oncorhynchus mykiss* is 108 mg/L (64.8 mg acetic acid/L) (unpublished data, ECHA). In a chronic study with *Oncorhynchus mykiss*, the 21-day LC_{50} and NOEC for 60% acetic acid were 87 mg/L and 57.2 mg/L, respectively (unpublished data, ECHA). The 21-day LC_{50} and NOEC for 100% acetic acid were 52.2 mg/L and 34.3 mg/L, respectively (unpublished data, ECHA).

The 24-hour EC_{50} to Daphnia was reported to be 95 mg/L (un-neutralized) and 6,000 mg/L (neutralized to pH 8.0) (Bringmann and Kuehn, 1982). One other study showed the 48-hour EC_{50} to be 65 mg/L (Janssen *et al.*, 1993). In a chronic Daphnia study, the 21-day NOEC for reproduction was reported to be 22.7 mg/L for 100% acetic acid (unpublished data, ECHA). In another chronic Daphnia study, the 21-day NOEC for reproduction was 31.4 mg/L for 100% acetic acid (unpublished data, ECHA).

In an algae growth inhibition study, the reported nominal ErC_{50} to *Desmodesmus subspicatus* was 810.9 mg/L for 60% acetic acid (unpublished data, ECHA). The reported

nominal ErC_{50} was 486.5 mg/L for 100% acetic acid (unpublished data, ECHA). The toxicity threshold to algae after 8 days in a growth inhibition test was reported to be 4,000 mg/L (Bringmann and Kuehn, 1980).

Toxicity to Terrestrial Organisms

No data could be located.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (65 mg/L) and Daphnia (65 mg/L), and algae (487 mg/L). Long-term results are also available for fish (NOEC = 34 mg/L) and Daphnia (NOEC = 23 mg/L). On the basis that the data consists of short-term results from three trophic levels and two chronic study for fish and another chronic study for Daphnia, an assessment factor of 50 has been applied to the lowest NOEC of 23 mg/L for Daphnia.
The $PNEC_{aquatic}$ was calculated to be 0.5 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Acetic acid dissociates completely in water with its environmental distribution dominated by its high water solubility. Since log Kow and Koc are only applicable to the non-ionized forms of a substance, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Thus, the determination of the $PNEC_{sediment}$ is not possible. Based on its properties, no adsorption of acetic acid to sediment is to be expected and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. Acetic acid dissociates completely in water with its environmental distribution dominated by its high water solubility. Since log Kow and Koc are only applicable to the non-ionized forms of a substance, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Thus, the determination of the $PNEC_{soil}$ is not possible. Based on its properties, no adsorption of acetic acid to soil is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

The acetate ion of acetic acid is readily biodegradable and thus it does not meet the screening criteria for persistence.

The log Kow for acetic acid is reported to be -0.17 (Verschueren, 1966). Acetate is also found in the body and is metabolized as part of the body's biochemical pathways. Thus,

acetic acid (specifically, the acetate ion) does not meet the screening criteria for bioaccumulation.

The NOECs from the chronic aquatic toxicity data on acetic acid are >0.01 mg/L. Thus, acetic acid does not meet the criteria for toxicity.

The overall conclusion is that acetic acid is not a PBT substance.

References

Bringmann, G.,and Kuehn, R. (1980). Comparison of the toxicity thresholds of water pollutants to bacteria, algae, and protozoa in the cell multiplication inhibition test. Water Res. 14: 231-241.

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U.S. EPA HPVIS database: http://www.epa.gov/chemrtk/hpvis/index.html

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Wallen I.E., Greer, W.C., and Lasater, R. (1957). Toxicity to *Gambusia affinis* of certain pure chemicals in turbid waters. Sewage Ind. Wastes 23: 695-711.

Environmental Assessment

Guar Gum
(CAS No. 9000-30-0)

Guar gum (CAS No. 9000-30-0) is the milled endosperm of the leguminous plant *Cyanopsis tetragonolobus*. Structurally, it is a galactomannan (a polysaccharide) consisting of a main chain of D-mannose with a side chain of D-galactose at approximately every second mannose unit. The mannose units are β-(l-4) linked, and the single D-galactose units are joined to the main chain by α-(1-6) linkages. The estimated molecular weight of guar gum ranges from 200,000 to 300,000 daltons (Glickman, 1969).

Biodegradation

No information was found. Guar gum, being a polysaccharide composed of galactomannan, would be expected to be readily biodegradable.

Bioaccumulation

Not expected to bioaccumulate as a polysaccharide composed of galactomannans.

Aquatic Toxicity

The 48-hour LC_{50} for *Daphnia magna* was reported to be 42 mg/L (Biesinger *et al.*, 1976).

Toxicity to Terrestrial Organisms

No data were located.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for one trophic level. An acute LC_{50} value is available for the invertebrate Daphnia (42 mg/L). On the basis that the data consists of only one short-term result from one trophic level, an assessment factor of 1,000 has been applied to the reported effect concentration of 42 mg/L for Daphnia. The $PNEC_{aquatic}$ is 0.042 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The Kow and Koc of guar gum cannot be calculated using EPISUITE because the molecular weight of guar gum greatly exceeds the limit of 1,000. Thus, the equilibrium partition

method cannot be used to determine a $PNEC_{sediment}$ and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on soil organisms are available. The Kow and Koc of guar gum cannot be calculated using EPISUITE because the molecular weight of guar gum greatly exceeds the limit of 1,000. Thus, the equilibrium partition method cannot be used to determine a $PNEC_{soil}$ and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

No biodegradation was found on guar gum. However, guar gum is a naturally occurring polysaccharide which would be expected to readily biodegrade. Thus, it is not expected to meet the screening criteria for persistence.

The molecular weight of guar gum ranges from 200,000 to 300,000 daltons, and it is also water soluble. Thus, guar gum is not expected to meet the criteria for bioaccumulation.

The acute aquatic toxicity of guar gum is >0.1 mg/L. Thus, guar gum is not expected to meet the screening criteria for toxicity.

The overall conclusion is that guar gum is not a PBT substance.

References

Biesinger, K.E. et al. (1976). Comparative toxicity of polyelectrolytes to selected aquatic animals. J. Water Pollut. Control Fed. 48: 183-187; cited in NZ HSNO CCID. http://www.epa.govt.nz/search-databases/Pages/ccid-details.aspx?SubstanceID=1930

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Environmental Assessment

Hemicellulase
(CAS No. 9025-56-3)

Hemicellulases are a group of enzymes that break down hemicellulose, which are polysaccharides that are present in cell walls of all terrestrial plants. These polysaccharides have a β-(1→4)-linked backbone and are composed of pentoses (xylose, arabinoses), hexoses (mannose, glucose, galactose), and sugar acids. Unlike cellulose which are polysaccharides consisting of linear chains of several hundred to over ten thousand β-(1→4) linked D-glucoses, hemicelluloses are not chemically homogeneous. The best characterized hemicellulases are the 1,4- β -D-xylanases and, in particular, those derived from fungal sources presumably because their substrates, xylans, constitute the largest proportion of hemicelluloses in pasture plants.

No toxicity information could be located on hemicellulases; however, mammalian toxicity information were found on the cellulase enzymes (HERA report, 2005). Cellulases cleave the ß-1,4-glycosidic bonds in cellulose, and are used in the pulp and paper industry, the textile industry, and in detergents to remove deposits and stains.

Enzymes are catalytic proteins or polypeptides and consist of amino acid residues coupled via peptide bonds. They are primarily characterized by their biocatalytic or enzymatic activity. There is a broad range of detergent cellulases used both from fungal as well as from bacterial origin; all are characterized by ß-1,4-endoglucanase activity. For the purposes of risk assessment, the structure of hemicellulases would be expected to be similar to that of cellulases, given that hemicellulases and cellulases are both enzyme families that hydrolyze polysaccharides, although differing in their substrates. Thus, the toxicity data on cellulases will be used as read-across to hemicellulases.

Biodegradation

Three different cellulase enzymes were considered readily biodegradable based on the results of OECD 301C and 301E tests (HERA, 2005). In an OECD 301E test, there was 84% DOC removal of the enzyme Carezyme after 28 days. In another OECD 301E test, there was 92% DOC removal of the enzyme Clazinase® after 28 days. In an OECD 301C test, BOD/COD was 78% after 28 days. Likewise, hemicellulase is expected to be readily biodegradable.

Aquatic Toxicity

The 96-hour LC_{50} of an alkaline cellulase to zebrafish (*Brachydanio rerio*) is 330 mg aep/L (HERA, 2005). The 48-hour EC_{50} of the same alkaline cellulase to *Daphnia magna* is >1,000 mg aep/L (HERA, 2005). The same alkaline cellulase was also tested in algae (*Scenedesmus subspicatus*), with a 72-hour EC_{50} of >1000 mg aep/L (HERA, 2005).

The 24- and 48-hour EC_{50} values of an alkaline cellulase (SP 227, Celluzyme) to *Daphnia magna* are >1,000 mg aep/L and approximately 1,000 mg aep/L respectively (HERA, 2005).

Two additional acute fish toxicity studies showed findings with LC_{50} values of >100 mg aep/L, but no references were provided (HERA, 2005).

Toxicity to Sediment Organisms

No data could be located.

Toxicity to Terrestial Organisms

No data could be located.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (330 mg aep/L), Daphnia (>1,000 mg aep/L), and algae (1,000 mg aep/L). Although the HERA report provides information on two acute fish studies with LC_{50} values of >100 mg aep/L, no references were provided and were therefore excluded from the determination of PNECs. On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 330 mg aep/L for fish. The $PNEC_{aquatic}$ is 0.33 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$. A calculated Koc of <1.3 was reported in the HERA report, calculated according to the TGD. Using a Koc of 1.3 and a $PNEC_{aquatic}$ of 0.33 mg aep/L, the $PNEC_{sediment}$ was calculated to be 0.21 mg aeg/kg.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The equilibrium partition method was used to determine a $PNEC_{soil}$. A calculated Koc of <1.3 was reported in the HERA report, calculated according to the TGD. Using a Koc of 1.3 and a $PNEC_{aquatic}$ of 0.33 mg aep/L, the $PNEC_{soil}$ was calculated to be 0.006 mg aeg/kg.

PBT Assessment

Hemicellulase is expected to be readily biodegradable based on read-across to cellulases. Thus, hemicellulase does not meet the screening criteria for persistence.

Based on the similarity to cellulase, hemicellulase has a high molecular weight (20 to 80 kD), has hydrophilic properties (high water solubility, log Kow <0), and is readily metabolized in organisms by proteolytic enzymes or proteases. Thus, hemicellulose does not meet the screening criteria for bioaccumulation.

The acute $EC(L)_{50}$ of hemicellulase is >0.1 mg/L in fish, invertebrates and algae. Thus, hemicellulase does not meet the screening criteria for toxicity.

The overall conclusion is that hemicellulase is not a PBT substance.

Reference

Human and Environmental Risk Assessment (HERA) on Ingredients of Household Cleaning Products: α-amylase, CAS No. 9000-90-2; Cellulase (β-(1,4)-glucanase), CAS No. 9012-54-8; Lipase, 9001-62-1, 2005. http://www.heraproject.com

Environmental Assessment

Lactose
(CAS No. 63-42-3)

Lactose is a disaccharide sugar composed of galactose and glucose. It is naturally synthesized in the mammary gland of virtually all mammals, occurring in milk at levels between 1 and 7%. Commercially, lactose is extracted from the whey of cow's milk (whey is the residual liquid of milk following cheese and casein production) and is purified extensively to remove fats, proteins, vitamins and minerals (Baldrick and Bamford, 1997; Goodhart, 1994).

Biodegradation

No biodegradation studies were found on lactose. The QSAR model BIOWIN estimates that the biodegradation of lactose would be fast, with primary degradation in hours-days and ultimate degradation in days-weeks (U.S. EPA, 2011).

Aquatic Toxicity

No aquatic toxicity studies were found on lactose.

Using ECOSAR, the 96-hour LC_{50} in fish was estimated to be 81,045 mg/L; the 48-hour LC_{50} in *Daphnia* was estimated to be 3,460,000 mg/L; and the 96-hour EC_{50} in green algae was estimated to be 583,000 mg/L (U.S. EPA, 2011).

Toxicity to Sediment Organisms

No data could be located.

Toxicity to Terrestrial Organisms

No data could be located.

Determination of PNECs

$PNEC_{aquatic}$: No experimental results are available for lactose. Acute $E(L)C_{50}$ estimates using the QSAR model ECOSAR are: fish (81,045 mg/L), Daphnia (3,460,000 mg/L), and algae (583,000 mg/L). On the basis that the data consists of short-term results from three

trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 81,045 mg/L for fish. The $PNEC_{aquatic}$ is 81 mg/L.

PBT Assessment

No experimental biodegradation data are available on lactose. The QSAR model BIOWIN predict that lactose will biodegrade fast, with primary degradation in hours-days and ultimate degradation in days-weeks. Thus, lactose does not meet the screening criteria for persistence.

The estimated log K_{ow} and BCF for lactose is -5.03 and 3.162, respectively (U.S. EPA, 2011). Thus, lactose does not meet the screening criteria for bioaccumulation.

The estimated acute $EC(L)_{50}$ values of lactose indicate that it is non-toxic to fish, invertebrates and algae. Thus, it does not meet the screening criteria for toxicity.

The overall conclusion is that lactose is not a PBT substance.

References

Baldrick, P., and Bamford, D.R. (1997). A toxicological review of lactose to support clinical administration by inhalation. Food Chem. Toxicol. 35: 719-733.

Goodhart, F.W. (1994). Lactose. In: handbook of Pharmaceutical Excipients, 2nd Edition, pp. 252-261, The Pharmaceutical Press, London.

U.S. EPA (2011). EPISuite v. 4.10, United States Environmental Protection Agency, Office of Pollution Prevention and Toxics and Syracuse Research Corporation.

Environmental Assessment

Monoethanolamine borate
(CAS No. 26038-87-9)

Monoethanolamine borate is also known as orthoboric acid, compound with 2-aminoethanol. It is a UVCB substance with the chemical formula: $C_2H_7NO.xBH_3O_3$.

Environmental Transport

Monoethanolamine (MEA) Polyborate 1:1 and MEA Polyborate 1:3 do not significantly adsorb to soil. The experimental log Koc was determined to be approximately 1.26.

Biodegradation

MEA Polyborate 1:1 was considered readily biodegradable in a modified Sturm test (OECD 301B). Degradation was 73% after 28 days.

MEA Polyborate 1:3 was considered readily biodegradable in a modified Sturm test (OECD 301B). Degradation was 75% after 28 days.

Aquatic Toxicity

The 96-hour LC_{50} in Carp for MEA Polyborate 1:3 is 617 mg/L.

The 48-hour EC_{50}s in *Daphnia magna* for MEA Polyborate 1:3 and MEA Polyborate 1:1 are 496 and 423 mg/L, respectively.

The 72-hour ErC_{50} in fresh water algae species *Pseudokirchneriella subcapitata* for MEA Polyborate 1:1 is 26 mg/L. The 72-hr EyC_{50} (yield inhibition) is 13 mg/L. The NOEC for growth rate reduction and yield inhibition is 3.2 mg/L. The 72-hr ErC_{50} in fresh water algae species *Pseudokirchneriella subcapitata* for MEA Polyborate 1:3 is 67 mg/L.

Toxicity to Sediment Organisms

No data are available.

Toxicity to Terrestrial Organisms

No data are available.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (617 mg/L), Daphnia (423 mg/L), and algae (13 mg/L). On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 13 mg/L for algae. The $PNEC_{aquatic}$ is 0.013 mg/L.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. The equilibrium partition method was used to determine a $PNEC_{sediment}$. The Koc was experimentally determined to be approximately 18.20. Using a Koc of 18.20 and a $PNEC_{aquatic}$ of 0.013 mg/L, the $PNEC_{sediment}$ was calculated to be 0.012 mg/kg.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The equilibrium partition method was used to determine a $PNEC_{soil}$. The Koc was experimentally determined to be approximately 18.20. Using a Koc of 18.20 and a $PNEC_{aquatic}$ of 0.013 mg/L, the $PNEC_{soil}$ was calculated to be 0.003 mg/kg (3.1 µg/kg).

PBT Assessment

Monoethanolamine borate is readily biodegradable and thus it does not meet the screening criteria for persistence.

Monoethanolamine borate is a UVCB substance and a log Kow cannot be accurately determined. For monoethanolamine itself, the measured log Kow and estimated BCF from BCFBAF v.3.01 are -1.6122 and 3.16 L/kg, respectively. The borate salt of monoethanolamine would not be expected to meet the screening criteria for bioaccumulation.

No chronic aquatic toxicity studies are available for monoethanolamine borate. The acute toxicity studies in fish, invertebrates and algae are >0.1 mg/L. Thus, monoethanolamine borate does not meet the criteria for toxicity.

The overall conclusion is that monoethanolamine borate is not a PBT substance.

Reference

ECHA REACH database: http://apps.echa.europa.eu/registered/registered-sub.aspx

Environmental Assessment

Sodium hydroxide
(CAS No. 1310-73-2)

Sodium hydroxide (NaOH) has been reviewed in the OECD-SIDS program (OECD, 2002a,b).

Environmental Fate

The high water solubility and low vapor pressure indicate that sodium hydroxide (NaOH) will be found predominantly in the aquatic environment. NaOH is present in the environment as sodium (Na^+) and hydroxyl (OH^-) ions, which implies that it will not adsorb on particulate matter or surfaces and will not accumulate in living tissues.

Measured concentrations in aquatic ecosystems
The concentration of hydroxyl ions in the environment has been determined very extensively via pH measurements. The pH is a very important parameter of aquatic ecosystems and it is a standard parameter of water quality monitoring programs. The most important freshwater aquatic ecosystems of the world revealed average annual pH values between 6.5 and 8.3 but lower and higher values have been measured in other aquatic ecosystems (UNEP, 1995). In aquatic ecosystems with dissolved organic acids a pH of less than 4.0 has been measured, while in waters with a high chlorophyll content the bicarbonate assimilation can result in pH values of higher than 9.0 at midday (UNEP, 1995). The pH of an aquatic ecosystem is mainly determined by geochemical, hydrological and/or biological processes.

Also sodium has been measured extensively in aquatic ecosystems. For example UNEP (1995) reported the concentration for a total number of 75 rivers in North-America, South-America, Asia, Africa, Europe and Oceania. The 10th –percentile, mean and 90th-percentile were 1.5, 28 and 68 mg/l, respectively.

NaOH addition and buffer capacity
An addition of NaOH to an aquatic ecosystem may increase the pH depending on the buffer capacity of the receiving water. In general the buffer capacity is regulated by the equilibria between CO_2, HCO_3^- and CO_3^{2-}:

$CO_2 + H_2O \leftrightarrow HCO_3^- + H^+$ ($pKa_1 = 6.35$)
$HCO_3^- \leftrightarrow CO_3^{2-} + H^+$ ($pKa_2 = 10.33$)

If the pH is between 7 and 9 then the bicarbonate ion is the most important species responsible for the buffer capacity of aquatic ecosystems. UNEP (1995) reported the bicarbonate concentration for a total number of 77 rivers in North-America, South-America, Asia, Africa, Europe and Oceania. The 10th– percentile, mean and 90th-percentile were 20, 106 and 195 mg/l, respectively.

Aquatic Toxicity

At concentrations reported in publications and study reports, the toxicity has been assumed to be due to hydroxide only, because at these effect concentrations the concentration of sodium is too low to explain the effects. However, it should be realized that the results of toxicity tests with NaOH depend on the buffer capacity of the test medium. In a highly buffered test medium the hydroxyl ion will be neutralized and the observed toxicity will be low, while in a poorly buffered test medium the pH will increase rapidly and therefore the observed toxicity will be relatively high. Besides the direct effects (pH change) NaOH could also have indirect effects. The pH change could influence the speciation of other chemicals and therefore increase and/or decrease the toxicity *e.g.*, NH_3 is more toxic than NH_4^+.

The 24-hour LC_{50} to *Carassius auratus* (goldfish) is 160 mg/L . At 100 mg/L, which was equivalent to a pH of 9.8, no mortality was observed. The 48-hour LC_{50} to *Leuciscus idus melanotus*, is 189 mg/L. The 96-hour LC_{50} of *Gambusia affinis* (mosquitofish) is 125 mg/L. At 84 mg/L, no effects on the fish were observed. The pH was 9 at 100 mg/L. The 48-hour LC_{50} is 40 mg/L for *Ceriodaphnia* cf. *dubia*. The toxicity threshold concentration of NaOH for *Daphnia magna* was reported to range from 40 to 240 mg/L.

No data are available on the effects of NaOH on algae.

Toxicity to Terrestrial Organisms

Toxicity tests, which determined the effects of NaOH on terrestrial organisms, are not available. Significant exposure of the terrestrial environment is not expected and for this reason there is no need to perform toxicity test with terrestrial organisms. The results of terrestrial toxicity tests will depend strongly on the buffer capacity of the soil and can probably be predicted based on the buffer capacity of the soil.

Determination of PNECs

In many cases pH, buffer capacity and/or medium composition were not discussed in the publications, although this is essential information for toxicity tests with NaOH. This is the most important reason why most of the studies, mentioned above were considered invalid. Although valid acute ecotoxicity tests and chronic ecotoxicity tests with NaOH are not available there is no need for additional testing with NaOH. A significant number of acute toxicity tests are available and the results of the tests are more or less consistent. Altogether they give a sufficient indication about acute toxicity levels of sodium hydroxide.

Furthermore acute toxicity data cannot be used to derive a PNEC or a PNEC added for sodium hydroxide. Aquatic ecosystems are characterized by an alkalinity/pH and the organisms of the ecosystem are adapted to these specific natural conditions. Based on the natural alkalinity of waters, organisms will have different optimum pH conditions, ranging from poorly buffered waters with a pH of 6 or less to very hard waters with pH values up to 9. A lot of information is available about the relationship between pH and ecosystem structure and also natural variations in pH of aquatic ecosystems have been quantified and reported extensively in ecological publications and handbooks.

Normally a PNEC or a PNEC added has to be derived from the available ecotoxicity data. A PNEC added is a PNEC which is based on added concentrations of a chemical (added risk approach). Based on the available data it is not considered useful to derive a PNEC or a PNEC added for NaOH because:

- The natural pH of aquatic ecosystems can vary significantly between aquatic ecosystems,

- Also the sensitivity of the aquatic ecosystems to a change of the pH can vary significantly between aquatic ecosystems and

- The change in pH due to an anthropogenic NaOH addition is influenced significantly by the buffer capacity of the receiving water.

Although a PNEC or a PNEC added was not calculated for NaOH there is a need to assess the environmental effect of an NaOH (alkaline) discharge. Based on the pH and buffer capacity of effluent and receiving water and the dilution factor of the effluent, the pH of the receiving water after the discharge can be calculated. Of course the pH change can be measured also very easily via a laboratory experiment or by conducting field measurements. The change in pH should be compared with the natural variation in pH of the receiving water and based on this comparison it should be assessed if the pH change is acceptable.

$PNEC_{aquatic}$: Based on the information above, a PNEC was not derived for sodium hydroxide.

$PNEC_{sediment}$: No experimental toxicity data on sediment organisms are available. Sodium hydroxide dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc parameters do not readily apply to inorganics, such as sodium hydroxide. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of sodium hydroxide to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No experimental toxicity data on terrestrial organisms are available. The environmental distribution of sodium hydroxide is dominated by its water solubility. Sorption of sodium hydroxide should probably be regarded as a reversible situation, i.e.,

the substance is not tightly nor permanently bound. Koc and Kow parameters do not readily apply to inorganics, such as sodium hydroxide Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, sodium hydroxide is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Sodium hydroxide is an organic salt that dissociates completely to sodium and hydroxide ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both sodium and hydroxide ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria is not considered applicable to this inorganic salt.

Sodium and hydroxide ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, sodium hydroxide is not expected to bioaccumulate.

No chronic toxicity data exist on sodium hydroxide; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, sodium hydroxide does not meet the screening criteria for toxicity.

The overall conclusion is that sodium hydroxide is not a PBT substance.

References

OECD (2002a). IUCLID Data Set for Sodium hydroxide (CAS No. 1310-73-2), UNEP Publications.

OECD (2002b). Screening Information Dataset (SIDS) Initial Assessment Report for Sodium hydroxide (CAS No. 1310-73-2), UNEP Publications.

Environmental Assessment

Tributyl Tetradecyl Phosphonium Chloride [TTPC]
(CAS No. 81741-28-8)

Limited information was located for TTPC, with most coming from secondary sources.

Biodegradation
TTPC was not readily biodegradable in an OECD 301 test (BuruEnergy).

In a die-away test (using activated sludge) with radiolabelled TTPC for 168 hours at 0.31 mg/L, the first-order rate constant was 0.69/hour and the half-life was 6.6 hours. After 24 and 168 hours, degradation was >81% and >98%, respectively (BuruEnergy).

TTPC was evaluation in simulation tests over a 40-day period using double ^{14}C labeled TTPC. In activated sludge, there was >40% degradation after 30 days with 50 ppb TTPC and >30% degradation after 7 days with 5 ppb TTPC. In sea water, there was >30% degradation after 35 days with 5 ppb TTPC. In river water, there was >20% after 35 days with 5 TTPC (BuruEnergy).

Environmental Fate
The soil adsorption/desorption of TTPC was tested with three soils differing in sand/silt/clay content, by running an aqueous solution of radiolabelled TTPC through a column of soil. Soil adsorption ranged from 93-96% (BuruEnergy). TTPC is freely soluble in water (BuruEnergy). It is stable in water over a wide pH range (BuruEnergy).

Bioaccumulation
The octanol-water coefficient (K_{ow}) was determined experimentally to be 2.45 from an OECD 107 test (BuruEnergy).

Aquatic Toxicity

Bellacide 350 MSDS: The 96-hour LC_{50}s in rainbow trout and Bluegill sunfish were reported to be 0.46 mg/L and 0.06 mg/L, respectively. The 48-hour EC_{50} in *Daphnia* was reported to be 0.025 mg/L.

U.S. EPA OPP Pesticide Ecotoxicity Database (wit study details): The 96-hour LC_{50}s in rainbow trout are 0.49 and 0.2 mg/L. The 96-hour LC_{50}s in Bluegill sunfish and common carp (*Cyprinus carpio*) are 0.06 and 0.09 mg/L, respectively. The 48-hour EC_{50} in *Daphnia* is 0.025 mg/L.

Environmental Properties of Proposed Biocide BE-9 (Document from BuruEnergy)
The 96-hour LC_{50}s in rainbow trout and Bluegill sunfish were reported to be 0.46 mg/L

and 0.06 mg/L, respectively. The 48-hour EC_{50} in *Daphnia* was reported to be 0.025 mg/L. The 72-hour EC_{50} in green algae *Selenastrum capricornutum* was reported to be 0.019 mg/L.

Toxicity to Sediment Organisms

No data were found.

Toxicity to Terrestrial Organisms

U.S. EPA OPP Pesticide Ecotoxicity Database: The 8-day dietary LC_{50} in Bobwhite Quail is 4,215 ppm, with a NOEL of 1,980 ppm. The 8-day dietary LC_{50} in Mallard Duck is 3,663 ppm, with a NOEL of 1,780 ppm. The 14-day oral gavage LD_{50} in Mallard Duck is 232 mg/kg, with a NOEL of 178 mg/kg.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (0.2 mg/L), Daphnia (0.025 mg/L), and algae (0.019 mg/L). While the lowest acute value is 0.019 mg/L, it has only been reported in summary document from BuruEnergy and needs to be substantiated. For the purposes of PNEC determination, the acute EC_{50} value for Daphnia will be used. It should be noted that the two values are very similar.

On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the effect concentration of 0.025 mg/L for Daphnia. The $PNEC_{aquatic}$ is calculated to be 2.5×10^{-5} mg/L (0.025 µg/L).

PBT Assessment

TTPC is not readily biodegradable. In a simulation test using river water, there was >20% after 35 days. Thus, TTPC appears to meet the screening criteria for persistence.

The octanol-water coefficient (K_{ow}) for TTPC is 2.45. Thus, TTPC does not meet the screening criteria for bioaccumulation.

No chronic toxicity data are available for TTPC. The lowest acute $EC(L)_{50}$ of TTPC is 0.025 mg/L in invertebrates. Since this value is <0.1 mg/L, TTPC does meet the screening criteria for toxicity.

References

Environmental Properties of Proposed Biocide BE-9. BuruEnergy. Accessed at: http://www.buruenergy.com/wp-content/uploads/BE-Environmental-Properties-of-Proposed-Biocide-BE-91.pdf

Material Safety Data Sheet for Bellacide 350, BWA Water Additives, SDS No. 10794, Report Date: 10/03/2009.

National Information System of the Regional Integrated Pest Management (IPM) Centers, U.S. Department of Agriculture and National Institutes of Food and Agriculture (www.ipmcenters.org).

Attachment 3 Safety Data Sheets

multi-chem® | mintech
A HALLIBURTON SERVICE

SAFETY DATA SHEET

ACETIC ACID 55%-90%

Revision Date: 20-Aug-2018 **Revision Number:** 3

1. Product Identifier & Identity for the Chemical

Statement of Hazardous Nature Hazardous according to the criteria of the 3rd Revised Edition of the Globally Harmonised System of Classification and Labelling of Chemicals (GHS), Dangerous Goods according to the criteria of ADG.

1.1. Product Identifier

Product Name ACETIC ACID 55%-90%

Other means of Identification

Synonyms None

Hazardous Material Number: MC600186

Recommended use of the chemical and restrictions on use

Recommended Use Scale Control

Uses advised against Consumer use

Supplier's name, address and phone number

Manufacturer/Supplier Multi-Chem Mintech
1 Ward Road
East Rockingham
WA 6168
Australia

Telephone Number: 61 (08) 9419 5300
Fax Number: 61 (08) 9439 1055
Emergency Telephone Number: + 61 1 800 686 951

E-mail Address fdunexchem@halliburton.com

Emergency phone number

+ 61 1 800 686 951
Global Incident Response Access Code: 334305
Contract Number: 14012

Australian Poisons Information Centre
24 Hour Service: - 13 11 26
Police or Fire Brigade: - 000 (exchange): - 1100

2. Hazard Identification

Statement of Hazardous Nature Hazardous according to the criteria of the 3rd Revised Edition of the Globally Harmonised System of Classification and Labelling of Chemicals (GHS), Dangerous Goods according to the criteria of ADG.

Classification of the hazardous chemical

Skin Corrosion/Irritation	Category 1 - H314
Serious Eye Damage/Irritation	Category 1 - H318
Specific Target Organ Toxicity - (Single Exposure)	Category 3 - H335
Flammable liquids.	Category 3 - H226

Label elements, including precautionary statements

Hazard Pictograms



Signal Word DANGER

Hazard Statements:
H226 - Flammable liquid and vapor
H314 - Causes severe skin burns and eye damage
H318 - Causes serious eye damage
H335 - May cause respiratory irritation

Precautionary Statements

Prevention
P210 - Keep away from heat, hot surfaces, sparks, open flames and other ignition sources. No smoking.
P233 - Keep container tightly closed
P240 - Ground and bond container and receiving equipment.
P241 - Use explosion-proof electrical/ventilating/lighting/equipment
P242 - Use only non-sparking tools
P243 - Take action to prevent static discharges.
P260 - Do not breathe dust/fume/gas/mist/vapors/spray
P261 - Avoid breathing dust/fume/gas/mist/vapors/spray
P271 - Use only outdoors or in a well-ventilated area
P280 - Wear protective gloves/protective clothing/eye protection/face protection

Response
P301 + P330 + P331 - IF SWALLOWED: rinse mouth. Do NOT induce vomiting
P303 + P361 + P353 - IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water [or shower].
P363 - Wash contaminated clothing before reuse
P304 + P340 - IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing
P305 + P351 + P338 - IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing
P310 - Immediately call a POISON CENTER or doctor/physician
P370 + P378 - In case of fire: Use water spray for extinction

Storage
P403 + P233 - Store in a well-ventilated place. Keep container tightly closed
P403 + P235 - Store in a well-ventilated place. Keep cool
P405 - Store locked up

Disposal
P501 - Dispose of contents/container in accordance with local/regional/national/international regulations

Contains Substances	**CAS Number**
Acetic acid	64-19-7

Other hazards which do not result in classification
This mixture contains no substance considered to be persistent, bioaccumulating nor toxic (PBT).
This mixture contains no substance considered to be very persistent nor very bioaccumulating (vPvB).

For the full text of the H-phrases mentioned in this Section, see Section 16

3. Composition/information on Ingredients

Substances	CAS Number	PERCENT (w/w)	GHS Classification - Australia
Acetic acid	64-19-7	60 - 100%	Skin Corr. 1A (H314) Eye Corr. 1 (H318) STOT SE 3 (H335) Flam. Liq. 3 (H226)

4. First aid measures

Description of necessary first aid measures

Inhalation If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Eyes In case of contact, immediately flush eyes with plenty of water for at least 30 minutes. Remove contact lenses after the first 5 minutes and continue washing. Seek immediate medical attention/advice. Suitable emergency eye wash facility should be immediately available

Skin In case of contact, immediately flush skin with plenty of soap and water for at least 30 minutes and remove contaminated clothing, shoes and leather goods immediately. Get medical attention immediately.

Ingestion Rinse mouth with water many times. Get medical attention, if symptoms occur

Symptoms caused by exposure

Causes severe skin irritation with tissue destruction. Causes severe eye irritation which may damage tissue. May cause respiratory irritation.

Medical Attention and Special Treatment

Notes to Physician Treat symptomatically

5. Fire Fighting Measures

Suitable extinguishing equipment

Suitable Extinguishing Media

Water fog, carbon dioxide, foam, dry chemical.

Extinguishing media which must not be used for safety reasons

Do NOT spray pool fires directly with water. A solid stream of water directed into hot burning liquid can cause splattering.

Specific hazards arising from the chemical

Special exposure hazards in a fire

Decomposition in fire may produce harmful gases.

Special protective equipment and precautions for fire fighters

Special protective equipment for firefighters

Full protective clothing and approved self-contained breathing apparatus required for fire fighting personnel.

6. Accidental release measures

6.1. Personal precautions, protective equipment and emergency procedures

Ensure adequate ventilation. Use appropriate protective equipment. Do not breathe dust/fume/gas/mist/vapors/spray. Remove sources of ignition. Take precautionary measures against static discharges All equipment used when handling the product must be grounded Avoid contact with skin, eyes and clothing.

6.2. Environmental precautions

Prevent from entering sewers, waterways, or low areas.

6.3. Methods and material for containment and cleaning up

Dike far ahead of liquid spill for later disposal. Soak up with inert absorbent material. Pick up and transfer to properly labeled containers. Remove ignition sources and work with non-sparking tools.

7. Handling and storage

7.1. Precautions for safe handling

Handling Precautions

Do not breathe dust/fume/gas/mist/vapors/spray. Ensure adequate ventilation. Use appropriate protective equipment. Remove sources of ignition. Ground and bond containers when transferring from one container to another. Avoid contact with eyes, skin, or clothing.

Hygiene Measures

Handle in accordance with good industrial hygiene and safety practice.

7.2. Conditions for safe storage, including any incompatibilities

Storage Information

Store in a cool well ventilated area. Keep from heat, sparks, and open flames.

Other Guidelines

No information available

8. Exposure Controls/Personal Protection

Control parameters - exposure standards, biological monitoring

Exposure Limits

Substances	CAS Number	Australia NOHSC	ACGIH TLV-TWA
Acetic acid	64-19-7	TWA: 10 ppm TWA: 25 mg/m^3 STEL: 15 ppm STEL: 37 mg/m^3	TWA: 10 ppm STEL: 15 ppm

Appropriate engineering controls

Engineering Controls Ensure adequate ventilation, especially in confined areas

Personal protective equipment (PPE)

Personal Protective Equipment If engineering controls and work practices cannot prevent excessive exposures, the selection and proper use of personal protective equipment should be determined by an industrial hygienist or other qualified professional based on the specific application of this product.

Respiratory Protection If engineering controls and work practices cannot keep exposure below occupational exposure limits or if exposure is unknown, wear a NIOSH certified, European Standard EN 149, AS/NZS 1715:2009, or equivalent respirator when using this product. Selection of and instruction on using all personal protective equipment, including respirators, should be performed by an Industrial Hygienist or other qualified professional.

Hand Protection Use gloves which are suitable for the chemicals present in this product as well as other environmental factors in the workplace.

Skin Protection Wear impervious protective clothing, including boots, gloves, lab coat, apron, rain jacket, pants or coverall, as appropriate, to prevent skin contact.

Eye Protection None known.

Other Precautions None known.

Environmental Exposure Controls No information available

9. Physical and Chemical Properties

9.1. Information on basic physical and chemical properties

Physical State: Liquid

Color Light Amber to Dark Amber , Clear to Slightly Hazy

Odor: Pungent

Odor Threshold: No information available

Property Remarks/ - Method	Values
pH:	2.5-3.8 (10% in 1:1 IPA:H2O)
Freezing Point / Range	No data available
Melting Point / Range	No data available
Boiling Point / Range	No data available
Flash Point	> 40 °C / > 104 °F (SFCC)
Evaporation rate	No data available
Vapor Pressure	No data available
Vapor Density	No data available
Specific Gravity	1.0653-1.0903 (20 °C/68 °F)
Water Solubility	Soluble in water
Solubility in other solvents	No data available
Partition coefficient: n-octanol/water	No data available
Autoignition Temperature	No data available
Decomposition Temperature	No data available
Viscosity	No data available
Explosive Properties	No information available
Oxidizing Properties	No information available

9.2. Other information

VOC Content (%)	No data available
Liquid Density	8.88-9.09 lbs/gal
Bulk Density	1065-1090 kg/m^3

10. Stability and Reactivity

10.1. Reactivity
Not expected to be reactive.
10.2. Chemical stability
Stable
10.3. Possibility of hazardous reactions
Will Not Occur
10.4. Conditions to avoid
Keep away from heat, sparks and flame.
10.5. Incompatible materials
Strong oxidizers.
10.6. Hazardous decomposition products
Carbon oxides.

11. Toxicological Information

Information on routes of exposure
Principle Route of Exposure Skin contact. Eye contact. Inhalation.

Symptoms related to exposure
Most Important Symptoms/Effects
Causes severe skin irritation with tissue destruction. Causes severe eye irritation which may damage tissue. May cause respiratory irritation.

Toxicology data for the components

Substances	CAS Number	LD50 Oral	LD50 Dermal	LC50 Inhalation
Acetic acid	64-19-7	No data available	1060 mg/kg-bw (rabbit)	11.4 mg/L (rat, 4 h, vapor)

Immediate, delayed and chronic health effects from exposure
Inhalation May cause respiratory irritation.
Eye Contact Causes serious eye damage.
Skin Contact Causes severe burns.

Ingestion Causes burns of the mouth, throat and stomach.

Exposure Levels
No data available

Interactive effects
No data available

Data limitations
No data available

Substances	CAS Number	Skin corrosion/irritation
Acetic acid	64-19-7	Extremely corrosive and destructive to tissue Skin, rabbit:

Substances	CAS Number	Serious eye damage/irritation
Acetic acid	64-19-7	Eye, rabbit: Causes serious eye damage

Substances	CAS Number	Skin Sensitization
Acetic acid	64-19-7	Not regarded as a sensitizer.

Substances	CAS Number	Respiratory Sensitization
Acetic acid	64-19-7	No information available

Substances	CAS Number	Mutagenic Effects
Acetic acid	64-19-7	In vivo tests did not show mutagenic effects. In vitro tests did not show mutagenic effects.

Substances	CAS Number	Carcinogenic Effects
Acetic acid	64-19-7	Did not show carcinogenic effects in animal experiments

Substances	CAS Number	Reproductive toxicity
Acetic acid	64-19-7	Did not show teratogenic effects in animal experiments. Animal testing did not show any effects on fertility.

Substances	CAS Number	STOT - single exposure
Acetic acid	64-19-7	May cause respiratory irritation. No information available

Substances	CAS Number	STOT - repeated exposure
Acetic acid	64-19-7	No significant toxicity observed in animal studies at concentration requiring classification.

Substances	CAS Number	Aspiration hazard
Acetic acid	64-19-7	Not applicable

12. Ecological Information

Ecotoxicity
Product Ecotoxicity Data
Product is not classified as hazardous to the environment.

Substance Ecotoxicity Data

Substances	CAS Number	Toxicity to Algae	Toxicity to Fish	Toxicity to Microorganisms	Toxicity to Invertebrates
Acetic acid	64-19-7	EC50(72 h)=55.22 mg/L (Anabaena flos-aquae)	LC50(96 h)=251 mg/L (Gambusia affinis) LC50(96 h)=75 mg/L (Lepomis macrochirus)	NOAEC (16 h) =1150 mg/L (Pseudomonas putida)	EC50(48 h)=65 mg/L (Daphnia magna)

12.2. Persistence and degradability

Substances	CAS Number	Persistence and Degradability
Acetic acid	64-19-7	Readily biodegradable (99% @ 7d)

12.3. Bioaccumulative potential

Substances	CAS Number	Bioaccumulation
Acetic acid	64-19-7	LogPow-0.17

12.4. Mobility in soil

Substances	CAS Number	Mobility
Acetic acid	64-19-7	No information available

12.6. Other adverse effects

Endocrine Disruptor Information
This product does not contain any known or suspected endocrine disruptors

13. Disposal Considerations

Safe handling and disposal methods
Disposal should be made in accordance with federal, state, and local regulations.

Disposal of any contaminated packaging
Follow all applicable national or local regulations.

Environmental regulations
Not applicable

14. Transport Information

Transportation Information

Australia ADG

UN Number UN2789
UN proper shipping name: Acetic Acid Solution
Transport Hazard Class(es): 8 (3)
Packing Group: III
Environmental Hazards: Not applicable

IMDG/IMO

UN Number UN2789
UN proper shipping name: Acetic Acid Solution
Transport Hazard Class(es): 8 (3)
Packing Group: III
Environmental Hazards: Not applicable
EMS: EmS F-E, S-C

IATA/ICAO

UN Number UN2789
UN proper shipping name: Acetic Acid Solution
Transport Hazard Class(es): 8 (3)
Packing Group: III
Environmental Hazards: Not applicable

Special precautions during transport
None

HazChem Code
•2P

15. Regulatory Information

Safety, health and environmental regulations specific for the product

International Inventories

Australian AICS Inventory	All components are listed on the AICS or are subject to a relevant exemption, permit, or assessment certificate.
New Zealand Inventory of Chemicals	All components are listed on the NZIoC or are subject to a relevant exemption, permit, or assessment certificate.
EINECS (European Inventory of Existing Chemical Substances)	This product, and all its components, complies with EINECS
US TSCA Inventory	All components listed on inventory or are exempt.
Canadian Domestic Substances List (DSL)	All components listed on inventory or are exempt.

Poisons Schedule number
S6

International Agreements

Montreal Protocol - Ozone Depleting Substances:	Does not apply.
Stockholm Convention - Persistent Organic Pollutants:	Does not apply
Rotterdam Convention - Prior Informed Consent:	Does not apply.
Basel Convention - Hazardous Waste:	Does not apply.

16. Other information

Date of preparation or review

Revision Date: 20-Aug-2018

Revision Note
Update to Format

Full text of H-Statements referred to under sections 2 and 3
H226 - Flammable liquid and vapor
H314 - Causes severe skin burns and eye damage
H318 - Causes serious eye damage
H335 - May cause respiratory irritation

Additional information For additional information on the use of this product, contact your local Halliburton representative.

For questions about the Safety Data Sheet for this or other Halliburton products, contact Chemical Stewardship at 1-580-251-4335.

Key abreviations or acronyms used
bw – body weight
CAS – Chemical Abstracts Service
EC50 – Effective Concentration 50%
LC50 – Lethal Concentration 50%
LD50 – Lethal Dose 50%
LL50 – Lethal Loading 50%
mg/kg – milligram/kilogram
mg/L – milligram/liter
NOEC – No Observed Effect Concentration
OEL – Occupational Exposure Limit
PBT – Persistent Bioaccumulative and Toxic
ppm – parts per million
STEL – Short Term Exposure Limit
TWA – Time-Weighted Average
vPvB – very Persistent and very Bioaccumulative
h - hour
mg/m^3 - milligram/cubic meter
mm - millimeter
mmHg - millimeter mercury

w/w - weight/weight
d - day

Key literature references and sources for data
www.ChemADVISOR.com/

Disclaimer Statement
This information is furnished without warranty, expressed or implied, as to accuracy or completeness. The information is obtained from various sources including the manufacturer and other third party sources. The information may not be valid under all conditions nor if this material is used in combination with other materials or in any process. Final determination of suitability of any material is the sole responsibility of the user.

End of Safety Data Sheet

HALLIBURTON

SAFETY DATA SHEET

BC-140C

Revision Date: 01-Oct-2015 **Revision Number:** 18

1. Product Identifier & Identity for the Chemical

Statement of Hazardous Nature Non-Hazardous according to the criteria of the 3rd Revised Edition of the Globally Harmonised System of Classification and Labelling of Chemicals (GHS), Non-Dangerous Goods according to the criteria of ADG.

1.1. Product Identifier

Product Name BC-140C

Other means of Identification

Synonyms: None

Product Code: HM000110

Recommended use of the chemical and restrictions on use

Recommended Use Crosslinker

Uses Advised Against No information available

Supplier's name, address and phone number

Manufacturer/Supplier Halliburton Australia Pty. Ltd.
15 Marriott Road
Jandakot
WA 6164
Australia

ACN Number: 009 000 775
Telephone Number: + 61 1 800 686 951
Fax Number: 61 (08) 9455 5300

E-Mail address: fdunexchem@halliburton.com

Emergency phone number

+ 61 1 800 686 951

Australian Poisons Information Centre

24 Hour Service: - 13 11 26

Police or Fire Brigade: - 000 (exchange): - 1100

2. Hazard Identification

Statement of Hazardous Nature Non-Hazardous according to the criteria of the 3rd Revised Edition of the Globally Harmonised System of Classification and Labelling of Chemicals (GHS), Non-Dangerous Goods according to the criteria of ADG.

Classification of the hazardous chemical

Not classified

Label elements, including precautionary statements

Hazard Pictograms

Signal Word Not Hazardous

Hazard Statements Not Classified

Precautionary Statements

Prevention None

Response None

Storage None

Disposal None

Contains

Substances	**CAS Number**
Contains no hazardous substances in concentrations above cut-off values according to the competent authority	NA

Other hazards which do not result in classification

This mixture contains no substance considered to be persistent, bioaccumulating nor toxic (PBT).
This mixture contains no substance considered to be very persistent nor very bioaccumulating (vPvB).

Australia Classification

For the full text of the H-phrases mentioned in this Section, see Section 16

Classification Not Classified
Risk Phrases None

3. Composition/information on Ingredients

Substances	CAS Number	PERCENT (w/w)	GHS Classification - Australia
Contains no hazardous substances in concentrations above cut-off values according to the competent authority	NA	60 - 100%	Not Applicable

4. First aid measures

Description of necessary first aid measures

Inhalation If inhaled, move victim to fresh air and seek medical attention.

Eyes In case of contact, or suspected contact, immediately flush eyes with plenty of water for at least 15 minutes and get medical attention immediately after flushing.

Skin In case of contact, immediately flush skin with plenty of soap and water for at least 15 minutes. Get medical attention. Remove contaminated clothing and launder before reuse.

Ingestion Do NOT induce vomiting. Give nothing by mouth. Obtain immediate medical attention.

Symptoms caused by exposure

No significant hazards expected.

Medical Attention and Special Treatment

Notes to Physician Treat symptomatically

5. Fire Fighting Measures

Suitable extinguishing equipment

Suitable Extinguishing Media

Water fog, carbon dioxide, foam, dry chemical.

Extinguishing media which must not be used for safety reasons
None known.

Specific hazards arising from the chemical
Special Exposure Hazards
Decomposition in fire may produce harmful gases.

Special protective equipment and precautions for fire fighters
Special Protective Equipment for Fire-Fighters
Full protective clothing and approved self-contained breathing apparatus required for fire fighting personnel.

6. Accidental release measures

6.1. Personal precautions, protective equipment and emergency procedures
Use appropriate protective equipment. Avoid contact with skin, eyes and clothing. Avoid breathing vapors. Ensure adequate ventilation.

6.2. Environmental precautions
Prevent from entering sewers, waterways, or low areas.

6.3. Methods and material for containment and cleaning up
Isolate spill and stop leak where safe. Contain spill with sand or other inert materials. Scoop up and remove.

7. Handling and storage

7.1. Precautions for Safe Handling
Handling Precautions
Avoid contact with eyes, skin, or clothing. Avoid breathing vapors. Ensure adequate ventilation. Wash hands after use. Launder contaminated clothing before reuse. Use appropriate protective equipment.
Hygiene Measures
Handle in accordance with good industrial hygiene and safety practice.

7.2. Conditions for safe storage, including any incompatibilities
Storage Information
Store away from oxidizers. Store in a cool well ventilated area. Keep container closed when not in use. Product has a shelf life of 36 months.
Other Guidelines
No information available

8. Exposure Controls/Personal Protection

Control parameters - exposure standards, biological monitoring
Exposure Limits

Substances	CAS Number	Australia NOHSC	ACGIH TLV-TWA
Contains no hazardous substances in concentrations above cut-off values according to the competent authority	NA	Not applicable	Not applicable

Appropriate engineering controls
Engineering Controls Use in a well ventilated area. Local exhaust ventilation should be used in areas without good cross ventilation.

Personal protective equipment (PPE)
Respiratory Protection Not normally needed. But if significant exposures are possible then the following respirator is recommended:
Organic vapor respirator.

Hand Protection Impervious rubber gloves.
Skin Protection Rubber apron.
Eye Protection Safety glasses.

Other Precautions None known.
Environmental Exposure Controls Do not allow material to contaminate ground water system

9. Physical and Chemical Properties

9.1. Information on basic physical and chemical properties

Physical State: Liquid
Odor: Amine
Color: Blue
Odor Threshold: No information available

Property Remarks/ - Method	Values
pH:	7.9
Freezing Point/Range	No data available
Melting Point/Range	No data available
Boiling Point/Range	No data available
Flash Point	No data available
Evaporation rate	No data available
Vapor Pressure	No data available
Vapor Density	No data available
Specific Gravity	1.16
Water Solubility	Soluble in water
Solubility in other solvents	No data available
Partition coefficient: n-octanol/water	No data available
Autoignition Temperature	No data available
Decomposition Temperature	No data available
Viscosity	No data available
Explosive Properties	No information available
Oxidizing Properties	No information available

9.2. Other information

VOC Content (%)	No data available
Liquid Density	9.66 lbs/gal @ 20 C

10. Stability and Reactivity

10.1. Reactivity
Not expected to be reactive.
10.2. Chemical Stability
Stable
10.3. Possibility of Hazardous Reactions
Will Not Occur
10.4. Conditions to Avoid
None anticipated
10.5. Incompatible Materials
Strong oxidizers. Dehydrating agents.
10.6. Hazardous Decomposition Products
Toxic fumes. Carbon monoxide and carbon dioxide.

11. Toxicological Information

Information on routes of exposure
Principle Route of Exposure Eye or skin contact, inhalation.

Sympotoms related to exposure
Most Important Symptoms/Effects
No significant hazards expected.

Numerical measures of toxicity

Toxicology data for the components

Substances	CAS Number	LD50 Oral	LD50 Dermal	LC50 Inhalation
Contains no hazardous substances in concentrations above cut-off values according to the competent authority	NA	No data available	No data available	No data available

Immediate, delayed and chronic health effects from exposure

Inhalation May cause mild respiratory irritation.
Eye Contact May cause mild eye irritation.
Skin Contact May cause mild skin irritation.
Ingestion None known.

Chronic Effects/Carcinogenicity No data available to indicate product or components present at greater than 0.1% are chronic health hazards.

Exposure Levels
No data available

Interactive effects
Skin disorders. Eye ailments.

Data limitations
No data available

12. Ecological Information

Ecotoxicity
Product Ecotoxicity Data
No data available

Substance Ecotoxicity Data

Substances	CAS Number	Toxicity to Algae	Toxicity to Fish	Toxicity to Microorganisms	Toxicity to Invertebrates
Contains no hazardous substances in concentrations above cut-off values according to the competent authority	NA	No information available	No information available	No information available	No information available

12.2. Persistence and degradability

Substances	CAS Number	Persistence and Degradability
Contains no hazardous substances in concentrations above cut-off values according to the competent authority	NA	No information available

12.3. Bioaccumulative potential

Substances	CAS Number	Log Pow
Contains no hazardous substances in concentrations above cut-off values according to the competent authority	NA	No information available

12.4. Mobility in soil

Substances	CAS Number	Mobility
Contains no hazardous substances in concentrations above cut-off values according to the competent authority	NA	No information available

12.6. Other adverse effects

Endocrine Disruptor Information

This product does not contain any known or suspected endocrine disruptors

13. Disposal Considerations

Safe handling and disposal methods

Disposal should be made in accordance with federal, state, and local regulations.

Disposal of any contaminated packaging

Follow all applicable national or local regulations.

Environmental regulations

Not applicable

14. Transport Information

Transportation Information

UN Number: Not restricted
UN Proper Shipping Name: Not restricted
Transport Hazard Class(es): Not applicable
Packing Group: Not applicable
Environmental Hazards: Not applicable

Special precautions during transport

None

HazChem Code

None Allocated

15. Regulatory Information

Safety, health and environmental regulations specific for the product

International Inventories

Australian AICS Inventory All components listed on inventory or are exempt.
New Zealand Inventory of Chemicals All components listed on inventory or are exempt.
EINECS Inventory This product, and all its components, complies with EINECS
US TSCA Inventory All components listed on inventory or are exempt.
Canadian DSL Inventory All components listed on inventory or are exempt.

Poisons Schedule number

None Allocated

16. Other information

Date of preparation or review

Revision Date: 01-Oct-2015

Revision Note
SDS sections updated: 2

Full text of R-phrases referred to under Sections 2 and 3
None

Full text of H-Statements referred to under sections 2 and 3
None

Additional information

For additional information on the use of this product, contact your local Halliburton representative.

For questions about the Safety Data Sheet for this or other Halliburton products, contact Chemical Stewardship at 1-580-251-4335.

Key abreviations or acronyms used
bw – body weight
CAS – Chemical Abstracts Service
EC50 – Effective Concentration 50%
LC50 – Lethal Concentration 50%
LD50 – Lethal Dose 50%
LL50 – Lethal Loading 50%
mg/kg – milligram/kilogram
mg/L – milligram/liter
NOEC – No Observed Effect Concentration
OEL – Occupational Exposure Limit
PBT – Persistent Bioaccumulative and Toxic
ppm – parts per million
STEL – Short Term Exposure Limit
TWA – Time-Weighted Average
vPvB – very Persistent and very Bioaccumulative
h - hour
mg/m^3 - milligram/cubic meter
mm - millimeter
mmHg - millimeter mercury
w/w - weight/weight
d - day

Key literature references and sources for data
www.ChemADVISOR.com/

Disclaimer Statement
This information is furnished without warranty, expressed or implied, as to accuracy or completeness. The information is obtained from various sources including the manufacturer and other third party sources. The information may not be valid under all conditions nor if this material is used in combination with other materials or in any process. Final determination of suitability of any material is the sole responsibility of the user.

End of Safety Data Sheet

HALLIBURTON

SAFETY DATA SHEET

BE-9

Revision Date: 13-Oct-2017 **Revision Number:** 20

1. Product Identifier & Identity for the Chemical

Statement of Hazardous Nature Hazardous according to the criteria of the 3rd Revised Edition of the Globally Harmonised System of Classification and Labelling of Chemicals (GHS), Dangerous Goods according to the criteria of ADG.

1.1. Product Identifier

Product Name BE-9

Other means of Identification

Synonyms None

Hazardous Material Number: HB006583

Recommended use of the chemical and restrictions on use

Recommended Use Biocide

Uses advised against No information available

Supplier's name, address and phone number

Manufacturer/Supplier Halliburton Australia Pty. Ltd.
15 Marriott Road, Jandakot, WA 6164
Australia
ACN Number: 009 000 775
Telephone Number: + 61 1 800 686 951
Fax Number: 61 (08) 9455 5300

E-mail Address fdunexchem@halliburton.com

Emergency phone number

+ 61 1 800 686 951
Global Incident Response Access Code: 334305
Contract Number: 14012

Australian Poisons Information Centre
24 Hour Service: - 13 11 26
Police or Fire Brigade: - 000 (exchange): - 1100

2. Hazard Identification

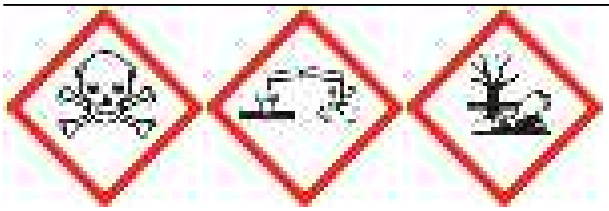
Statement of Hazardous Nature Hazardous according to the criteria of the 3rd Revised Edition of the Globally Harmonised System of Classification and Labelling of Chemicals (GHS), Dangerous Goods according to the criteria of ADG.

Classification of the hazardous chemical

Skin Corrosion/Irritation	Category 1 - H314
Serious Eye Damage/Irritation	Category 1 - H318
Acute Aquatic Toxicity	Category 1 - H400
Chronic Aquatic Toxicity	Category 2 - H411

Label elements, including precautionary statements

Hazard Pictograms



Signal Word DANGER

Hazard Statements:
H314 - Causes severe skin burns and eye damage
H318 - Causes serious eye damage
H400 - Very toxic to aquatic life
H411 - Toxic to aquatic life with long lasting effects

Precautionary Statements

Prevention
P260 - Do not breathe dust/fume/gas/mist/vapors/spray
P273 - Avoid release to the environment
P280 - Wear protective gloves/protective clothing/eye protection/face protection

Response
P301 + P330 + P331 - IF SWALLOWED: rinse mouth. Do NOT induce vomiting
P303 + P361 + P353 - IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water [or shower].
P363 - Wash contaminated clothing before reuse
P304 + P340 - IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing
P310 - Immediately call a POISON CENTER or doctor/physician
P305 + P351 + P338 - IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing
P391 - Collect spillage

Storage
P405 - Store locked up

Disposal
P501 - Dispose of contents/container in accordance with local/regional/national/international regulations

Contains

Substances	**CAS Number**
Tributyl tetradecyl phosphonium chloride	81741-28-8

Other hazards which do not result in classification
None known

For the full text of the H-phrases mentioned in this Section, see Section 16

3. Composition/information on Ingredients

Substances	CAS Number	PERCENT (w/w)	GHS Classification - Australia
Tributyl tetradecyl phosphonium chloride	81741-28-8	5 - 10%	Acute Tox. 4 (H302) Acute Tox. 2 (H330) Skin Corr. 1B (H314) Eye Corr. 1 (H318) Aquatic Acute 1 (H400) Aquatic Chronic 1 (H410)

4. First aid measures

Description of necessary first aid measures

Inhalation If inhaled, move victim to fresh air and seek medical attention.

Eyes Immediately flush eyes with large amounts of water for at least 30 minutes. Seek prompt medical attention.

Skin In case of contact, immediately flush skin with plenty of soap and water for at least 30 minutes and remove contaminated clothing, shoes and leather goods immediately. Get medical attention immediately.

Ingestion Do NOT induce vomiting. Give nothing by mouth. Obtain immediate medical attention.

Symptoms caused by exposure

Causes severe eye irritation which may damage tissue. Causes severe skin irritation with tissue destruction.

Medical Attention and Special Treatment

Notes to Physician Treat symptomatically

5. Fire Fighting Measures

Suitable extinguishing equipment

Suitable Extinguishing Media

Water fog, carbon dioxide, foam, dry chemical.

Extinguishing media which must not be used for safety reasons

None known.

Specific hazards arising from the chemical

Special exposure hazards in a fire

Decomposition in fire may produce harmful gases. Do not allow runoff to enter waterways. Use water spray to cool fire exposed surfaces.

Special protective equipment and precautions for fire fighters

Special protective equipment for firefighters

Full protective clothing and approved self-contained breathing apparatus required for fire fighting personnel.

6. Accidental release measures

6.1. Personal precautions, protective equipment and emergency procedures

Use appropriate protective equipment.

6.2. Environmental precautions

Prevent from entering sewers, waterways, or low areas.

6.3. Methods and material for containment and cleaning up

Isolate spill and stop leak where safe. Contain spill with sand or other inert materials. Scoop up and remove.

7. Handling and storage

7.1. Precautions for safe handling

Handling Precautions

Avoid contact with eyes, skin, or clothing. Wash hands after use. Launder contaminated clothing before reuse. Do NOT consume food, drink, or tobacco in contaminated areas.

Hygiene Measures

Handle in accordance with good industrial hygiene and safety practice.

7.2. Conditions for safe storage, including any incompatibilities

Storage Information

Store in a cool well ventilated area. Keep container closed when not in use. Store away from direct sunlight. Store in a dry location. Store in a manner to prevent commingling with incompatible materials. Store away from alkalis. Store away from reducing agents. Store locked up.

Other Guidelines

No information available

8. Exposure Controls/Personal Protection

Control parameters - exposure standards, biological monitoring

Exposure Limits

Substances	CAS Number	Australia NOHSC	ACGIH TLV-TWA
Tributyl tetradecyl phosphonium chloride	81741-28-8	Not applicable	Not applicable

Appropriate engineering controls

Engineering Controls Use in a well ventilated area. Local exhaust ventilation should be used in areas without good cross ventilation.

Personal protective equipment (PPE)

Personal Protective Equipment If engineering controls and work practices cannot prevent excessive exposures, the selection and proper use of personal protective equipment should be determined by an industrial hygienist or other qualified professional based on the specific application of this product.

Respiratory Protection If engineering controls and work practices cannot keep exposure below occupational exposure limits or if exposure is unknown, wear a NIOSH certified, European Standard EN 149, AS/NZS 1715:2009, or equivalent respirator when using this product. Selection of and instruction on using all personal protective equipment, including respirators, should be performed by an Industrial Hygienist or other qualified professional.
Dust/mist respirator. (N95, P2/P3)

Hand Protection Chemical-resistant protective gloves (EN 374) Suitable materials for longer, direct contact (recommended: protection index 6, corresponding to > 480 minutes permeation time as per EN 374): Neoprene gloves. (>= 0.75 mm thickness)
This information is based on literature references and on information provided by glove manufacturers, or is derived by analogy with similar substances. Please note that in practice the working life of chemical-resistant protective gloves may be considerably shorter than the permeation time determined in accordance with EN 374 as a result of the many influencing factors (e.g. temperature). If signs of wear and tear are noticed then the gloves should be replaced. Manufacturer's directions for use should be observed because of great diversity of types.

Skin Protection Wear impervious protective clothing, including boots, gloves, lab coat, apron, rain jacket, pants or coverall, as appropriate, to prevent skin contact.

Eye Protection Chemical goggles; also wear a face shield if splashing hazard exists.

Other Precautions Eyewash fountains and safety showers must be easily accessible.

Environmental Exposure Controls No information available

9. Physical and Chemical Properties

9.1. Information on basic physical and chemical properties

Physical State: Liquid
Color Clear colorless
Odor: Slight
Odor Threshold: No information available

Property Remarks/ - Method	Values
pH:	6-8
Freezing Point / Range	-8 - -10 °C
Melting Point / Range	No data available
Boiling Point / Range	100 °C / 212 °F
Flash Point	No data available
Evaporation rate	No data available
Vapor Pressure	No data available
Vapor Density	No data available
Specific Gravity	0.95 - 1.0
Water Solubility	Miscible with water
Solubility in other solvents	No data available
Partition coefficient: n-octanol/water	No data available
Autoignition Temperature	No data available
Decomposition Temperature	No data available
Viscosity	No data available
Explosive Properties	No information available
Oxidizing Properties	No information available

9.2. Other information

VOC Content (%) No data available

10. Stability and Reactivity

10.1. Reactivity

Not expected to be reactive.

10.2. Chemical stability

Stable

10.3. Possibility of hazardous reactions

Will Not Occur

10.4. Conditions to avoid

None anticipated

10.5. Incompatible materials

Reducing agents. Strong alkalis.

10.6. Hazardous decomposition products

Chlorine. Phosphorus acids. Carbon monoxide and carbon dioxide.

11. Toxicological Information

Information on routes of exposure

Principle Route of Exposure Eye or skin contact, inhalation.

Symptoms related to exposure

Most Important Symptoms/Effects

Causes severe eye irritation which may damage tissue. Causes severe skin irritation with tissue destruction.

Toxicology data for the components

Substances	CAS Number	LD50 Oral	LD50 Dermal	LC50 Inhalation
Tributyl tetradecyl phosphonium chloride	81741-28-8	= 611 mg/kg (rat)	No data of sufficient quality are available	> 0.908 mg/L (rat, 4hr, mist)

Immediate, delayed and chronic health effects from exposure

Inhalation May cause respiratory irritation.

Eye Contact Causes severe eye irritation which may damage tissue. May cause eye burns.

Skin Contact Causes severe skin irritation with tissue destruction.

Ingestion Irritation of the mouth, throat, and stomach. May cause abdominal pain, vomiting, nausea, and diarrhea.

Chronic Effects/Carcinogenicity No data available to indicate product or components present at greater than 0.1% are chronic health hazards.

Exposure Levels

No data available

Interactive effects

Lung disorders. Skin disorders.

Data limitations

No data available

Substances	CAS Number	Skin corrosion/irritation
Tributyl tetradecyl phosphonium chloride	81741-28-8	Causes burns (Rabbit)

Substances	CAS Number	Serious eye damage/irritation
Tributyl tetradecyl phosphonium chloride	81741-28-8	Causes severe eye irritation which may damage tissue. (Rabbit)

Substances	CAS Number	Skin Sensitization
Tributyl tetradecyl phosphonium chloride	81741-28-8	No information available

Substances	CAS Number	Respiratory Sensitization
Tributyl tetradecyl phosphonium chloride	81741-28-8	No information available

Substances	CAS Number	Mutagenic Effects
Tributyl tetradecyl phosphonium chloride	81741-28-8	No data of sufficient quality are available.

Substances	CAS Number	Carcinogenic Effects
Tributyl tetradecyl phosphonium chloride	81741-28-8	No information available

Substances	CAS Number	Reproductive toxicity
Tributyl tetradecyl phosphonium chloride	81741-28-8	No information available

Substances	CAS Number	STOT - single exposure
Tributyl tetradecyl phosphonium chloride	81741-28-8	No information available

Substances	CAS Number	STOT - repeated exposure
Tributyl tetradecyl phosphonium chloride	81741-28-8	No data of sufficient quality are available.

Substances	CAS Number	Aspiration hazard
Tributyl tetradecyl phosphonium chloride	81741-28-8	No information available

12. Ecological Information

Ecotoxicity

Substance Ecotoxicity Data

Substances	CAS Number	Toxicity to Algae	Toxicity to Fish	Toxicity to Microorganisms	Toxicity to Invertebrates
Tributyl tetradecyl phosphonium chloride	81741-28-8	No information available	LC50 (96 h) 0.46 mg/L (Oncorhynchus mykiss) LC50 (96 h) 0.06 mg/L (Lepomis macrochirus)	No information available	EC50 (48 h) 0.025 mg/L (Daphnia sp.)

12.2. Persistence and degradability

Substances	CAS Number	Persistence and Degradability
Tributyl tetradecyl phosphonium chloride	81741-28-8	(0% @ 28d)

12.3. Bioaccumulative potential

Substances	CAS Number	Log Pow
Tributyl tetradecyl phosphonium chloride	81741-28-8	< 3

12.4. Mobility in soil

Substances	CAS Number	Mobility
Tributyl tetradecyl phosphonium chloride	81741-28-8	No information available

12.6. Other adverse effects

Endocrine Disruptor Information

This product does not contain any known or suspected endocrine disruptors

13. Disposal Considerations

Safe handling and disposal methods
Disposal should be made in accordance with federal, state, and local regulations. Incineration recommended in approved incinerator according to federal, state, and local regulations. Substance should NOT be deposited into a sewage facility.

Disposal of any contaminated packaging
Follow all applicable national or local regulations.

Environmental regulations
Not applicable

14. Transport Information

Transportation Information

Australia ADG

UN Number	UN2922
UN proper shipping name:	Corrosive Liquid, Toxic, N.O.S. (contains Tributyl Tetradecyl Phosphonium Chloride)
Transport Hazard Class(es):	8, (6.1)
Packing Group:	II
Environmental Hazards:	Marine Pollutant

IMDG/IMO

UN Number	UN2922
UN proper shipping name:	Corrosive Liquid, Toxic, N.O.S. (contains Tributyl Tetradecyl Phosphonium Chloride)
Transport Hazard Class(es):	8, (6.1)
Packing Group:	II
Environmental Hazards:	Marine Pollutant
EMS:	EmS F-A, S-B

IATA/ICAO

UN Number	UN2922
UN proper shipping name:	Corrosive Liquid, Toxic, N.O.S. (contains Tributyl Tetradecyl Phosphonium Chloride)
Transport Hazard Class(es):	8, (6.1)
Packing Group:	II
Environmental Hazards:	Marine Pollutant

Special precautions during transport
None

HazChem Code
2X

15. Regulatory Information

Safety, health and environmental regulations specific for the product

International Inventories

Australian AICS Inventory	All components are listed on the AICS or are subject to a relevant exemption, permit, or assessment certificate.
New Zealand Inventory of Chemicals	All components are listed on the NZIoC or are subject to a relevant exemption, permit, or assessment certificate.
EINECS (European Inventory of Existing Chemical Substances)	This product, and all its components, complies with EINECS
US TSCA Inventory	All components listed on inventory or are exempt.
Canadian Domestic Substances List (DSL)	All components listed on inventory or are exempt.

Poisons Schedule number

None Allocated

International Agreements

Montreal Protocol - Ozone Depleting Substances:	Does not apply
Stockholm Convention - Persistent Organic Pollutants:	Does not apply
Rotterdam Convention - Prior Informed Consent:	Does not apply
Basel Convention - Hazardous Waste:	Does not apply

16. Other information

Date of preparation or review

Revision Date: 13-Oct-2017

Revision Note
SDS sections updated:
2

Full text of H-Statements referred to under sections 2 and 3
H302 - Harmful if swallowed
H314 - Causes severe skin burns and eye damage
H318 - Causes serious eye damage
H330 - Fatal if inhaled
H400 - Very toxic to aquatic life
H401 - Toxic to aquatic life
H410 - Very toxic to aquatic life with long lasting effects
H411 - Toxic to aquatic life with long lasting effects

Additional information

For additional information on the use of this product, contact your local Halliburton representative.

For questions about the Safety Data Sheet for this or other Halliburton products, contact Chemical Stewardship at 1-580-251-4335.

Key abreviations or acronyms used
bw – body weight
CAS – Chemical Abstracts Service
EC50 – Effective Concentration 50%
LC50 – Lethal Concentration 50%
LD50 – Lethal Dose 50%
LL50 – Lethal Loading 50%
mg/kg – milligram/kilogram
mg/L – milligram/liter
NOEC – No Observed Effect Concentration
OEL – Occupational Exposure Limit
PBT – Persistent Bioaccumulative and Toxic
ppm – parts per million
STEL – Short Term Exposure Limit
TWA – Time-Weighted Average
vPvB – very Persistent and very Bioaccumulative
h - hour
mg/m^3 - milligram/cubic meter
mm - millimeter
mmHg - millimeter mercury
w/w - weight/weight
d - day

Key literature references and sources for data
www.ChemADVISOR.com/
NZ CCID

Disclaimer Statement

This information is furnished without warranty, expressed or implied, as to accuracy or completeness. The information is obtained from various sources including the manufacturer and other third party sources. The information may not be valid under all conditions nor if this material is used in combination with other materials or in any process. Final determination of suitability of any material is the sole responsibility of the user.

End of Safety Data Sheet

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SAFETY DATA SHEET

Caustic Soda 30% / CAU-186

Revision Date: 29-Dec-2015 **Revision Number:** 2

1. Product Identifier & Identity for the Chemical

Statement of Hazardous Nature Hazardous according to the criteria of the 3rd Revised Edition of the Globally Harmonised System of Classification and Labelling of Chemicals (GHS), Dangerous Goods according to the criteria of ADG.

1.1. Product Identifier

Product Name Caustic Soda 30% / CAU-186

Other means of Identification

Synonyms: None

Product Code: MC600012

Recommended use of the chemical and restrictions on use

Recommended Use pH Control

Uses Advised Against No information available

Supplier's name, address and phone number

Manufacturer/Supplier Multi-Chem Mintech
1 Ward Road
East Rockingham
WA 6168
Australia

Telephone Number: 61 (08) 9419 5300
Fax Number: 61 (08) 9439 1055 Emergency Telephone Number: + 61 1 800 686 951

E-Mail address: fdunexchem@halliburton.com

Emergency phone number

+ 61 1 800 686 951

Australian Poisons Information Centre

24 Hour Service: - 13 11 26

Police or Fire Brigade: - 000 (exchange): - 1100

2. Hazard Identification

Statement of Hazardous Nature Hazardous according to the criteria of the 3rd Revised Edition of the Globally Harmonised System of Classification and Labelling of Chemicals (GHS), Dangerous Goods according to the criteria of ADG.

Classification of the hazardous chemical

Skin Corrosion / irritation	Category 1 - H314
Serious Eye Damage / Eye Irritation	Category 1 - H318
Specific Target Organ Toxicity - (Single Exposure)	Category 3 - H335
Substances/mixtures corrosive to metal.	Category 1 - H290

Label elements, including precautionary statements

Hazard Pictograms



Signal Word Danger

Hazard Statements
H314 - Causes severe skin burns and eye damage
H318 - Causes serious eye damage
H335 - May cause respiratory irritation
H290 - May be corrosive to metals

Precautionary Statements

Prevention
P234 - Keep only in original container
P260 - Do not breathe dust/fume/gas/mist/vapors/spray
P264 - Wash face, hands and any exposed skin thoroughly after handling
P280 - Wear protective gloves/eye protection/face protection

Response
P301+ P330 + P331 - IF SWALLOWED: Rinse mouth. Do NOT induce vomiting
P303 + P361 + P353 - IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water/shower
P363 - Wash contaminated clothing before reuse
P304 + P340 - IF INHALED: Remove to fresh air and keep at rest in a position comfortable for breathing
P310 - Immediately call a POISON CENTER or doctor/physician
P305 + P351 + P338 - IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing
P390 - Absorb spillage to prevent material damage

Storage
P403 + P233 - Store in a well-ventilated place. Keep container tightly closed
P405 - Store locked up

Disposal
P501 - Dispose of contents/container in accordance with local/regional/national/international regulations

Contains Substances	**CAS Number**
Sodium hydroxide	1310-73-2

Other hazards which do not result in classification
None known

Australia Classification
For the full text of the H-phrases mentioned in this Section, see Section 16

Classification C - Corrosive.

Risk Phrases
R35 Causes severe burns.
R37 Irritating to respiratory system.

3. Composition/information on Ingredients

Substances	CAS Number	PERCENT (w/w)	GHS Classification - Australia

Sodium hydroxide	1310-73-2	30 - 60%	Skin Corr. 1A (H314) Eye Corr. 1 (H318) STOT SE 3 (H335) Met. Corr. 1 (H290)

4. First aid measures

Description of necessary first aid measures

Inhalation If inhaled, move victim to fresh air and seek medical attention.

Eyes In case of contact, or suspected contact, immediately flush eyes with plenty of water for at least 15 minutes and get medical attention immediately after flushing.

Skin In case of contact, immediately flush skin with plenty of soap and water for at least 15 minutes. Get medical attention. Remove contaminated clothing and launder before reuse. Destroy or properly dispose of contaminated shoes.

Ingestion Do NOT induce vomiting. Give nothing by mouth. Obtain immediate medical attention.

Symptoms caused by exposure

Causes severe eye irritation which may damage tissue. Causes severe skin irritation with tissue destruction. May cause respiratory irritation.

Medical Attention and Special Treatment

Notes to Physician Treat symptomatically

5. Fire Fighting Measures

Suitable extinguishing equipment

Suitable Extinguishing Media

All standard fire fighting media

Extinguishing media which must not be used for safety reasons

None known.

Specific hazards arising from the chemical

Special Exposure Hazards

May form explosive mixtures with strong acids. Reaction with steel and certain other metals generates flammable hydrogen gas.

Special protective equipment and precautions for fire fighters

Special Protective Equipment for Fire-Fighters

Full protective clothing and approved self-contained breathing apparatus required for fire fighting personnel.

6. Accidental release measures

6.1. Personal precautions, protective equipment and emergency procedures

Use appropriate protective equipment.

6.2. Environmental precautions

Prevent from entering sewers, waterways, or low areas.

6.3. Methods and material for containment and cleaning up

Isolate spill and stop leak where safe. Contain spill with sand or other inert materials. Neutralize to pH of 6-8. Scoop up and remove.

7. Handling and storage

7.1. Precautions for Safe Handling

Handling Precautions

Avoid contact with eyes, skin, or clothing. Avoid breathing vapors. Wash hands after use. Launder contaminated clothing before reuse.

Hygiene Measures
Handle in accordance with good industrial hygiene and safety practice.

7.2. Conditions for safe storage, including any incompatibilities
Storage Information
Store away from acids. Store in a cool well ventilated area. Keep container closed when not in use. Product has a shelf life of 12 months. Store locked up.
Other Guidelines
No information available

8. Exposure Controls/Personal Protection

Control parameters - exposure standards, biological monitoring
Exposure Limits

Substances	CAS Number	Australia NOHSC	ACGIH TLV-TWA
Sodium hydroxide	1310-73-2	2 mg/m^3	2 mg/M3

Appropriate engineering controls
Engineering Controls Use in a well ventilated area. Local exhaust ventilation should be used in areas without good cross ventilation.

Personal protective equipment (PPE)
Personal Protective Equipment If engineering controls and work practices cannot prevent excessive exposures, the selection and proper use of personal protective equipment should be determined by an industrial hygienist or other qualified professional based on the specific application of this product.
Respiratory Protection Dust/mist respirator. (N95, P2/P3)
Hand Protection Impervious rubber gloves.
Skin Protection Full protective chemical resistant clothing.
Eye Protection Chemical goggles; also wear a face shield if splashing hazard exists.
Other Precautions Eyewash fountains and safety showers must be easily accessible.
Environmental Exposure Controls No information available

9. Physical and Chemical Properties

9.1. Information on basic physical and chemical properties
Physical State: Liquid **Color:** Clear colorless
Odor: Odorless **Odor Threshold:** No information available

Property	Values	Remarks/ - Method
pH:	14	
Freezing Point/Range	No data available	
Melting Point/Range	No data available	
Boiling Point/Range	144 °C / 291 °F	
Flash Point	No data available	
Evaporation rate	No data available	
Vapor Pressure	No data available	
Vapor Density	No data available	
Specific Gravity	1.52	
Water Solubility	Miscible with water	
Solubility in other solvents	No data available	
Partition coefficient: n-octanol/water	No data available	
Autoignition Temperature	No data available	
Decomposition Temperature	No data available	
Viscosity	No data available	
Explosive Properties	No information available	
Oxidizing Properties	No information available	

9.2. Other information
Molecular Weight 40

VOC Content (%) No data available

10. Stability and Reactivity

10.1. Reactivity
Not expected to be reactive.
10.2. Chemical Stability
Stable
10.3. Possibility of Hazardous Reactions
Will Not Occur
10.4. Conditions to Avoid
None anticipated
10.5. Incompatible Materials
Strong acids. Peroxides. Halogenated compounds. Amphoteric metals such as aluminum, magnesium, lead, tin, or zinc.
10.6. Hazardous Decomposition Products
None known.

11. Toxicological Information

Information on routes of exposure
Principle Route of Exposure Eye or skin contact, inhalation.

Symptoms related to exposure
Most Important Symptoms/Effects
Causes severe eye irritation which may damage tissue. Causes severe skin irritation with tissue destruction. May cause respiratory irritation.

Numerical measures of toxicity

Toxicology data for the components

Substances	CAS Number	LD50 Oral	LD50 Dermal	LC50 Inhalation
Sodium hydroxide	1310-73-2	No data available	1350 mg/kg (Rabbit)	No data available

Immediate, delayed and chronic health effects from exposure
Inhalation Causes severe respiratory burns.
Eye Contact Causes severe eye burns.
Skin Contact Causes severe burns.
Ingestion Causes burns of the mouth, throat and stomach.

Chronic Effects/Carcinogenicity Prolonged, excessive exposure may cause erosion of the teeth.

Exposure Levels
No data available

Interactive effects
Skin disorders.

Data limitations
No data available

Substances	CAS Number	Skin corrosion/irritation
Sodium hydroxide	1310-73-2	Causes severe burns

Substances	CAS Number	Eye damage/irritation
Sodium hydroxide	1310-73-2	Causes severe eye burns (Rabbit)

Substances	CAS Number	Skin Sensitization
Sodium hydroxide	1310-73-2	Did not cause sensitization on laboratory animals (guinea pig)

Substances	CAS Number	Respiratory Sensitization
Sodium hydroxide	1310-73-2	No information available

Substances	CAS Number	Mutagenic Effects
Sodium hydroxide	1310-73-2	Did not show mutagenic effects in animal experiments In vitro tests did not show mutagenic effects

Substances	CAS Number	Carcinogenic Effects
Sodium hydroxide	1310-73-2	No data of sufficient quality are available.

Substances	CAS Number	Reproductive toxicity
Sodium hydroxide	1310-73-2	No information available

Substances	CAS Number	STOT - single exposure
Sodium hydroxide	1310-73-2	May cause respiratory irritation.

Substances	CAS Number	STOT - repeated exposure
Sodium hydroxide	1310-73-2	No significant toxicity observed in animal studies at concentration requiring classification. Not applicable due to corrosivity of the substance.

Substances	CAS Number	Aspiration hazard
Sodium hydroxide	1310-73-2	Not applicable

12. Ecological Information

Ecotoxicity

Product Ecotoxicity Data

No data available

Substance Ecotoxicity Data

Substances	CAS Number	Toxicity to Algae	Toxicity to Fish	Toxicity to Microorganisms	Toxicity to Invertebrates
Sodium hydroxide	1310-73-2	No information available	LC50 (96h) 125 mg/L (Gambusia affinis) LC50 (48h) 189 mg/L (Leuciscus melanotus) LC50 (24h) 145 mg/L (Poecilia reticulate)	No information available	EC50 (48h) 40.4 mg/L (Ceriodaphnia sp.)

12.2. Persistence and degradability

The methods for determining biodegradability are not applicable to inorganic substances.

Substances	CAS Number	Persistence and Degradability
Sodium hydroxide	1310-73-2	The methods for determining biodegradability are not applicable to inorganic substances.

12.3. Bioaccumulative potential

Does not bioaccumulate.

Substances	CAS Number	Log Pow
Sodium hydroxide	1310-73-2	No information available

12.4. Mobility in soil

Substances	CAS Number	Mobility
Sodium hydroxide	1310-73-2	No information available

12.6. Other adverse effects

Endocrine Disruptor Information

This product does not contain any known or suspected endocrine disruptors

13. Disposal Considerations

Safe handling and disposal methods

Disposal should be made in accordance with federal, state, and local regulations. Substance should NOT be deposited into a sewage facility.

Disposal of any contaminated packaging
Follow all applicable national or local regulations. Contaminated packaging may be disposed of by: rendering packaging incapable of containing any substance, or treating packaging to remove residual contents, or treating packaging to make sure the residual contents are no longer hazardous, or by disposing of packaging into commercial waste collection.

Environmental regulations
Not applicable

14. Transport Information

Transportation Information

UN Number:	UN1824
UN Proper Shipping Name:	Sodium Hydroxide Solution
Transport Hazard Class(es):	8
Packing Group:	II
Environmental Hazards:	Not applicable

Special precautions during transport
None

HazChem Code
2R

15. Regulatory Information

Safety, health and environmental regulations specific for the product

International Inventories

Australian AICS Inventory	All components are listed on the AICS or are subject to a relevant exemption, permit, or assessment certificate.
New Zealand Inventory of Chemicals	All components are listed on the AICS or are subject to a relevant exemption, permit, or assessment certificate.
EINECS Inventory	This product, and all its components, complies with EINECS
US TSCA Inventory	All components listed on inventory or are exempt.
Canadian DSL Inventory	All components listed on inventory or are exempt.

Poisons Schedule number
S6

International Agreements

Montreal Protocol - Ozone Depleting Substances:	Does not apply
Stolkhom Convention - Persistent Organic Pollutants:	Does not apply
Rotterdam Convention - Prior Informed Consent:	Does not apply
Basel Convention - Hazardous Waste:	Does not apply

16. Other information

Date of preparation or review

Revision Date: 29-Dec-2015

Revision Note
SDS sections updated: 2

Full text of R-phrases referred to under Sections 2 and 3
C - Corrosive.
R34 Causes burns.

R35 Causes severe burns.
R37 Irritating to respiratory system.

Full text of H-Statements referred to under sections 2 and 3
H290 - May be corrosive to metals
H314 - Causes severe skin burns and eye damage
H318 - Causes serious eye damage
H335 - May cause respiratory irritation

Additional information

For additional information on the use of this product, contact your local Halliburton representative.

For questions about the Safety Data Sheet for this or other Halliburton products, contact Chemical Stewardship at 1-580-251-4335.

Key abreviations or acronyms used

bw – body weight
CAS – Chemical Abstracts Service
EC50 – Effective Concentration 50%
LC50 – Lethal Concentration 50%
LD50 – Lethal Dose 50%
LL50 – Lethal Loading 50%
mg/kg – milligram/kilogram
mg/L – milligram/liter
NOEC – No Observed Effect Concentration
OEL – Occupational Exposure Limit
PBT – Persistent Bioaccumulative and Toxic
ppm – parts per million
STEL – Short Term Exposure Limit
TWA – Time-Weighted Average
vPvB – very Persistent and very Bioaccumulative
h - hour
mg/m^3 - milligram/cubic meter
mm - millimeter
mmHg - millimeter mercury
w/w - weight/weight
d - day

Key literature references and sources for data
www.ChemADVISOR.com/
NZ CCID

Disclaimer Statement
This information is furnished without warranty, expressed or implied, as to accuracy or completeness. The information is obtained from various sources including the manufacturer and other third party sources. The information may not be valid under all conditions nor if this material is used in combination with other materials or in any process. Final determination of suitability of any material is the sole responsibility of the user.

End of Safety Data Sheet

HALLIBURTON

MATERIAL SAFETY DATA SHEET

Product Trade Name: **CLBEAU196**

Revision Date: 27-Aug-2013

1. IDENTIFICATION OF THE SUBSTANCE/PREPARATION AND OF THE COMPANY/UNDERTAKING

Statement of Hazardous Nature Hazardous according to the criteria of NOHSC, Non-Dangerous Goods according to the criteria of ADG.

Manufacturer/Supplier

Halliburton Australia Pty. Ltd.
15 Marriott Road
Jandakot
WA 6164
Australia

ACN Number: 009 000 775
Telephone Number: 61 (08) 9455 8300
Fax Number: 61 (08) 9455 5300

Product Emergency Telephone
Australia: 08-64244950
Papua New Guinea: 05 1 281 575 5000
NewZealand: 06-7559274

Fire, Police & Ambulance - Emergency Telephone
Australia: 000
Papua New Guinea: 000
New Zealand: 111

Identification of Substances or Preparation

Product Trade Name: CLBEAU196
Synonyms: None
Chemical Family: Polysaccharide
UN Number: None
Dangerous Goods Class: None
Subsidiary Risk: None
Hazchem Code: None Allocated
Poisons Schedule: None Allocated
Application: Breaker

Prepared By

Chemical Compliance
Telephone: 1-580-251-4335
e-mail: fdunexchem@halliburton.com

2. COMPOSITION/INFORMATION ON INGREDIENTS

Substances	CAS Number	PERCENT (w/w)	Australia NOHSC	New Zealand WES	ACGIH TLV-TWA
Hemicellulase enzyme	9012-54-8	1 - 5%	Not applicable	Not applicable	Not applicable

Non-Hazardous Substance to Total of 100%

3. HAZARDS IDENTIFICATION

Hazard Overview Airborne dust may be explosive. May cause allergic respiratory reaction. May cause eye and respiratory irritation.

Risk Phrases R42 May cause sensitization by inhalation.

HSNO Classification 6.5A Respiratory sensitisers

4. FIRST AID MEASURES

Inhalation If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Skin Wash with soap and water. Get medical attention if irritation persists.

Eyes In case of contact, immediately flush eyes with plenty of water for at least 15 minutes and get medical attention if irritation persists.

Ingestion Under normal conditions, first aid procedures are not required.

Notes to Physician Not Applicable

5. FIRE FIGHTING MEASURES

Suitable Extinguishing Media
All standard fire fighting media

Extinguishing media which must not be used for safety reasons
None known.

Special Exposure Hazards Organic dust in the presence of an ignition source can be explosive in high concentrations. Good housekeeping practices are required to minimize this potential.

Special Protective Equipment for Fire-Fighters Full protective clothing and approved self-contained breathing apparatus required for fire fighting personnel.

6. ACCIDENTAL RELEASE MEASURES

Personal Precautionary Measures Use appropriate protective equipment. Avoid creating and breathing dust.

Environmental Precautionary Measures Prevent from entering sewers, waterways, or low areas.

Procedure for Cleaning / Absorption Scoop up and remove.

7. HANDLING AND STORAGE

Handling Precautions Avoid creating or inhaling dust. Slippery when wet.

Storage Information Store away from oxidizers. Store in a cool, dry location. Product has a shelf life of 18 months.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Engineering Controls	Use in a well ventilated area.
Personal Protective Equipment	If engineering controls and work practices cannot prevent excessive exposures, the selection and proper use of personal protective equipment should be determined by an industrial hygienist or other qualified professional based on the specific application of this product.
Respiratory Protection	Not normally needed. But if significant exposures are possible then the following respirator is recommended: Dust/mist respirator. (N95, P2/P3)
Hand Protection	Impervious rubber gloves.
Skin Protection	Normal work coveralls.
Eye Protection	Wear safety glasses or goggles to protect against exposure.
Other Precautions	None known.

9. PHYSICAL AND CHEMICAL PROPERTIES

Physical State:	Powder
Color:	White to Tan
Odor:	Characteristic
pH:	3.8-8 (1%)
Specific Gravity @ 20 C (Water=1):	Not Determined
Density @ 20 C (kg/l):	Not Determined
Bulk Density @ 20 C (kg/M3):	Not Determined
Boiling Point/Range (C):	Not Determined
Freezing Point/Range (C):	Not Determined
Pour Point/Range (C):	Not Determined
Flash Point/Range (C):	Not Determined **Min:** > 93
Flash Point Method:	Not Determined
Autoignition Temperature (C):	Not Determined
Flammability Limits in Air - Lower (g/m^3):	Not Determined
Flammability Limits in Air - Lower (%):	Not Determined
Flammability Limits in Air - Upper (g/m^3):	Not Determined
Flammability Limits in Air - Upper (%):	Not Determined
Vapor Pressure @ 20 C (mmHg):	Not Determined
Vapor Density (Air=1):	Not Determined
Percent Volatiles:	Not Determined
Evaporation Rate (Butyl Acetate=1):	Not Determined
Solubility in Water (g/100ml):	Disperses
Solubility in Solvents (g/100ml):	Not Determined
VOCs (g/l):	Not Determined
Viscosity, Dynamic @ 20 C (centipoise):	Not Determined
Viscosity, Kinematic @ 20 C (centistokes):	Not Determined
Partition Coefficient/n-Octanol/Water:	Not Determined
Molecular Weight (g/mole):	Not Determined
Decomposition Temperature (C):	Not Determined

10. STABILITY AND REACTIVITY

Stability Data: Stable

Hazardous Polymerization: Will Not Occur

Conditions to Avoid None anticipated

Incompatibility (Materials to Avoid) Strong oxidizers.

Hazardous Decomposition Products Carbon monoxide and carbon dioxide.

Additional Guidelines Not Applicable

11. TOXICOLOGICAL INFORMATION

Principle Route of Exposure Eye or skin contact, inhalation.

Sympotoms related to exposure

Acute Toxicity

Inhalation May cause allergic respiratory reaction. May cause mild respiratory irritation.

Eye Contact May cause mild eye irritation.

Skin Contact None known.

Ingestion None known

Chronic Effects/Carcinogenicity No data available to indicate product or components present at greater than 1% are chronic health hazards.

Toxicology data for the components

Substances	CAS Number	LD50 Oral	LD50 Dermal	LC50 Inhalation
Hemicellulase enzyme	9012-54-8	> 2000 mg/kg (Rat)	No data available	No data available

12. ECOLOGICAL INFORMATION

Ecotoxicological Information

Ecotoxicity Product

Acute Fish Toxicity: Not determined

Acute Crustaceans Toxicity: Not determined

Acute Algae Toxicity: Not determined

Ecotoxicity Substance

Substances	CAS Number	Toxicity to Algae	Toxicity to Fish	Toxicity to Microorganisms	Daphnia Magna (Water Flea)
Hemicellulase enzyme	9012-54-8	No information available	No information available	No information available	EC50: > 39.5 mg/L (Daphnia magna)

Persistence and degradability

Readily biodegradable

Bioaccumulative potential

Does not bioaccumulate

Mobility in soil

No information available

Results of PBT and vPvB assessment

No information available.

Other adverse effects

13. DISPOSAL CONSIDERATIONS

Disposal Method Bury in a licensed landfill according to federal, state, and local regulations.

Contaminated Packaging Follow all applicable national or local regulations.

14. TRANSPORT INFORMATION

Land Transportation

ADR
Not restricted

Air Transportation

ICAO/IATA
Not restricted

Sea Transportation

IMDG
Not restricted

Other Transportation Information

Labels: None

15. REGULATORY INFORMATION

Chemical Inventories

Australian AICS Inventory	All components listed on inventory or are exempt.
New Zealand Inventory of Chemicals	All components listed on inventory or are exempt.
US TSCA Inventory	All components listed on inventory or are exempt.
EINECS Inventory	This product, and all its components, complies with EINECS
Classification	Xn - Harmful.
Risk Phrases	R42 May cause sensitization by inhalation.
Safety Phrases	S2 Keep out of reach of children. S22 Do not breathe dust. S24 Avoid contact with skin. S36/37 Wear suitable protective clothing and gloves.

16. OTHER INFORMATION

The following sections have been revised since the last issue of this SDS
Not applicable

Contact

Australian Poisons Information Centre
24 Hour Service: - 13 11 26
Police or Fire Brigade: - 000 (exchange): - 1100

New Zealand National Poisons Centre
0800 764 766

Additional Information

For additional information on the use of this product, contact your local Halliburton representative.

For questions about the Safety Data Sheet for this or other Halliburton products, contact Chemical Compliance at 1-580-251-4335.

Disclaimer Statement

This information is furnished without warranty, expressed or implied, as to accuracy or completeness. The information is obtained from various sources including the manufacturer and other third party sources. The information may not be valid under all conditions nor if this material is used in combination with other materials or in any process. Final determination of suitability of any material is the sole responsibility of the user.

*****END OF MSDS*****

HALLIBURTON

MATERIAL SAFETY DATA SHEET

Product Trade Name: **CLWGAU421**

Revision Date: 05-Sep-2012

1. IDENTIFICATION OF THE SUBSTANCE/PREPARATION AND OF THE COMPANY/UNDERTAKING

Statement of Hazardous Nature Non-Hazardous according to the criteria of NOHSC, Non-Dangerous Goods according to the criteria of ADG.

Manufacturer/Supplier

Halliburton/Baroid Australia Pty. Ltd.
15 Marriott Road
Jandakot
WA 6164
Australia

ACN Number: 009 000 775
Telephone Number: 61 (08) 9455 8300
Fax Number: 61 (08) 9455 5300

Product Emergency Telephone
Australia: 08-64244950
Papua New Guinea: 05 1 281 575 5000
New Zealand: 06-7559274

Fire, Police & Ambulance - Emergency Telephone
Australia: 000
Papua New Guinea: 000
New Zealand: 111

Identification of Substances or Preparation

Product Trade Name: CLWGAU421
Synonyms: None
Chemical Family: Carbohydrate
UN Number: None
Dangerous Goods Class: None
Subsidiary Risk: None
Hazchem Code: None Allocated
Poisons Schedule: None Allocated
Application: Gelling Agent

Prepared By

Chemical Compliance
Telephone: 1-580-251-4335
e-mail: fdunexchem@halliburton.com

2. COMPOSITION/INFORMATION ON INGREDIENTS

Substances	CAS Number	PERCENT	Australia NOHSC	New Zealand WES	ACGIH TLV-TWA
Polysaccharide	Proprietary	60 - 100%	Not applicable	Not applicable	Not applicable

Non-Hazardous Substance to Total of 100%

3. HAZARDS IDENTIFICATION

Hazard Overview	May cause eye, skin, and respiratory irritation. Airborne dust may be explosive.
Risk Phrases	None
HSNO Classification	9.1C Harmful in the aquatic environment

4. FIRST AID MEASURES

Inhalation	If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.
Skin	Wash with soap and water. Get medical attention if irritation persists.
Eyes	In case of contact, immediately flush eyes with plenty of water for at least 15 minutes and get medical attention if irritation persists.
Ingestion	Do NOT induce vomiting. Give nothing by mouth. Obtain immediate medical attention.
Notes to Physician	Not Applicable

5. FIRE FIGHTING MEASURES

Suitable Extinguishing Media	Water fog, carbon dioxide, foam, dry chemical.
Extinguishing media which must not be used for safety reasons	None known.
Special Exposure Hazards	Organic dust in the presence of an ignition source can be explosive in high concentrations. Good housekeeping practices are required to minimize this potential.
Special Protective Equipment for Fire-Fighters	Full protective clothing and approved self-contained breathing apparatus required for fire fighting personnel.

6. ACCIDENTAL RELEASE MEASURES

Personal Precautionary Measures	Avoid creating and breathing dust. Slippery when wet.
Environmental Precautionary Measures	None known.
Procedure for Cleaning / Absorption	Scoop up and remove.

7. HANDLING AND STORAGE

Handling Precautions	Wash hands after use. Launder contaminated clothing before reuse. Avoid contact with eyes, skin, or clothing. Avoid creating or inhaling dust. Avoid dust accumulations. Slippery when wet. Ground and bond containers when transferring from one container to another.

Storage Information Store in a well ventilated area. Store away from oxidizers. Keep container closed when not in use. Store in a cool, dry location. Keep from heat, sparks, and open flames. Product has a shelf life of 24 months.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Engineering Controls A well ventilated area to control dust levels. Local exhaust ventilation should be used in areas without good cross ventilation.

Respiratory Protection If engineering controls and work practices cannot keep exposure below occupational exposure limits or if exposure is unknown, wear a NIOSH certified, European Standard EN 149, or equivalent respirator when using this product. Selection of and instruction on using all personal protective equipment, including respirators, should be performed by an Industrial Hygienist or other qualified professional.

Not normally needed. But if significant exposures are possible then the following respirator is recommended:
Dust/mist respirator. (N95, P2/P3)

Hand Protection Normal work gloves.

Skin Protection Normal work coveralls.

Eye Protection Wear safety glasses or goggles to protect against exposure.

Other Precautions Eyewash fountains and safety showers must be easily accessible.

9. PHYSICAL AND CHEMICAL PROPERTIES

Physical State:	Powder
Color:	White to off white
Odor:	Odorless
pH:	6.5-8 (1%)
Specific Gravity @ 20 C (Water=1):	1.6
Density @ 20 C (kg/l):	Not Determined
Bulk Density @ 20 C (kg/m^3):	750
Boiling Point/Range (C):	Not Determined
Freezing Point/Range (C):	Not Determined
Pour Point/Range (C):	Not Determined
Flash Point/Range (C):	Not Determined
Flash Point Method:	Not Determined
Autoignition Temperature (C):	> 370
Flammability Limits in Air - Lower (g/m^3):	Not Determined
Flammability Limits in Air - Lower (%):	Not Determined
Flammability Limits in Air - Upper (g/m^3):	Not Determined
Flammability Limits in Air - Upper (%):	Not Determined
Vapor Pressure @ 20 C (mmHg):	Not Determined
Vapor Density (Air=1):	Not Determined
Percent Volatiles:	Not Determined
Evaporation Rate (Butyl Acetate=1):	Not Determined
Solubility in Water (g/100ml):	Forms gel
Solubility in Solvents (g/100ml):	Not Determined
VOCs (g/l):	Not Determined
Viscosity, Dynamic @ 20 C (centipoise):	Not Determined
Viscosity, Kinematic @ 20 C (centistokes):	Not Determined
Partition Coefficient/n-Octanol/Water:	Not Determined
Molecular Weight (g/mole):	Not Determined
Decomposition Temperature (C):	Not Determined

10. STABILITY AND REACTIVITY

Stability Data:	Stable
Hazardous Polymerization:	Will Not Occur
Conditions to Avoid	None known.
Incompatibility (Materials to Avoid)	Strong oxidizers.
Hazardous Decomposition Products	Carbon monoxide and carbon dioxide.
Additional Guidelines	Not Applicable

11. TOXICOLOGICAL INFORMATION

Principle Route of Exposure	Eye or skin contact, inhalation.

Sympotoms related to exposure

Inhalation	May cause mild respiratory irritation. In high air concentrations: May impede respiration.
Skin Contact	May cause an allergic skin reaction. Prolonged or repeated contact may cause skin irritation.
Eye Contact	May cause mild eye irritation.
Ingestion	May cause allergic reaction.
Aggravated Medical Conditions	None known.
Chronic Effects/Carcinogenicity	No data available to indicate product or components present at greater than 1% are chronic health hazards.
Other Information	None known.

Toxicity Tests

Oral Toxicity:	Not determined
Dermal Toxicity:	Not determined
Inhalation Toxicity:	Not determined
Primary Irritation Effect:	Not determined
Carcinogenicity	Not determined
Genotoxicity:	Not determined
Reproductive / Developmental Toxicity:	Not determined

12. ECOLOGICAL INFORMATION

Mobility (Water/Soil/Air)	Not determined
Persistence/Degradability	Readily biodegradable

Bio-accumulation Not determined

Ecotoxicological Information

Acute Fish Toxicity: Not determined
Acute Crustaceans Toxicity: Not determined
Acute Algae Toxicity: Not determined

Chemical Fate Information Not determined

Other Information Not applicable

13. DISPOSAL CONSIDERATIONS

Disposal Method Bury in a licensed landfill according to federal, state, and local regulations.

Contaminated Packaging Follow all applicable national or local regulations.

14. TRANSPORT INFORMATION

Land Transportation

ADR
Not restricted

Air Transportation

ICAO/IATA
Not restricted

Sea Transportation

IMDG
Not restricted

Other Transportation Information

Labels: None

15. REGULATORY INFORMATION

Chemical Inventories

Australian AICS Inventory All components listed on inventory or are exempt.
New Zealand Inventory of Chemicals All components listed on inventory or are exempt.
US TSCA Inventory All components listed on inventory or are exempt.
EINECS Inventory This product, and all its components, complies with EINECS

Classification Not Classified

Risk Phrases None

Safety Phrases None

16. OTHER INFORMATION

The following sections have been revised since the last issue of this SDS
Not applicable

Contact

Australian Poisons Information Centre
24 Hour Service: - 13 11 26
Police or Fire Brigade: - 000 (exchange): - 1100

New Zealand National Poisons Centre
0800 764 766

Additional Information

For additional information on the use of this product, contact your local Halliburton representative.

For questions about the Safety Data Sheet for this or other Halliburton products, contact Chemical Compliance at 1-580-251-4335.

Disclaimer Statement

This information is furnished without warranty, expressed or implied, as to accuracy or completeness. The information is obtained from various sources including the manufacturer and other third party sources. The information may not be valid under all conditions nor if this material is used in combination with other materials or in any process. Final determination of suitability of any material is the sole responsibility of the user.

*****END OF MSDS*****

HALLIBURTON

MATERIAL SAFETY DATA SHEET

Product Trade Name: **DCA-25005**

Revision Date: 05-Mar-2014

1. IDENTIFICATION OF THE SUBSTANCE/PREPARATION AND OF THE COMPANY/UNDERTAKING

Statement of Hazardous Nature Non-Hazardous according to the criteria of NOHSC, Non-Dangerous Goods according to the criteria of ADG.

Manufacturer/Supplier

Halliburton Australia Pty. Ltd.
15 Marriott Road
Jandakot
WA 6164
Australia

ACN Number: 009 000 775
Telephone Number: 61 (08) 9455 8300
Fax Number: 61 (08) 9455 5300

Product Emergency Telephone
Australia: 08-64244950
Papua New Guinea: 05 1 281 575 5000
NewZealand: 06-7559274

Fire, Police & Ambulance - Emergency Telephone
Australia: 000
Papua New Guinea: 000
New Zealand: 111

Identification of Substances or Preparation

Product Trade Name:	DCA-25005
Synonyms:	None
Chemical Family:	Polysaccharide
UN Number:	None
Dangerous Goods Class:	None
Subsidiary Risk:	None
Hazchem Code:	None Allocated
Poisons Schedule:	None Allocated
Application:	Gelling Agent

Prepared By

Chemical Compliance
Telephone: 1-580-251-4335
e-mail: fdunexchem@halliburton.com

2. HAZARDS IDENTIFICATION

Statement of Hazardous Nature Non-Hazardous according to the criteria of NOHSC, Non-Dangerous Goods according to the criteria of ADG.

Hazard Overview May cause mild eye, skin, and respiratory irritation. Organic dust in the presence of an ignition source can be explosive in high concentrations. Good housekeeping practices are required to minimize this potential.

Classification None

Risk Phrases None

Safety Phrases None

HSNO Classification
6.3B Mildly irritating to the skin
6.5A Respiratory sensitisers
6.5B Contact sensitisers
9.1D Slightly harmful in the aquatic environment

3. COMPOSITION/INFORMATION ON INGREDIENTS

Substances	CAS Number	PERCENT (w/w)	Australia NOHSC	New Zealand WES	ACGIH TLV-TWA
Contains no hazardous substances	Mixture	60 - 100%	Not applicable	Not applicable	Not applicable

Non-Hazardous Substance to Total of 100%

4. FIRST AID MEASURES

Inhalation If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Skin Wash with soap and water. Get medical attention if irritation persists.

Eyes In case of contact, immediately flush eyes with plenty of water for at least 15 minutes and get medical attention if irritation persists.

Ingestion Under normal conditions, first aid procedures are not required.

Notes to Physician Not Applicable

5. FIRE FIGHTING MEASURES

Suitable Extinguishing Media
Water fog, carbon dioxide, foam, dry chemical.

Extinguishing media which must not be used for safety reasons
None known.

Special Exposure Hazards Decomposition in fire may produce toxic gases. Organic dust in the presence of an ignition source can be explosive in high concentrations. Good housekeeping practices are required to minimize this potential.

Special Protective Equipment for Fire-Fighters Full protective clothing and approved self-contained breathing apparatus required for fire fighting personnel.

6. ACCIDENTAL RELEASE MEASURES

Personal Precautionary Measures Use appropriate protective equipment. Avoid creating and breathing dust.

Environmental Precautionary Measures	Prevent from entering sewers, waterways, or low areas.
Procedure for Cleaning / Absorption	Scoop up and remove.

7. HANDLING AND STORAGE

Handling Precautions	Avoid contact with eyes, skin, or clothing. Avoid creating or inhaling dust.
Storage Information	Store away from oxidizers. Store in a cool, dry location. Product has a shelf life of 24 months.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Engineering Controls	Use in a well ventilated area.
Respiratory Protection	Not normally needed. But if significant exposures are possible then the following respirator is recommended: Dust/mist respirator. (N95, P2/P3)
Hand Protection	Normal work gloves.
Skin Protection	Normal work coveralls.
Eye Protection	Wear safety glasses or goggles to protect against exposure.
Other Precautions	None known.

9. PHYSICAL AND CHEMICAL PROPERTIES

Physical State:	Solid
Color:	Off white
Odor:	Bean
pH:	6.5-7.5
Specific Gravity @ 20 C (Water=1):	1.42 -1.47
Density @ 20 C (kg/l):	Not Determined
Bulk Density @ 20 C (kg/M3):	Not Determined
Boiling Point/Range (C):	Not Determined
Freezing Point/Range (C):	Not Determined
Pour Point/Range (C):	Not Determined
Flash Point/Range (C):	Not Determined **Min:** > 93
Flash Point Method:	COC
Autoignition Temperature (C):	Not Determined
Flammability Limits in Air - Lower (g/m^3):	Not Determined
Flammability Limits in Air - Lower (%):	Not Determined
Flammability Limits in Air - Upper (g/m^3):	Not Determined
Flammability Limits in Air - Upper (%):	Not Determined
Vapor Pressure @ 20 C (mmHg):	Not Determined
Vapor Density (Air=1):	Not Determined
Percent Volatiles:	Not Determined
Evaporation Rate (Butyl Acetate=1):	Not Determined
Solubility in Water (g/100ml):	Soluble
Solubility in Solvents (g/100ml):	Not Determined
VOCs (g/l):	Not Determined
Viscosity, Dynamic @ 20 C (centipoise):	Not Determined
Viscosity, Kinematic @ 20 C (centistokes):	Not Determined
Partition Coefficient/n-Octanol/Water:	Not Determined

Molecular Weight (g/mole): Not Determined
Decomposition Temperature (C): Not Determined

10. STABILITY AND REACTIVITY

Stability Data: Stable

Hazardous Polymerization: Will Not Occur

Conditions to Avoid None anticipated

Incompatibility (Materials to Avoid) Strong oxidizers.

Hazardous Decomposition Products Carbon monoxide and carbon dioxide.

Additional Guidelines Not Applicable

11. TOXICOLOGICAL INFORMATION

Principle Route of Exposure Eye or skin contact, inhalation.

Sympotoms related to exposure

Acute Toxicity

Inhalation May cause mild respiratory irritation. May cause allergic respiratory reaction.
Eye Contact May cause mild eye irritation.
Skin Contact None known.
Ingestion None known

Chronic Effects/Carcinogenicity No data available to indicate product or components present at greater than 1% are chronic health hazards.

Toxicology data for the components

Substances	CAS Number	LD50 Oral	LD50 Dermal	LC50 Inhalation
Contains no hazardous substances	Mixture	No data available	No data available	No data available

12. ECOLOGICAL INFORMATION

Ecotoxicological Information

Ecotoxicity Product

Acute Fish Toxicity: Not determined
Acute Crustaceans Toxicity: Not determined
Acute Algae Toxicity: Not determined

Ecotoxicity Substance

Substances	CAS Number	Toxicity to Algae	Toxicity to Fish	Toxicity to Microorganisms	Toxicity to Invertebrates
Contains no hazardous substances	Mixture	No information available	No information available	No information available	No information available

12.2 Persistence and degradability

Readily biodegradable

12.3 Bioaccumulative potential
Does not bioaccumulate

12.4 Mobility in soil
No information available

12.5 Results of PBT and vPvB assessment
No information available.

12.6 Other adverse effects

13. DISPOSAL CONSIDERATIONS

Disposal Method Bury in a licensed landfill according to federal, state, and local regulations.

Contaminated Packaging Follow all applicable national or local regulations.

14. TRANSPORT INFORMATION

Land Transportation

ADR
Not restricted

Air Transportation

ICAO/IATA
Not restricted

Sea Transportation

IMDG
Not restricted

Other Transportation Information

Labels: None

15. REGULATORY INFORMATION

Chemical Inventories

Australian AICS Inventory	All components listed on inventory or are exempt.
New Zealand Inventory of Chemicals	All components listed on inventory or are exempt.
US TSCA Inventory	All components listed on inventory or are exempt.
EINECS Inventory	This product, and all its components, complies with EINECS
Classification	Not Classified
Risk Phrases	None
Safety Phrases	None

16. OTHER INFORMATION

The following sections have been revised since the last issue of this SDS
Not applicable

Contact

Australian Poisons Information Centre
24 Hour Service: - 13 11 26
Police or Fire Brigade: - 000 (exchange): - 1100

New Zealand National Poisons Centre
0800 764 766

Additional information

For additional information on the use of this product, contact your local Halliburton representative.

For questions about the Safety Data Sheet for this or other Halliburton products, contact Chemical Compliance at 1-580-251-4335.

Disclaimer Statement

This information is furnished without warranty, expressed or implied, as to accuracy or completeness. The information is obtained from various sources including the manufacturer and other third party sources. The information may not be valid under all conditions nor if this material is used in combination with other materials or in any process. Final determination of suitability of any material is the sole responsibility of the user.

*****END OF MSDS*****

HALLIBURTON

SAFETY DATA SHEET

GBW-30 BREAKER

Revision Date: 20-Jun-2016 **Revision Number:** 30

1. Product Identifier & Identity for the Chemical

Statement of Hazardous Nature Hazardous according to the criteria of the 3rd Revised Edition of the Globally Harmonised System of Classification and Labelling of Chemicals (GHS), Non-Dangerous Goods according to the criteria of ADG.

1.1. Product Identifier

Product Name GBW-30 BREAKER

Other means of Identification

Synonyms None

Hazardous Material Number: HM000762

Recommended use of the chemical and restrictions on use

Recommended Use Breaker

Uses advised against No information available

Supplier's name, address and phone number

Manufacturer/Supplier

Halliburton Australia Pty. Ltd.
15 Marriott Road
Jandakot
WA 6164
Australia

ACN Number: 009 000 775
Telephone Number: + 61 1 800 686 951
Fax Number: 61 (08) 9455 5300

E-mail Address fdunexchem@halliburton.com

Emergency phone number

+ 61 1 800 686 951

Australian Poisons Information Centre

24 Hour Service: - 13 11 26

Police or Fire Brigade: - 000 (exchange): - 1100

2. Hazard Identification

Statement of Hazardous Nature Hazardous according to the criteria of the 3rd Revised Edition of the Globally Harmonised System of Classification and Labelling of Chemicals (GHS), Non-Dangerous Goods according to the criteria of ADG.

Classification of the hazardous chemical

Respiratory Sensitization	Category 1 - H334

Label elements, including precautionary statements

Hazard pictograms



Signal Word Danger

Hazard Statements: H334 - May cause allergy or asthma symptoms or breathing difficulties if inhaled

Precautionary Statements

Prevention P261 - Avoid breathing dust/fume/gas/mist/vapors/spray
P285 - In case of inadequate ventilation wear respiratory protection

Response P304 + P341 - IF INHALED: If breathing is difficult, remove to fresh air and keep at rest in a position comfortable for breathing
P342 + P311 - If experiencing respiratory symptoms: Call a POISON CENTER or doctor/physician

Storage None

Disposal P501 - Dispose of contents/container in accordance with local/regional/national/international regulations

Contains

Substances	**CAS Number**
Hemicellulase enzyme	9012-54-8

Other hazards which do not result in classification
This mixture contains no substance considered to be persistent, bioaccumulating nor toxic (PBT).
This mixture contains no substance considered to be very persistent nor very bioaccumulating (vPvB).

For the full text of the H-phrases mentioned in this Section, see Section 16

3. Composition/information on Ingredients

Substances	CAS Number	PERCENT (w/w)	GHS Classification - Australia
Hemicellulase enzyme	9012-54-8	10 - 30%	Resp. Sens. 1 (H334)

4. First aid measures

Description of necessary first aid measures

Inhalation If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Eyes In case of contact, immediately flush eyes with plenty of water for at least 15 minutes and get medical attention if irritation persists.

Skin Wash with soap and water. Get medical attention if irritation persists.

Ingestion Under normal conditions, first aid procedures are not required.

Symptoms caused by exposure
May cause allergic respiratory reaction.

Medical Attention and Special Treatment

Notes to Physician Treat symptomatically

5. Fire Fighting Measures

Suitable extinguishing equipment
Suitable Extinguishing Media
All standard fire fighting media
Extinguishing media which must not be used for safety reasons
None known.

Specific hazards arising from the chemical
Special exposure hazards in a fire
Organic dust in the presence of an ignition source can be explosive in high concentrations. Good housekeeping practices are required to minimize this potential.

Special protective equipment and precautions for fire fighters
Special protective equipment for firefighters
Full protective clothing and approved self-contained breathing apparatus required for fire fighting personnel.

6. Accidental release measures

6.1. Personal precautions, protective equipment and emergency procedures
Use appropriate protective equipment. Avoid creating and breathing dust. Avoid contact with skin, eyes and clothing. Ensure adequate ventilation. Evacuate all persons from the area.

6.2. Environmental precautions
Prevent from entering sewers, waterways, or low areas.

6.3. Methods and material for containment and cleaning up
Scoop up and remove.

7. Handling and storage

7.1. Precautions for safe handling
Handling Precautions
Avoid creating or inhaling dust. Ensure adequate ventilation. Avoid contact with eyes, skin, or clothing. Wash hands after use. Launder contaminated clothing before reuse. Use appropriate protective equipment.
Hygiene Measures
Handle in accordance with good industrial hygiene and safety practice.

7.2. Conditions for safe storage, including any incompatibilities
Storage Information
Store away from oxidizers. Store in a cool, dry location. Product has a shelf life of 12 months.
Other Guidelines
No information available

8. Exposure Controls/Personal Protection

Control parameters - exposure standards, biological monitoring
Exposure Limits

Substances	CAS Number	Australia NOHSC	ACGIH TLV-TWA
Hemicellulase enzyme	9012-54-8	Not applicable	Not applicable

Appropriate engineering controls
Engineering Controls Use in a well ventilated area.

Personal protective equipment (PPE)
Personal Protective Equipment If engineering controls and work practices cannot prevent excessive exposures, the selection and proper use of personal protective equipment should be determined by an industrial hygienist or other qualified professional based on the specific application of this product.

Respiratory Protection	If engineering controls and work practices cannot keep exposure below occupational exposure limits or if exposure is unknown, wear a NIOSH certified, European Standard EN 149, AS/NZS 1715:2009, or equivalent respirator when using this product. Selection of and instruction on using all personal protective equipment, including respirators, should be performed by an Industrial Hygienist or other qualified professional. Dust/mist respirator. (N95, P2/P3)
Hand Protection	Normal work gloves.
Skin Protection	Normal work coveralls.
Eye Protection	Wear safety glasses or goggles to protect against exposure.
Other Precautions	None known.
Environmental Exposure Controls	Do not allow material to contaminate ground water system

9. Physical and Chemical Properties

9.1. Information on basic physical and chemical properties

Physical State:	Powder	**Color**	White
Odor:	Odorless	**Odor Threshold:**	No information available

Property Remarks/ - Method	Values
pH:	7
Freezing Point / Range	No data available
Melting Point / Range	No data available
Boiling Point / Range	No data available
Flash Point	No data available
Evaporation rate	No data available
Vapor Pressure	No data available
Vapor Density	No data available
Specific Gravity	1.5
Water Solubility	Soluble in water
Solubility in other solvents	No data available
Partition coefficient: n-octanol/water	No data available
Autoignition Temperature	No data available
Decomposition Temperature	No data available
Viscosity	No data available
Explosive Properties	No information available
Oxidizing Properties	No information available

9.2. Other information

VOC Content (%)	No data available

10. Stability and Reactivity

10.1. Reactivity
Not expected to be reactive.
10.2. Chemical stability
Stable
10.3. Possibility of hazardous reactions
Will Not Occur
10.4. Conditions to avoid
None anticipated
10.5. Incompatible materials
Strong oxidizers.
10.6. Hazardous decomposition products
Carbon monoxide and carbon dioxide.

11. Toxicological Information

Information on routes of exposure

Principle Route of Exposure	Eye or skin contact, inhalation.

Symptoms related to exposure

Most Important Symptoms/Effects

May cause allergic respiratory reaction.

Numerical measures of toxicity

Toxicology data for the components

Substances	CAS Number	LD50 Oral	LD50 Dermal	LC50 Inhalation
Hemicellulase enzyme	9012-54-8	> 2000 mg/kg (Rat) (Similar substance) > 10000 mg/kg (Rat) > 8000 mg/kg (Mouse) > 2880 mg/kg (Rat)	No data available	> 3.5 mg/L (Rat) 4h > 4.86 mg/L (Rat) 4h

Immediate, delayed and chronic health effects from exposure

Inhalation May cause allergic respiratory reaction. May cause mild respiratory irritation.

Eye Contact May cause mild eye irritation.

Skin Contact None known.

Ingestion None known.

Chronic Effects/Carcinogenicity No data available to indicate product or components present at greater than 0.1% are chronic health hazards.

Exposure Levels

No data available

Interactive effects

None known.

Data limitations

No data available

Substances	CAS Number	Skin corrosion/irritation
Hemicellulase enzyme	9012-54-8	Non-irritating to the skin (Rabbit)

Substances	CAS Number	Serious eye damage/irritation
Hemicellulase enzyme	9012-54-8	Non-irritating to the eye (Rabbit)

Substances	CAS Number	Skin Sensitization
Hemicellulase enzyme	9012-54-8	No information available

Substances	CAS Number	Respiratory Sensitization
Hemicellulase enzyme	9012-54-8	May cause sensitization by inhalation

Substances	CAS Number	Mutagenic Effects
Hemicellulase enzyme	9012-54-8	In vitro tests did not show mutagenic effects.

Substances	CAS Number	Carcinogenic Effects
Hemicellulase enzyme	9012-54-8	No information available

Substances	CAS Number	Reproductive toxicity
Hemicellulase enzyme	9012-54-8	No information available

Substances	CAS Number	STOT - single exposure
Hemicellulase enzyme	9012-54-8	No significant toxicity observed in animal studies at concentration requiring classification.

Substances	CAS Number	STOT - repeated exposure
Hemicellulase enzyme	9012-54-8	No significant toxicity observed in animal studies at concentration requiring classification.

Substances	CAS Number	Aspiration hazard
Hemicellulase enzyme	9012-54-8	Not applicable

12. Ecological Information

Ecotoxicity

Product Ecotoxicity Data

No data available

Substance Ecotoxicity Data

Substances	CAS Number	Toxicity to Algae	Toxicity to Fish	Toxicity to Microorganisms	Toxicity to Invertebrates
Hemicellulase enzyme	9012-54-8	EC50 (72h) > 99 mg/L (Pseudokirchnerella subcapitata) EC50 (72h) > 52.1 mg/L (Pseudokirchneriella subcapitata)	LC50 (96h) > 100 mg/L (Oncorhynchus mykiss) LC50 (96h) > 52.1 mg/L (Oncorhynchus mykiss)	No information available	EC50 (48h) > 39.5 mg/L (Daphnia magna) EC50 (48h) > 99 mg/L (Daphnia magna) EC50 (48h) > 52.1 mg/L (Daphnia magna)

12.2. Persistence and degradability

Substances	CAS Number	Persistence and Degradability
Hemicellulase enzyme	9012-54-8	Readily biodegradable (129% @ 28d)

12.3. Bioaccumulative potential

Does not bioaccumulate.

Substances	CAS Number	Log Pow
Hemicellulase enzyme	9012-54-8	-2.95 (Similar substance)

12.4. Mobility in soil

Substances	CAS Number	Mobility
Hemicellulase enzyme	9012-54-8	No information available

12.6. Other adverse effects

Endocrine Disruptor Information

This product does not contain any known or suspected endocrine disruptors

13. Disposal Considerations

Safe handling and disposal methods

Bury in a licensed landfill according to federal, state, and local regulations.

Disposal of any contaminated packaging

Follow all applicable national or local regulations.

Environmental regulations

Not applicable

14. Transport Information

Transportation Information

UN Number Not restricted
UN proper shipping name: Not restricted
Transport Hazard Class(es): Not applicable
Packing Group: Not applicable
Environmental Hazards: Not applicable

Special precautions during transport

None

HazChem Code

None Allocated

15. Regulatory Information

Safety, health and environmental regulations specific for the product

International Inventories

Australian AICS Inventory	All components are listed on the AICS or are subject to a relevant exemption, permit, or assessment certificate.
New Zealand Inventory of Chemicals	All components are listed on the NZIoC or are subject to a relevant exemption, permit, or assessment certificate.
EINECS (European Inventory of Existing Chemical Substances)	This product, and all its components, complies with EINECS
US TSCA Inventory	All components listed on inventory or are exempt.
Canadian Domestic Substances List (DSL)	All components listed on inventory or are exempt.

Poisons Schedule number
None Allocated

International Agreements

Montreal Protocol - Ozone Depleting Substances:	Does not apply
Stolkhom Convention - Persistent Organic Pollutants:	Does not apply
Rotterdam Convention - Prior Informed Consent:	Does not apply
Basel Convention - Hazardous Waste:	Does not apply

16. Other information

Date of preparation or review

Revision Date: 20-Jun-2016

Revision Note
SDS sections updated: 2

Full text of H-Statements referred to under sections 2 and 3
H334 - May cause allergy or asthma symptoms or breathing difficulties if inhaled

Additional information For additional information on the use of this product, contact your local Halliburton representative.

For questions about the Safety Data Sheet for this or other Halliburton products, contact Chemical Stewardship at 1-580-251-4335.

Key abreviations or acronyms used
bw – body weight
CAS – Chemical Abstracts Service
EC50 – Effective Concentration 50%
LC50 – Lethal Concentration 50%
LD50 – Lethal Dose 50%
LL50 – Lethal Loading 50%
mg/kg – milligram/kilogram
mg/L – milligram/liter
NOEC – No Observed Effect Concentration
OEL – Occupational Exposure Limit
PBT – Persistent Bioaccumulative and Toxic
ppm – parts per million
STEL – Short Term Exposure Limit
TWA – Time-Weighted Average
vPvB – very Persistent and very Bioaccumulative

h - hour
mg/m^3 - milligram/cubic meter
mm - millimeter
mmHg - millimeter mercury
w/w - weight/weight
d - day

Key literature references and sources for data
www.ChemADVISOR.com/
NZ CCID

Disclaimer Statement
This information is furnished without warranty, expressed or implied, as to accuracy or completeness. The information is obtained from various sources including the manufacturer and other third party sources. The information may not be valid under all conditions nor if this material is used in combination with other materials or in any process. Final determination of suitability of any material is the sole responsibility of the user.

End of Safety Data Sheet

Attachment 4 Australian Government's NATA Reports of Analyses

REPORT OF ANALYSIS

Report No. RN1066398

Client	: HALLIBURTON AUSTRALIA PTY LTD	**Job No.**	: HALL11_W/150505
	15 MARRIOTT ROAD	**Quote No.**	: QT-02002
	JANDAKOT WA 6164	**Order No.**	:
		Date Sampled	: 4-MAY-2015
		Date Received	: 5-MAY-2015
Attention	: AARON CROSLEY	**Sampled By**	: CLIENT
Project Name	:		
Your Client Services Manager	: KOON-BAY HO	**Phone**	: (08) 9368 8400

Lab Reg No.	Sample Ref	Sample Description
W15/008590	Carbo NRT LITE 20/40	SOLID 04/05/15
W15/008591	Carbo NRT ECONO 20/40	SOLID 04/05/15
W15/008592	Carbo NRT CP 20/40	SOLID 04/05/15

Lab Reg No.		W15/008590	W15/008591	W15/008592		
Sample Reference	Units	Carbo NRT LI	Carbo NRT EC	Carbo NRT CP		Method
Polycyclic Aromatic Hydrocarbons						
Naphthalene	mg/kg	<0.01	<0.01	<0.01		WL206
Acenaphthylene	mg/kg	<0.01	<0.01	<0.01		WL206
Acenaphthene	mg/kg	<0.01	<0.01	<0.01		WL206
Fluorene	mg/kg	<0.01	<0.01	<0.01		WL206
Phenanthrene	mg/kg	<0.01	<0.01	<0.01		WL206
Anthracene	mg/kg	<0.01	<0.01	<0.01		WL206
Fluoranthene	mg/kg	<0.01	<0.01	<0.01		WL206
Pyrene	mg/kg	<0.01	<0.01	<0.01		WL206
Benz(a)anthracene	mg/kg	<0.01	<0.01	<0.01		WL206
Chrysene	mg/kg	<0.01	<0.01	<0.01		WL206
Benzo(b+k)fluoranthene	mg/kg	<0.02	<0.02	<0.02		WL206
Benzo(a)pyrene	mg/kg	<0.01	<0.01	<0.01		WL206
Indeno(1,2,3,c,d)pyrene	mg/kg	<0.01	<0.01	<0.01		WL206
Dibenz(a,h)anthracene	mg/kg	<0.01	<0.01	<0.01		WL206
Benzo(g,h,i)perylene	mg/kg	<0.01	<0.01	<0.01		WL206
Total PAH's (as above)	mg/kg	<0.16	<0.16	<0.16		WL206
BTEX						
Benzene	mg/kg	<0.20	<0.20	<0.20		WL244
Toluene	mg/kg	<0.20	<0.20	<0.20		WL244
Ethylbenzene	mg/kg	<0.20	<0.20	<0.20		WL244
m,p-Xylene	mg/kg	<0.20	<0.20	<0.20		WL244
o-Xylene	mg/kg	<0.20	<0.20	<0.20		WL244
Total BTEX	mg/kg	<0.80	<0.80	<0.80		WL244
Dates						
Date extracted		6-MAY-2015	6-MAY-2015	6-MAY-2015		
Date analysed		6-MAY-2015	6-MAY-2015	6-MAY-2015		
Sample condition on receipt		COLD	COLD	COLD		

Australian Government
National Measurement Institute

ORGANIC QUALITY ASSURANCE REPORT

NMI Job No: HALL11_W/150505

Sample Matrix: **Solid**

		Reagent	Sample Duplicates			LCS	Matrix	Extracted *
Analyte	**LOR**	**Blank**	**Sample**	**Duplicate**	**RPD**	**Recovery**	**Spike**	**within**
	mg/kg	**mg/kg**	**mg/kg**	**mg/kg**	**%**	**%**	**%**	**holding time**
BTEX			**W15/008590**					
Benzene	0.20	<0.20	<0.20	<0.20	-	107	-	✓
Toluene	0.20	<0.20	<0.20	<0.20	-	106	-	✓
Ethylbenzene	0.20	<0.20	<0.20	<0.20	-	90	-	✓
m,p-Xylene	0.20	<0.20	<0.20	<0.20	-	93	-	✓
o-Xylene	0.20	<0.20	<0.20	<0.20	-	96	-	✓

	BTEX
Spike criteria	70 - 130%
Acceptable duplicate RPD	60%
Method used	WL 244
Holding time	14 days

Results expressed in percentage (%) or mg/kg wherever appropriate on dry weight basis.
RPD = Relative Percentage Difference.
'-' = Not Applicable.
* Applies to all samples in the job.

Signed: KBHo
Koon-Bay Ho
Organic Chemistry
Date: **8/05/2015**

THIS REPORT SHALL NOT BE REPRODUCED EXCEPT IN FULL

Australian Government
National Measurement Institute

ORGANIC QUALITY ASSURANCE REPORT

NMI Job No: HALL11_W/150505

Sample Matrix **Solid**

			Sample Duplicates			LCS	Matrix	Acceptable	Extracted *
Analyte	**LOR**	**Blank**	**Sample**	**Duplicate**	**RPD**	**Recovery**	**Spike**	**Spike**	**within**
	mg/kg	**mg/kg**	**mg/kg**	**mg/kg**	**%**	**%**	**%**	**Recovery %**	**holding time**
Polycyclic Aromatic Hydrocarbons			**W15/008590**						
Naphthalene	0.01	<0.01	<0.01	<0.01	-	93	-	21 - 133	✓
Acenaphthylene	0.01	<0.01	<0.01	<0.01	-	-	-	47 - 145	✓
Acenaphthene	0.01	<0.01	<0.01	<0.01	-	-	-	33 - 145	✓
Fluorene	0.01	<0.01	<0.01	<0.01	-	97	-	59 - 121	✓
Phenanthrene	0.01	<0.01	<0.01	<0.01	-	104	-	54 - 120	✓
Anthracene	0.01	<0.01	<0.01	<0.01	-	82	-	27 - 133	✓
Fluoranthene	0.01	<0.01	<0.01	<0.01	-	-	-	26 - 137	✓
Pyrene	0.01	<0.01	<0.01	<0.01	-	-	-	52 - 115	✓
Benz[a]anthracene	0.01	<0.01	<0.01	<0.01	-	118	-	33 - 143	✓
Chrysene	0.01	<0.01	<0.01	<0.01	-	78	-	17 - 168	✓
Benzo[b+k]fluoranthene	0.02	<0.02	<0.02	<0.02	-	-	-	11 - 162	✓
Benzo[a]pyrene	0.01	<0.01	<0.01	<0.01	-	85	-	17 - 163	✓
Indeno[1,2,3-c,d]pyrene	0.01	<0.01	<0.01	<0.01	-	-	-	1 - 171	✓
Dibenz[a,h]anthracene	0.01	<0.01	<0.01	<0.01	-	89	-	1 - 227	✓
Benzo[g,h,i]perylene	0.01	<0.01	<0.01	<0.01	-	-	-	1 - 219	✓

Spike criteria as per USEPA method 8270B (noted above).
Acceptable duplicate RPD 60%
Method used WL 206
Holding time 14 days

Results expressed in percentage (%) or mg/kg wherever appropriate on dry weight basis.
RPD = Relative Percentage Difference.
'-' = Not Applicable.
* Applies to all samples in the job.

Signed: KBHo
Koon-Bay Ho
Organic Chemistry
Date: **8/05/2015**

THIS REPORT SHALL NOT BE REPRODUCED EXCEPT IN FULL

REPORT OF ANALYSIS

Report No. RN1066398

Lab Reg No.		W15/008590	W15/008591	W15/008592		
Sample Reference	Units	Carbo NRT LI	Carbo NRT EC	Carbo NRT CP		Method



Koon-Bay Ho, Section Manager
Organics - WA
Accreditation No. 2474

8-MAY-2015

All results (except moisture) are expressed on a dry weight basis. Unless notified to the contrary, the above samples will be disposed of one month from the reporting date.

NATA
ACCREDITED FOR
TECHNICAL
COMPETENCE

Accredited for compliance with ISO/IEC 17025.
This report shall not be reproduced except in full.
Results relate only to the sample(s) tested.

APPENDIX H.6 RISK ASSESSMENT – SCOTIA BE-9 ALGACIDE AND KCL SYSTEM

1.0 Introduction

Consistent with the risk assessment methodology utilised in Hydraulic Fracturing Risk Assessment Compendium (RA Compendium), Santos Ltd. (Santos) – refer Section 5, EHS Support LLC has used a weight-of-evidence approach to evaluate the potential for human health and environmental (e.g., ecological) risks as a result of use of production water potentially containing hydraulic fracturing chemicals. It is proposed that production water from the Scotia fields (potentially containing hydraulic fracturing chemicals) will be blended with groundwater to facilitate irrigation to land without treatment. A low toxicity hydraulic fracturing fluid system has been selected for use in the Scotia comprising KCL and a biocide (comprising either BE-9 or Algacide).

The methodology used in the Quantitative Risk Assessment (QRA) was designed to meet Conditions 49e and 49f of the 2 October 2011 approval under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC 2008/4059) and the Environmental Amendment (EA) conditions to assess the toxicity of the mixtures.

GLNG is a Santos PETRONAS Total KOGAS project.
Santos | PETRONAS | TOTAL | KOGAS

2.0 Qualitative Risk Assessment and Evaluation

2.1 Chemicals Evaluated

The Scotia BE-9 Algacide and KCL System was assessed. The list of individual chemicals is presented in **Table 1** below. A mass balance of the chemicals is provided as **Appendix 1**.

Material Safety Data Sheets (MSDSs) for each of the hydraulic fluid chemicals are included in **Appendix 2** of this report. Information regarding the chemical and physical properties of the individual chemicals listed below as well as the approximate percentage present in the hydraulic fracturing system can be found on the MSDSs.

While none of the fracturing fluid chemicals identified contain benzene, toluene, ethylbenzene, xylenes (BTEX) or polycyclic aromatic hydrocarbons (PAHs), PAHs occur naturally in coal and it is possible that certain PAHs may naturally be present in the coal seam groundwater used in the hydraulic fracturing process.

Table 1: Hydraulic Fracturing Chemicals

Chemical	CAS Number
Glutaraldehyde	111-30-8
Tributyl Tetradecyl Phosphonium Chloride	81741-28-8
Potassium chloride	7447-40-7

2.2 Risk Assessment Framework and Findings

As outlined in **Section 5.0** of the RA Compendium, a systematic weight of evidence approach has been used for the assessment of risks associated with hydraulic fracturing chemicals. This same methodology has been utilised to complete the RA for the Scotia BE-9 Algacide and KCL System and the proposed land irrigation activities. A detailed discussion of the methodologies and approach is contained within the RA Compendum and for consistency with the risk assessment methodology (and to streamline the text in this document) the key sections are referenced below. The assessment including the following evaluations:

Qualitative Assessment Methodologies

- Exposure Assessment
- Mass Balance of Fluid System

Quantitative Risk Assessment Methodologies

- Quantitative Human Health Risk Assessment (HHRA)
- Quantitative Ecological Risk Assessment for Terrestrial and Aquatic Receptors.

2.3 Exposure Assessment

As discussed in **Section 7.0** of the RA Compendium, the exposure assessment identified receptors potentially exposed to chemicals of potential concern (COPC) identified for the study, and outlines the exposure pathways by which the receptors may come in to contact with the COPCs. A detailed exposure assessment was not conducted in the qualitative RA.

2.4 Mass Balance of Fluid System

A quantitative mass balance calculation was undertaken to identify the amount of each chemical additive of the hydraulic fracturing fluid system. The results of the mass balance calculations are presented in **Appendix 1**.

2.5 Quantitative Risk Assessment

In accordance with the methodologies presented in **Section 8.0**, a QRA was conducted on theoretical datasets for those chemicals identified in the Scotia BE-9/Algacide and KCL System. The QRA approach evaluates the toxicity of the individual substances, and characterises the cumulative risks of the total effluent toxicity and ecotoxicity.

Generally, this methodology includes the identification of the hazards posed by constituents in the flowback water, compilation of the toxicity criteria for each constituent, development of exposure models to estimate the daily intake of the constituents, and calculations of individual constituent hazard quotients (daily intake divided by the toxicity criteria) and a cumulative constituent hazard index (HI) for each potentially complete exposure pathway for each human or terrestrial receptor.

Potential complete exposure pathways to the storage and land application of flowback/production water from hydraulically stimulated wells potential risks to humans, terrestrial and aquatic receptors from the potential storage and accidental releases are evaluated in the QRA.

The QRA considered the following specific exposure pathways:

1. Exposure of worker to flowback water contained within flowback storage tank.
2. Exposure of worker to flowback water used in the irrigation area.
3. Exposure of terrestrial receptors (e.g., livestock and wildlife) to flowback water contained within the flowback storage tank.
4. Exposure of aquatic receptors to flowback water in the situation of an accidental release, such as from piping or a release from the flowback storage tank. These potential releases could include a failure of containment systems, overtopping of the dam or in an extreme situation (considered highly unlikely) structural failure of the dam itself.

3.1 Exposure Assessment

The purpose of the exposure assessment in the QRA was to predict the magnitude and frequency of potential human exposure to each COPC following the methodologies presented in **Section 8.1**. A conceptual site model (CSM) was developed which describes the potential receptors and exposure scenarios for the flowback water used in this exposure assessment. The potential exposures to receptors were evaluated based on the potential for a complete exposure pathway.

As discussed in **Section 8.2**, exposure point concentrations (EPCs) were derived for the theoretical assessment; empirical data were not available for evaluation. The EPCs for the theoretical assessment were calculated by estimating the mass and discharge flow of the COPCs in the flowback water.

3.2 Human Health QRA

A human health hazard assessment was conducted according to the methodologies presented in **Section 8.4**. The purpose of the hazard assessment process was to summarise the environmental data, and to address the toxicological assessment of the COPCs that will be evaluated further in the RA process.

Exposure assumptions for the worker scenario were developed based on default or site-specific assumptions (**Section 8.4**). This receptor exposure pathway includes an adult worker, either exposed at the well pad tank or in the irrigation field, that may come in contact with the flowback water exposure scenarios. For the well pad worker, exposure may occur for approximately 1 hour/day, 250 days/year, for 3 years with potential incidental ingestion [of 50 millilitres (ML) of water] and dermal contact (e.g., water contact of arms and head). This is based on the expected operational period for a typical well pad. For the irrigation worker, exposure may occur for approximately 4 hours/day, 250 days/year, for 20 years with potential incidental ingestion [of 50 ML of water] and dermal contact (e.g., water contact of arms and head). This is based on the expected use of an irrigation field from multiple well pad tansk. The exposure parameters used in the QRA are presented on **Tables 2** and **3**.

Calculation of intake of COPCs was performed using the equations presented below:

Ingestion of water:

$$Intake\ (mg/kg-day)\ =\ (CW\ x\ IR\ X\ EF\ X\ ED)\ /\ (BW\ x\ AT)$$

Dermal contact with water:

$$Absorbed\ dose\ (mg/kg-day)\ =\ (CW\ x\ SA\ x\ DP\ x\ ET\ x\ EF\ x\ ED\ x\ CF)\ /\ (BW\ x\ AT)$$

Where:

CW = concentration in water (mg/l)
ET = exposure time (hr/day or hours/hours)
EF = exposure frequency (day/year)
ED = exposure duration (years)
CF = correction factor (1 x 10-3 l/cm3)
AT = averaging time (days)
IR = ingestion rate (l/hr)
BW = body weight (kg)
SA = skin surface area available for contact (cm2/d)
DP = dermal permeability factor (Kp – cm/hr).

3.3 Toxicity Assessment

A toxicity assessment was conducted to determine the relationship between the dose of a COPC taken into the body, and the probability that an adverse effect will result from that dose. Quantitative estimates of the potency of COPCs include two sets of toxicity values, one for genotoxic carcinogens and one for other non-genotoxic carcinogens and non-carcinogenic effects. Detailed toxicological profiles are included as **Appendix 3**. The derivation of Oral Reference Dose and Drinking Water Guideline Values are presented in **Table 4**.

3.4 Exposure Point Concentration

As presented above, the exposure scenarios are based on anticipated conditions, and the potential for exposure to the theoretical estimate of exposure. EPCs for the exposure assessment were calculated using the results of theoretical fate and transport modelling calculations and the existing environmental conditions within the fracturing fluids flowback storage ponds, and the flowback used in the irrigation fields.

To assess the potential flux of hydraulic fracturing chemicals to the environment, vendor disclosures for the hydraulic fracturing fluid systems were reviewed, and the chemical concentrations of key inputs were determined. It should be noted that two potential biocides (only one will be used at a time) have

been identified and the maximum and minimum concentrations of these chemicals with the following Scenarios used to estimate the EPCs:

- Scenario 1: a highly conservative base case where production water concentrations are equal to the concentrations in the hydraulic fracturing fluid system; and,

- Scenario 2: likely conditions where down well losses and dilution from other wells will lead to a production water quality with concentrations 50% reduced from the hydraulic fracturing fluid system. The losses accounting for this reduction, include dilution, ion exchange, sorption and bio-decay in the subsurface.

For the theoretical calculations, the estimated chemical concentrations of the COPCs in the Scotia BE-9/Algacide and KCL System, as presented in **Appendix 1**, were used to estimate the potential concentrations in water within the fracturing fluids flowback storage ponds and the irrigation fields.

The flowback water will be contained within production waterstorage tank and then blended with groundwater. The storage time in tanks is anticipated to be between 3 and 30 days where biological degradation of some constituent will occur. Water will be pumped from the tank for a range of beneficial uses including transfer to the irrigation area on an as needed basis. Therefore, the concentration of COPCs in the flowback storage tank was adjusted, where applicable, to account for the biodegradation of constituents over time. The biodegradation information was obtained from the Organisation for Economic Cooperation and Development (OECD) ready tests (OECD, 1992) that were developed as a first tier testing scheme to provide preliminary screening of organic chemicals. The ready tests are stringent screening tests that are conducted under aerobic conditions in which a high concentration of the test substance is used, and biodegradation is measured by non-specific parameters including dissolved organic carbon, biochemical oxygen demand and carbon dioxide production. **Table 5** presents the environmental fate information that was used to assess biodegradation of COPCs, and that was applied at the time periods of 0, 30, 150 and 300 days from initial flowback.

The water quality data derived using these assumptions for the theoretical COPCs are presented in **Appendix 1**.

The theoretical EPCs for the four exposure time periods (0, 30, 150 and 300 days) were compared to human health toxicity-based screening levels, and the results of this comparison, including the ratio of exceedance of screening levels, is presented in **Appendix 4**.

3.5 Risk Estimation

Risk estimation was performed in accordance with the methodologies outlined in **Section 8.4**. The total target risk range for carcinogens was 1×10^{-4} to 1×10^{-6}; the target HI for non-threshold effects is less than or equal to 1.0.

No carcinogenic compounds are present in the stimulation fluids injected into the subsurface and as a result, only non-carcinogenic risks were calculated.

The results of the theoretical assessments for Scotia BE-9/Algacide and KCL System for the two worker exposure scenarios (day 0 and day 150, Scotia BE-9 Algacide and KCL System events) are summarized in **Tables 6 through 9**. As discussed above, the theoretical assessment was conducted at the well pad sites and the irrigation fields.

The exposure scenarios include the Scotia BE-9 Algacide and KCL System event, as presented in **Appendix 1** for day 0 and day 150 from the production water storage tank. The absence of appreciable biodegradation of select constituents of concern did not result in appreciable declines in Hazard Indices (HI) over time. The operations worker (working at the well pad, gathering lines and tanks) had potential

unacceptable risks for the Scotia BE-9 Algacide and KCL System at Day 0 (HI=1.2, **Table 6**), and for day 150 (HI=1.2, **Table 7**). The irrigation field worker for day 0 had unacceptable risks for the Scotia BE-9 Algacide and KCL System (HI=1.2, **Table 8**), and for day 150 (HI=1.2, **Table 9**). All unacceptable risks were only associated with the ingestion of TTPC for the maximum concentration in the base case. Based on the likely operational conditions (with down well dilution and attenuation and blending in the water storage tank) no unacceptable risks were present (HI < 1).

On this basis and using the theoretical concentrations, no adverse effects are predicted on the workers in both exposure groups except under maximum conservative conditions for the estimated EPC.

3.6 Ecological Risk Assessment

As discussed in **Section 8.5**, a screening level ecological risk assessment (ERA) was conducted to evaluate the potential for adverse ecological effects to terrestrial and aquatic ecological receptors that may be exposed to residual levels of hydraulic fracturing chemicals in water stored, irrigated or potentially released to the environment.

3.7 Exposure Assessment

Terrestrial receptors evaluated in the ERA include domesticated livestock, large mammalian wildlife and small mammalian wildlife. Beef cattle were used to evaluate domesticated livestock, kangaroos evaluated for large mammalian wildlife, and dingos for small mammalian wildlife. Aquatic receptors evaluated included invertebrates and fishes.

The estimate for dose-based or intake rates for the assessment endpoints for wildlife representing domestic livestock and native mammalian species used the following general equation:

TI = Cwater x IRwater x EF x ED / BW x ED x 365 days/year

Where:

TI = Total intake of COPC (mg/kg/day)

Cwater = Concentration of COPC in water (mg/l)

IRwater = Ingestion rate (litres/day)

EF = Exposure frequency (days/year)

ED = Exposure duration (years)

BW = Body weight (kg).

Tables 10 through 12 provide the lift-history input values for ingestion rates, exposure frequency, exposure duration and BW.

3.8 Toxicity Assessment

To evaluate the potential for adverse ecological effects, toxicity reference values (TRVs) are selected as measurement endpoints for the ERA that will be used in the risk analysis. Detailed environmental profiles are included as **Appendix 5**. The TRVs are based on COPC levels that imply no adverse effects or levels that represent the lowest concentration at which adverse effects may occur. The ERA used two types of TRVs. The first TRV is a concentration-based TRV to evaluate the concentration of the selected COPC in the surface water and direct exposure by the aquatic ecological receptor. The determination of TRVs for freshwater was conducted according to the predicted no-effects concentration (PNEC) guidance in the Environmental Risk Assessment Guidance Manual for Industrial

Chemicals prepared by the Australian Environmental Agency (AEA, 2009). **Table 13** presents the COPC, the endpoint, NOEC [milligrams per litre (mg/L)], assessment factor and the aquatic PNEC (mg/L). The second TRV is a dose-based TRV to evaluate the intake dose of the selected COPC from exposure to surface water by ingestion. The calculated TRVs for each of the mammalian ecological receptors evaluated in the ERA are presented in the species-specific ecological risk models.

3.9 Exposure Point Concentration

EPCs for the exposure assessment were calculated using the results of theoretical fate and transport modelling calculations. The potentially affected flowback water that represents complete exposure pathways for the ecological receptors includes the surface water systems that were used to estimate the EPCs for the human health receptors. The EPCs for the ecological receptors were estimated assuming the same Scenarios, with exposure occurring in the irrigation area where irrigation water may pool and wildlife may drink from the standing water. **Appendix 1** presents the calculated EPCs for the ecological receptor exposure scenarios. The theoretical EPCs for the four exposure time periods (0, 30, 150, and 300 days) were compared to ecological based toxicity-based screening levels, and the results of this comparison, including the ratio of exceedance of screening levels, is presented in **Appenidix 6**.

Risks were characterised in accordance with the methodologies discussed in **Section 8.5.6**. The resulting ecological hazard quotient must be less than or equal to 1.0 for risks to be considered acceptable.

3.10 Estimation of Risk

The HI calculated for flowback water for aquatic risk were elevated above the acceptable level for the majority of COPCs evaluated (**Appendix 6**). Where large discharges of flowback water occur to surface water and/or flux dilution within the surface-water was insufficient, potential impacts on aquatic receptors could occur. As noted in the toxicity assessment section above, the lack of a robust aquatic toxicological database resulted in highly conservative aquatic screening values for the theoretical exposure scenario COPCs to be conservatively very low.

The results of the theoretical assessments for Scotia BE-9 Algacide and KCL System for the livestock cattle, kangaroo and dingo are summarized in **Tables 14 through 19**. The exposure scenarios include the Scotia BE-9 Algacide and KCL System EPCs presented in **Appendix 1** for day 0 and day 150 from the fracturing fluid well flowback. The modelled risks from Scotia BE-9/Algacide and KCL System chemicals in the flowback water were acceptable for the livestock cattle, kangaroo, and dingo for all exposure scenarios.

3.0 Summary of QRA Findings

An assessment was conducted using highly conservative theoretical calculations based on the chemicals utilised by in the hydraulic fracturing fluid system. This assessment assumed that a range of theoretical concentrations of injected chemicals would be present in the flowback/production water considering biodegradation rates, where applicable.

Consistent with the detailed Risk Assessments conducted for Hydraulic Fracturing no potentially complete exposure pathways were identified for groundwater. Potential exposures are limited to the aboveground storage and handling of flowback/production water and the proposed irrigation of water to land.

The two exposure scenarios modelled for the QRA were for an operations worker (well pad, gathering systems and water storage) and an irrigation worker (working in the irrigation area) being exposed to flowback water under various EPC Scenarios. Based on quantitative risk calculations, all potential risks for the various scenarios were acceptable except for the unacceptable risks that were associated with the ingestion of TTPC at the maximum concentration base case scenario. Considering the likely attenuation that will occur downhole (through sorption, dilution etc), the less conservative estimate is considered more representative of likely conditions within the irrigation area. Based on the chemicals proposed for use in the hydraulic fracturing fluid system no carcinogenic risks identified.

The modelled risks from Scotia BE-9 Algacide and KCL System chemicals in the flowback water were acceptable for the livestock cattle, kangaroo, and dingo for all EPC exposure scenarios. However, potential impacts could occur if releases of flowback water were to occur to aquatic environments. The presence of elevated salinity as well as biocides are key aquatic ecology stressors and would require high levels of dilution before adverse impacts could be prevented. The absence of watercourses in the immediate vicinity of the irrigation area, mitigation of potential impacts on aquatic systems will be managed through operational controls that minimize the potential for releases and manage irrigation rates to limit the potential for large-scale runoff.

A combination of management and operational controls will be implemented to eliminate and control the potential for exposures. These include:

- Worker training and hazard identification
- Use of appropriate personal protective equipment (gloves, etc.)
- Storage of production water in specifically designed tanks
- Management of irrigation rates to prevent ponding and runoff
- Routine operational and security patrols to prevent trespassing.

4.0 Conclusions

A weight-of-evidence evaluation of potential risks was performed for the Scotia BE-9/Algacide and KCL System. Based on the qualitative and quantitative risk characterisations, the overall risk to human health and the environment is low. Existing operational control activities employed by Santos are in place that will limit the potential risks to human health and the environment. These measures include:

- Occupational health and safety procedures implemented during hydraulic fracturing operations to prevent workers from direct contact with chemicals during spills and when handling flowback water or sediments;
- Construction of the irrigation areas away from sensitive receptors and watercourses to mitigate potential risks to aquatic receptors;
- Implementation of spill containment procedures during operations to prevent migration of and exposure to chemicals;
- Storage and management of production water within specially designed tanks; and
- Design and management of irrigation rates to prevent runoff and overland flow.

Tables

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Table 2 Exposure Assumptions - Well Pad Worker

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l	0.05
	EF	Exposure frequency	day/yr	250
	ED	Exposure duration	yr	3
	BW	Body weight	kg	78
	AT-NC	Averaging time - noncancer	days	1,095
	AT-C	Averaging time - cancer	days	25,550
Dermal	SA	Surface area for contact	cm^2/day	6,700
	DP	Dermal permeability factor	cm/h	chemical-specific
	ET	Exposure time	hr/day	1
	EF	Exposure frequency	day/yr	250
	ED	Exposure duration	yr	3
	BW	Body weight	kg	78
	AT-NC	Averaging time - noncancer	days	1,095
	AT-C	Averaging time - cancer	days	25,550
	CF	Conversion factor	l/cm^3	1.0E-03

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Table 3 Exposure Assumptions - Irrigation Worker

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l	0.05
	EF	Exposure frequency	day/yr	250
	ED	Exposure duration	yr	20
	BW	Body weight	kg	78
	AT-NC	Averaging time - noncancer	days	7,300
	AT-C	Averaging time - cancer	days	25,550
Dermal	SA	Surface area for contact	cm^2/day	6,700
	DP	Dermal permeability factor	cm/h	chemical-specific
	ET	Exposure time	hr/day	4
	EF	Exposure frequency	day/yr	250
	ED	Exposure duration	yr	20
	BW	Body weight	kg	78
	AT-NC	Averaging time - noncancer	days	7,300
	AT-C	Averaging time - cancer	days	25,550
	CF	Conversion factor	l/cm^3	1.0E-03

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Table 4 Oral Reference Doses and Drinking Water Guidelines Derived for Hydraulic Fracturing Chemicals

Chemical (CAS No.)	Study	Critical Effect/Target Organ(s)	NOAEL (mg/kg/day)	Uncertainty Factors	Oral Reference Dose (mg/kg/day)	Drinking Water Guideline (ppm)
Tributyl Tetradecyl Phosphonium Chloride (81741-28-8)	Rat 90-dr drinking water	General toxicity	8.66	1,000	0.009	0.03
Glutaraldehyde (111-30-8)	Rat 2-yr drinking water	General toxicity	4	100	0.04	0.14

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Table 5 Environmental Fate Information

Constituent	Biodegradation (a)
Tributyl Tetradecyl Phosphonium Chloride (81741-28-8)	Not readily biodegradable
Glutaraldehyde (111-30-8)	Readily biodegradable (half-life = 15 days)

a/ Source: EU Guidance Document: Half-life estimates from in vitro biodegradation test results

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Table 6 Risk Estimates for Well Pad Worker Scotia System Fluid Theoretical Exposure for Day 0

		Day 0		Toxicity	Scotia BE-9 Algacide and KCL System			
							Hazard Quotient	
Constituent Name	**Scenario**	**C_{frac} (mg/l)**	**PC (cm/hr)**	**RfDo**	**$CADD_{oral}$**	**$CADD_{derm}$**	**Incidental Ingestion**	**Dermal**
Tributyl Tetradecyl Phosphonium Chloride	1A - Maximum	2.4E+01	NA	9.0E-03	1.1E-02	-	1.2E+00	-
Glutaraldehyde	1B - Maximum	8.0E+01	5.4E-04	4.0E-02	3.5E-02	2.6E-03	8.8E-01	6.4E-02
Tributyl Tetradecyl Phosphonium Chloride	1A - Minimum	8.0E+00	NA	9.0E-03	3.5E-03	-	3.9E-01	-
Glutaraldehyde	1B - Minimum	2.8E+01	5.4E-04	4.0E-02	1.2E-02	8.9E-04	3.1E-01	2.2E-02
Tributyl Tetradecyl Phosphonium Chloride	2A - Maximum	1.2E+01	NA	9.0E-03	5.3E-03	-	5.9E-01	-
Glutaraldehyde	2B - Maximum	4.0E+01	5.4E-04	4.0E-02	1.8E-02	1.3E-03	4.4E-01	3.2E-02
Tributyl Tetradecyl Phosphonium Chloride	2A - Minimum	4.0E+00	NA	9.0E-03	1.8E-03	-	2.0E-01	-
Glutaraldehyde	2B - Minimum	1.4E+01	5.4E-04	4.0E-02	6.1E-03	4.5E-04	1.5E-01	1.1E-02

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Table 7 Risk Estimates for Well Pad Worker Scotia System Fluid Theoretical Exposure for Day 150

		Day 150		Toxicity	Scotia BE-9 Algacide and KCL System			
							Hazard Quotient	
Constituent Name	**Scenario**	**C_{frac} (mg/l)**	**PC (cm/hr)**	**RfDo**	**$CADD_{oral}$**	**$CADD_{derm}$**	**Incidental Ingestion**	**Dermal**
Tributyl Tetradecyl Phosphonium Chloride	1A - Maximum	2.4E+01	NA	9.0E-03	1.1E-02	-	1.2E+00	-
Glutaraldehyde	1B - Maximum	7.8E-02	5.4E-04	4.0E-02	3.4E-05	2.5E-06	8.6E-04	6.2E-05
Tributyl Tetradecyl Phosphonium Chloride	1A - Minimum	8.0E+00	NA	9.0E-03	3.5E-03	-	3.9E-01	-
Glutaraldehyde	1B - Minimum	2.7E-02	5.4E-04	4.0E-02	1.2E-05	8.7E-07	3.0E-04	2.2E-05
Tributyl Tetradecyl Phosphonium Chloride	2A - Maximum	1.2E+01	NA	9.0E-03	5.3E-03	-	5.9E-01	-
Glutaraldehyde	2B - Maximum	3.9E-02	5.4E-04	4.0E-02	1.7E-05	1.2E-06	4.3E-04	3.1E-05
Tributyl Tetradecyl Phosphonium Chloride	2A - Minimum	4.0E+00	NA	9.0E-03	1.8E-03	-	2.0E-01	-
Glutaraldehyde	2B - Minimum	1.4E-02	5.4E-04	4.0E-02	6.0E-06	4.4E-07	1.5E-04	1.1E-05

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Table 8 Risk Estimates for Irrigation Worker for Scotia System Fluid Theoretical Exposure for Day 0

		Day 0		Toxicity	Scotia BE-9 Algacide and KCL System			
							Hazard Quotient	
Constituent Name	**Scenario**	**C_{frac} (mg/l)**	**PC (cm/hr)**	**RfDo**	**$CADD_{oral}$**	**$CADD_{derm}$**	**Incidental Ingestion**	**Dermal**
Tributyl Tetradecyl Phosphonium Chloride	1A - Maximum	2.4E+01	NA	9.0E-03	1.1E-02	-	1.2E+00	-
Glutaraldehyde	1B - Maximum	8.0E+01	5.4E-04	4.0E-02	3.5E-02	1.0E-02	8.8E-01	2.6E-01
Tributyl Tetradecyl Phosphonium Chloride	1A - Minimum	8.0E+00	NA	9.0E-03	3.5E-03	-	3.9E-01	-
Glutaraldehyde	1B - Minimum	2.8E+01	5.4E-04	4.0E-02	1.2E-02	3.6E-03	3.1E-01	8.9E-02
Tributyl Tetradecyl Phosphonium Chloride	2A - Maximum	1.2E+01	NA	9.0E-03	5.3E-03	-	5.9E-01	-
Glutaraldehyde	2B - Maximum	4.0E+01	5.4E-04	4.0E-02	1.8E-02	5.1E-03	4.4E-01	1.3E-01
Tributyl Tetradecyl Phosphonium Chloride	2A - Minimum	4.0E+00	NA	9.0E-03	1.8E-03	-	2.0E-01	-
Glutaraldehyde	2B - Minimum	1.4E+01	5.4E-04	4.0E-02	6.1E-03	1.8E-03	1.5E-01	4.5E-02

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Table 9 Risk Estimates for Irrigation Worker for Scotia System Fluid Theoretical Exposure for Day 150

		Day 150		Toxicity	Scotia BE-9 Algacide and KCL System			
							Hazard Quotient	
Constituent Name	**Scenario**	**C_{frac} (mg/l)**	**PC (cm/hr)**	**RfDo**	**$CADD_{oral}$**	**$CADD_{derm}$**	**Incidental Ingestion**	**Dermal**
Tributyl Tetradecyl Phosphonium Chloride	1A - Maximum	2.4E+01	NA	9.0E-03	1.1E-02	-	1.2E+00	-
Glutaraldehyde	1B - Maximum	7.8E-02	5.4E-04	4.0E-02	3.4E-05	1.0E-05	8.6E-04	2.5E-04
Tributyl Tetradecyl Phosphonium Chloride	1A - Minimum	8.0E+00	NA	9.0E-03	3.5E-03	-	3.9E-01	-
Glutaraldehyde	1B - Minimum	2.7E-02	5.4E-04	4.0E-02	1.2E-05	3.5E-06	3.0E-04	8.7E-05
Tributyl Tetradecyl Phosphonium Chloride	2A - Maximum	1.2E+01	NA	9.0E-03	5.3E-03	-	5.9E-01	-
Glutaraldehyde	2B - Maximum	3.9E-02	5.4E-04	4.0E-02	1.7E-05	5.0E-06	4.3E-04	1.2E-04
Tributyl Tetradecyl Phosphonium Chloride	2A - Minimum	4.0E+00	NA	9.0E-03	1.8E-03	-	2.0E-01	-
Glutaraldehyde	2B - Minimum	1.4E-02	5.4E-04	4.0E-02	6.0E-06	1.7E-06	1.5E-04	4.4E-05

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Table 10 Exposure Assumptions - Cattle

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/day	86
	EF	Exposure frequency	day/yr	15
	ED	Exposure duration	yr	8
	BW	Body weight	kg	454
	AT-NC	Averaging time - noncancer	days	2,920

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Table 11 Exposure Assumptions - Kangaroo

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/day	3
	EF	Exposure frequency	day/yr	10
	ED	Exposure duration	yr	15
	BW	Body weight	kg	25
	AT-NC	Averaging time - noncancer	days	5,475

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Table 12 Exposure Assumptions - Dingo

Exposure Route	Parameter Code	Parameter Definition	Units	Parameter Value
Ingestion	IR	Ingestion rate	l/day	0.75
	EF	Exposure frequency	day/yr	10
	ED	Exposure duration	yr	15
	BW	Body weight	kg	13
	AT-NC	Averaging time - noncancer	days	5,475

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Table 13 Aquatic Toxicity Values (PNECs)

Chemical	Endpoint	NOEC (mg/L)	Assessment Factor	$PNEC_{aquatic}$ (mg/L)
Tributyl Tetradecyl Phosphonium Chloride (81741-28-8)	Acute EC_{50} (Daphnia)	0.025	1,000	2.5E-05
Glutaraldehyde (111-30-8)	Acute E(L)C_{50}	0.025	10	2.5E-03

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Table 14 Risk Estimates for Cattle Scotia System Fluid Theoretical Exposure for Day 0

		Day 0	Toxicity	Scotia BE-9 Algacide and KCL System	
					Hazard Quotient
Constituent Name	**Scenario**	**C_{frac} (mg/l)**	**TRVs**	**TI**	**Incidental Ingestion**
Tributyl Tetradecyl Phosphonium Chloride	1A - Maximum	2.4E+01	1.4E+00	1.9E-01	1.3E-01
Glutaraldehyde	1B - Maximum	8.0E+01	6.7E-01	6.2E-01	9.3E-01
Tributyl Tetradecyl Phosphonium Chloride	1A - Minimum	8.0E+00	1.4E+00	6.2E-02	4.3E-02
Glutaraldehyde	1B - Minimum	2.8E+01	6.7E-01	2.2E-01	3.3E-01
Tributyl Tetradecyl Phosphonium Chloride	2A - Maximum	1.2E+01	1.4E+00	9.3E-02	6.5E-02
Glutaraldehyde	2B - Maximum	4.0E+01	6.7E-01	3.1E-01	4.7E-01
Tributyl Tetradecyl Phosphonium Chloride	2A - Minimum	4.0E+00	1.4E+00	3.1E-02	2.2E-02
Glutaraldehyde	2B - Minimum	1.4E+01	6.7E-01	1.1E-01	1.6E-01

Scenario 1 - Dilution with groundwater in tank with flow back concentration equal to hydraulic fracturing fluid concentration and maximum/minimum with 60/40 dilution
Scenario 2 - Dilution with groundwater in tank with flow back concentration half of hydraulic fracturing fluid concentration (formation loss and dilution other wells) and maximu

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Table 15 Risk Estimates for Cattle Scotia System Fluid Theoretical Exposure for Day 150

		Day 150	Toxicity	Scotia BE-9 Algacide and KCL System	
					Hazard Quotient
Constituent Name	**Scenario**	**C_{frac} (mg/l)**	**TRVs**	**TI**	**Incidental Ingestion**
Tributyl Tetradecyl Phosphonium Chloride	1A - Maximum	2.4E+01	1.4E+00	1.9E-01	1.3E-01
Glutaraldehyde	1B - Maximum	7.8E-02	6.7E-01	6.1E-04	9.1E-04
Tributyl Tetradecyl Phosphonium Chloride	1A - Minimum	8.0E+00	1.4E+00	6.2E-02	4.3E-02
Glutaraldehyde	1B - Minimum	2.7E-02	6.7E-01	2.1E-04	3.2E-04
Tributyl Tetradecyl Phosphonium Chloride	2A - Maximum	1.2E+01	1.4E+00	9.3E-02	6.5E-02
Glutaraldehyde	2B - Maximum	3.9E-02	6.7E-01	3.0E-04	4.6E-04
Tributyl Tetradecyl Phosphonium Chloride	2A - Minimum	4.0E+00	1.4E+00	3.1E-02	2.2E-02
Glutaraldehyde	2B - Minimum	1.4E-02	6.7E-01	1.1E-04	1.6E-04

Scenario 1 - Dilution with groundwater in tank with flow back concentration equal to hydraulic fracturing fluid concentration and maximum/minimum with 60/40 dilution
Scenario 2 - Dilution with groundwater in tank with flow back concentration half of hydraulic fracturing fluid concentration (formation loss and dilution other wells) and maximum/minir

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Table 16 Risk Estimates for Kangaroo Scotia System Fluid Theoretical Exposure for Day 0

		Day 0	Toxicity	Scotia BE-9 Algacide and KCL System	
					Hazard Quotient
Constituent Name	**Scenario**	**C_{frac} (mg/l)**	**TRVs**	**TI**	**Incidental Ingestion**
Tributyl Tetradecyl Phosphonium Chloride	1A - Maximum	2.4E+01	3.0E+00	7.9E-02	2.6E-02
Glutaraldehyde	1B - Maximum	8.0E+01	1.4E+00	2.6E-01	1.9E-01
Tributyl Tetradecyl Phosphonium Chloride	1A - Minimum	8.0E+00	3.0E+00	2.6E-02	8.8E-03
Glutaraldehyde	1B - Minimum	2.8E+01	1.4E+00	9.2E-02	6.7E-02
Tributyl Tetradecyl Phosphonium Chloride	2A - Maximum	1.2E+01	3.0E+00	3.9E-02	1.3E-02
Glutaraldehyde	2B - Maximum	4.0E+01	1.4E+00	1.3E-01	9.6E-02
Tributyl Tetradecyl Phosphonium Chloride	2A - Minimum	4.0E+00	3.0E+00	1.3E-02	4.4E-03
Glutaraldehyde	2B - Minimum	1.4E+01	1.4E+00	4.6E-02	3.3E-02

Scenario 1 - Dilution with groundwater in tank with flow back concentration equal to hydraulic fracturing fluid concentration and maximum/minimum with 60/40 dilution
Scenario 2 - Dilution with groundwater in tank with flow back concentration half of hydraulic fracturing fluid concentration (formation loss and dilution other wells) and maximum/

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Table 17 Risk Estimates for Kangaroo Scotia System Fluid Theoretical Exposure for Day 150

		Day 150	Toxicity	Scotia BE-9 Algacide and KCL System	
					Hazard Quotient
Constituent Name	**Scenario**	**C_{frac} (mg/l)**	**TRVs**	**TI**	**Incidental Ingestion**
Tributyl Tetradecyl Phosphonium Chloride	1A - Maximum	2.4E+01	3.0E+00	7.9E-02	2.6E-02
Glutaraldehyde	1B - Maximum	7.8E-02	1.4E+00	2.6E-04	1.9E-04
Tributyl Tetradecyl Phosphonium Chloride	1A - Minimum	8.0E+00	3.0E+00	2.6E-02	8.8E-03
Glutaraldehyde	1B - Minimum	2.7E-02	1.4E+00	9.0E-05	6.5E-05
Tributyl Tetradecyl Phosphonium Chloride	2A - Maximum	1.2E+01	3.0E+00	3.9E-02	1.3E-02
Glutaraldehyde	2B - Maximum	3.9E-02	1.4E+00	1.3E-04	9.3E-05
Tributyl Tetradecyl Phosphonium Chloride	2A - Minimum	4.0E+00	3.0E+00	1.3E-02	4.4E-03
Glutaraldehyde	2B - Minimum	1.4E-02	1.4E+00	4.5E-05	3.3E-05

Scenario 1 - Dilution with groundwater in tank with flow back concentration equal to hydraulic fracturing fluid concentration and maximum/minimum with 60/40 dilution
Scenario 2 - Dilution with groundwater in tank with flow back concentration half of hydraulic fracturing fluid concentration (formation loss and dilution other wells) and maximum/

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Table 18 Risk Estimates for Dingo Scotia System Fluid Theoretical Exposure for Day 0

		Day 0	Toxicity	Scotia BE-9 Algacide and KCL System	
					Hazard Quotient
Constituent Name	**Scenario**	**C_{frac} (mg/l)**	**TRVs**	**TI**	**Incidental Ingestion**
Tributyl Tetradecyl Phosphonium Chloride	1A - Maximum	2.4E+01	3.5E+00	3.8E-02	1.1E-02
Glutaraldehyde	1B - Maximum	8.0E+01	1.6E+00	1.3E-01	7.8E-02
Tributyl Tetradecyl Phosphonium Chloride	1A - Minimum	8.0E+00	3.5E+00	1.3E-02	3.6E-03
Glutaraldehyde	1B - Minimum	2.8E+01	1.6E+00	4.4E-02	2.7E-02
Tributyl Tetradecyl Phosphonium Chloride	2A - Maximum	1.2E+01	3.5E+00	1.9E-02	5.4E-03
Glutaraldehyde	2B - Maximum	4.0E+01	1.6E+00	6.3E-02	3.9E-02
Tributyl Tetradecyl Phosphonium Chloride	2A - Minimum	4.0E+00	3.5E+00	6.3E-03	1.8E-03
Glutaraldehyde	2B - Minimum	1.4E+01	1.6E+00	2.2E-02	1.4E-02

Scenario 1 - Dilution with groundwater in tank with flow back concentration equal to hydraulic fracturing fluid concentration and maximum/minimum with 60/40 dilution
Scenario 2 - Dilution with groundwater in tank with flow back concentration half of hydraulic fracturing fluid concentration (formation loss and dilution other wells) and maximum/minir

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Table 19 Risk Estimates for Dingo Scotia System Fluid Theoretical Exposure for Day 150

		Day 150	Toxicity	Scotia BE-9 Algacide and KCL System	
					Hazard Quotient
Constituent Name	**Scenario**	**C_{frac} (mg/l)**	**TRVs**	**TI**	**Incidental Ingestion**
Tributyl Tetradecyl Phosphonium Chloride	1A - Maximum	2.4E+01	3.5E+00	3.8E-02	1.1E-02
Glutaraldehyde	1B - Maximum	7.8E-02	1.6E+00	1.2E-04	7.6E-05
Tributyl Tetradecyl Phosphonium Chloride	1A - Minimum	8.0E+00	3.5E+00	1.3E-02	3.6E-03
Glutaraldehyde	1B - Minimum	2.7E-02	1.6E+00	4.3E-05	2.7E-05
Tributyl Tetradecyl Phosphonium Chloride	2A - Maximum	1.2E+01	3.5E+00	1.9E-02	5.4E-03
Glutaraldehyde	2B - Maximum	3.9E-02	1.6E+00	6.2E-05	3.8E-05
Tributyl Tetradecyl Phosphonium Chloride	2A - Minimum	4.0E+00	3.5E+00	6.3E-03	1.8E-03
Glutaraldehyde	2B - Minimum	1.4E-02	1.6E+00	2.2E-05	1.3E-05

Scenario 1 - Dilution with groundwater in tank with flow back concentration equal to hydraulic fracturing fluid concentration and maximum/minimum with 60/40 dilution
Scenario 2 - Dilution with groundwater in tank with flow back concentration half of hydraulic fracturing fluid concentration (formation loss and dilution other wells) and maximum/m

Appendix 1

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Appendix 1 Surface Water Quality Data for Theoretical Scenario in Initial Flowback for Scotia System

Constituent Name	CAS No.	Scenario	Estimated concentration in tank (mg/L)	Fate and Transport Properties	Estimated Tank Concentration after application of Biodegradation (half life)			
					Temporal Scenario (days)			
				Half-Life (days)	0	30	150	300
Tributyl Tetradecyl Phosphonium Chloride	81741-28-8	1A - Maximum	24	NA	2.4E+01	2.4E+01	2.4E+01	2.4E+01
Glutaraldehyde	111-30-8	1B - Maximum	80	15	8.0E+01	2.0E+01	7.8E-02	7.6E-05
Tributyl Tetradecyl Phosphonium Chloride	81741-28-8	1A - Minimum	8	NA	8.0E+00	8.0E+00	8.0E+00	8.0E+00
Glutaraldehyde	111-30-8	1B - Minimum	28	15	2.8E+01	7.0E+00	2.7E-02	2.7E-05
Tributyl Tetradecyl Phosphonium Chloride	81741-28-8	2A - Maximum	12	NA	1.2E+01	1.2E+01	1.2E+01	1.2E+01
Glutaraldehyde	111-30-8	2B - Maximum	40	15	4.0E+01	1.0E+01	3.9E-02	3.8E-05
Tributyl Tetradecyl Phosphonium Chloride	81741-28-8	2A - Minimum	4	NA	4.0E+00	4.0E+00	4.0E+00	4.0E+00
Glutaraldehyde	111-30-8	2B - Minimum	14	15	1.4E+01	3.5E+00	1.4E-02	1.3E-05

Appendix 2

HALLIBURTON

MATERIAL SAFETY DATA SHEET

Product Trade Name: **ALDACIDE® G ANTIMICROBIAL**

Revision Date: 24-Sep-2014

1. IDENTIFICATION OF THE SUBSTANCE/PREPARATION AND OF THE COMPANY/UNDERTAKING

Statement of Hazardous Nature Hazardous according to the criteria of NOHSC, Dangerous Goods according to the criteria of ADG.

Manufacturer/Supplier

Halliburton Australia Pty. Ltd.
15 Marriott Road
Jandakot
WA 6164
Australia

ACN Number: 009 000 775
Telephone Number: 61 (08) 9455 8300
Fax Number: 61 (08) 9455 5300

Product Emergency Telephone
Australia: 08-64244950
Papua New Guinea: 05 1 281 575 5000
NewZealand: 06-7559274

Fire, Police & Ambulance - Emergency Telephone
Australia: 000
Papua New Guinea: 000
New Zealand: 111

Identification of Substances or Preparation

Product Trade Name:	ALDACIDE® G ANTIMICROBIAL
Synonyms:	None
Chemical Family:	Aldehyde
UN Number:	UN3265
Dangerous Goods Class:	8
Subsidiary Risk:	None
Hazchem Code:	None Allocated
Poisons Schedule:	S6
Application:	Biocide

Prepared By

Chemical Compliance
Telephone: 1-580-251-4335
e-mail: fdunexchem@halliburton.com

2. HAZARDS IDENTIFICATION

Statement of Hazardous Nature Hazardous according to the criteria of NOHSC, Dangerous Goods according to the criteria of ADG.

Hazard Overview

Keep out of reach of children May cause eye burns. May cause irreversible eye damage. May cause severe skin irritation. May be harmful if swallowed. May be harmful if inhaled May cause allergic skin reaction.

Classification

C - Corrosive.
Xn - Harmful.
N - Dangerous For The Environment.

Risk Phrases

R34 Causes burns.
R20/22 Harmful by inhalation and if swallowed.
R42/43 May cause sensitization by inhalation and skin contact.
R50/53 Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.

Safety Phrases

S23 Do not breathe gas, fumes, vapour or spray.

S26 In case of contact with eyes, rinse immediately with plenty of water and seek medical advice.

S45 In case of accident or if you feel unwell, seek medical advice immediately.
S1/2 Keep locked up and out of reach of children.

S36/37/39 Wear suitable protective clothing, gloves and eye/face protection.

HSNO Classification

6.1A (Inhalation) Acutely Toxic Substances
6.5A Respiratory sensitisers
6.5B Contact sensitisers
6.9B Harmful to human target organs or systems
8.2B Corrosive to dermal tissue if exposed for greater than 3 mins
8.3A Corrosive to ocular tissue
9.1D Slightly harmful in the aquatic environment
9.2B Ecotoxic in the soil environment
9.3B Ecotoxic to terrestrial invertebrates

3. COMPOSITION/INFORMATION ON INGREDIENTS

Substances	CAS Number	PERCENT (w/w)	Australia NOHSC	New Zealand WES	ACGIH TLV-TWA
Glutaraldehyde	111-30-8	10 - 30%	0.1 ppm	STEL: 0.05 ppm	0.05 ppm

Non-Hazardous Substance to Total of 100%

4. FIRST AID MEASURES

Inhalation

If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.

Skin

In case of contact, immediately flush skin with plenty of soap and water for at least 15 minutes. Get medical attention. Remove contaminated clothing and discard.

Eyes

Immediately flush eyes with large amounts of water for at least 30 minutes. Seek prompt medical attention.

Ingestion

Do NOT induce vomiting. Give nothing by mouth. Obtain immediate medical attention.

Notes to Physician	Probable mucosal damage may contraindicate the use of gastric lavage. No specific antidote. Treat symptomatically.

5. FIRE FIGHTING MEASURES

Suitable Extinguishing Media
Water fog, carbon dioxide, foam, dry chemical.

Extinguishing media which must not be used for safety reasons
None known.

Special Exposure Hazards	Decomposition in fire may produce toxic gases.
Special Protective Equipment for Fire-Fighters	Full protective clothing and approved self-contained breathing apparatus required for fire fighting personnel.

6. ACCIDENTAL RELEASE MEASURES

Personal Precautionary Measures	Use appropriate protective equipment. Use only competent persons for cleanup.
Environmental Precautionary Measures	Prevent from entering sewers, waterways, or low areas.
Procedure for Cleaning / Absorption	Isolate spill and stop leak where safe. Contain spill with sand or other inert materials. Scoop up and remove.

7. HANDLING AND STORAGE

Handling Precautions	Avoid contact with eyes, skin, or clothing. Avoid breathing vapors. Avoid breathing mist. Do not swallow. Wash hands after use. Launder contaminated clothing before reuse.
Storage Information	Store away from acids. Store away from alkalis. Keep container closed when not in use. Product has a shelf life of 36 months.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Engineering Controls	Use in a well ventilated area. Local exhaust ventilation should be used in areas without good cross ventilation. If vapors are strong enough to be irritating to the nose or eyes, the TLV is probably being exceeded and special ventilation or respiratory protection maybe required.
Respiratory Protection	If engineering controls and work practices cannot keep exposure below occupational exposure limits or if exposure is unknown, wear a NIOSH certified, European Standard EN 149, AS/NZS 1715:2009, or equivalent respirator when using this product. Selection of and instruction on using all personal protective equipment, including respirators, should be performed by an Industrial Hygienist or other qualified professional. Full Facepiece Respirator with Organic vapor cartridge with particulate prefilter.

Hand Protection	Chemical-resistant protective gloves (EN 374) Suitable materials for longer, direct contact (recommended: protection index 6, corresponding to > 480 minutes permeation time as per EN 374): Butyl rubber gloves. (>= 0.7 mm thickness) This information is based on literature references and on information provided by glove manufacturers, or is derived by analogy with similar substances. Please note that in practice the working life of chemical-resistant protective gloves may be considerably shorter than the permeation time determined in accordance with EN 374 as a result of the many influencing factors (e.g. temperature). If signs of wear and tear are noticed then the gloves should be replaced. Manufacturer's directions for use should be observed because of great diversity of types.
Skin Protection	Butyl coated apron or clothing.
Eye Protection	Splashproof chemical monogoggles or safety glasses with side shields in conjunction with a face shield. Do NOT wear contact lenses.
Other Precautions	Eyewash fountains and safety showers must be easily accessible.

9. PHYSICAL AND CHEMICAL PROPERTIES

Physical State:	Liquid
Color:	Clear light yellow
Odor:	Sharp
pH:	3.1-4.5
Specific Gravity @ 20 C (Water=1):	1.064
Density @ 20 C (kg/l):	1.064
Bulk Density @ 20 C (kg/M3):	Not Determined
Boiling Point/Range (C):	100.5
Freezing Point/Range (C):	-5 / -10
Pour Point/Range (C):	Not Determined
Flash Point/Range (C):	Not Determined
Flash Point Method:	Not Determined
Autoignition Temperature (C):	> 275
Flammability Limits in Air - Lower (g/m^3):	Not Determined
Flammability Limits in Air - Lower (%):	Not Determined
Flammability Limits in Air - Upper (g/m^3):	Not Determined
Flammability Limits in Air - Upper (%):	Not Determined
Vapor Pressure @ 20 C (mmHg):	0.2
Vapor Density (Air=1):	0.8
Percent Volatiles:	100
Evaporation Rate (Butyl Acetate=1):	0.9
Solubility in Water (g/100ml):	Soluble
Solubility in Solvents (g/100ml):	Not Determined
VOCs (g/l):	Not Determined
Viscosity, Dynamic @ 20 C (centipoise):	Not Determined
Viscosity, Kinematic @ 20 C (centistokes):	Not Determined
Partition Coefficient/n-Octanol/Water:	-0.333
Molecular Weight (g/mole):	Not Determined
Decomposition Temperature (C):	Not Determined

10. STABILITY AND REACTIVITY

Stability Data:	Stable
Hazardous Polymerization:	Will Not Occur
Conditions to Avoid	Keep away from heat, sparks and flame.

Incompatibility (Materials to Avoid) Strong acids. Strong alkalis.

Hazardous Decomposition Products Carbon monoxide and carbon dioxide.

Additional Guidelines Not Applicable

11. TOXICOLOGICAL INFORMATION

Principle Route of Exposure Eye or skin contact, inhalation.

Sympotoms related to exposure

Acute Toxicity

Inhalation Harmful if inhaled. Causes severe respiratory irritation. Vapors given off by heated product may be harmful. May cause allergic respiratory reaction. Inhalation of vapors may result in skin sensitization.

Eye Contact May cause eye burns. May cause permanent eye damage. High vapor concentration will cause irritation.

Skin Contact May cause skin burns. This product contains ingredients which may produce an allergic skin reaction. It should be treated as a skin sensitizer.

Ingestion Causes burns of the mouth, throat and stomach. Harmful if swallowed. Aspiration into the lungs may cause chemical pneumonitis including coughing, difficulty breathing, wheezing, coughing up blood and pneumonia, which can be fatal.

Chronic Effects/Carcinogenicity No data available to indicate product or components present at greater than 1% are chronic health hazards.

Toxicology data for the components

Substances	CAS Number	LD50 Oral	LD50 Dermal	LC50 Inhalation
Glutaraldehyde	111-30-8	252 mg/kg (Rat) 316 mg/kg (Rat)	> 2000 mg/kg (Rat) 560 µL/kg (Rabbit)	0.48 mg/L (Rat, 4h)

12. ECOLOGICAL INFORMATION

Ecotoxicological Information

Ecotoxicity Product

Acute Fish Toxicity: May be highly toxic to aquatic life.
LC50: (96 hour) 13 mg/l (Lepomis macrochirus)

Acute Crustaceans Toxicity: TLM48: 0.11 mg/l (Acartia tonsa)
TLM48: 29.73 mg/l (Daphnia magna)

Acute Algae Toxicity: EC50: 8.1 mg/l (Skeletonema costatum)

Ecotoxicity Substance

Substances	CAS Number	Toxicity to Algae	Toxicity to Fish	Toxicity to Microorganisms	Toxicity to Invertebrates
Glutaraldehyde	111-30-8	EC50(72h): 0.61 mg/L (Desmodesmus subspicatus)	LC50: 7.8-22 mg/L (Lepomis macrochirus); LC50: 7.8-13 mg/L (Oncorhynchus mykiss); LC50: 5.4 mg/L (Pimephales promelas)	No information available	EC50(48h): 0.56 - 1.0 mg/L (Daphnia magna)

12.2. Persistence and degradability

Readily biodegradable

Substances	CAS Number	Persistence and Degradability

Glutaraldehyde	111-30-8	Readily biodegradable (90-100% @ 28d)

12.3. Bioaccumulative potential

Does not bioaccumulate

Substances	CAS Number	Log Pow
Glutaraldehyde	111-30-8	0.22

12.4. Mobility in soil

No information available

12.5. Results of PBT and vPvB assessment

No information available.

12.6. Other adverse effects

13. DISPOSAL CONSIDERATIONS

Disposal Method Disposal should be made in accordance with federal, state, and local regulations.

Contaminated Packaging Follow all applicable national or local regulations.

14. TRANSPORT INFORMATION

Australia Dangerous Goods

UN Number: UN3265
UN Proper Shipping Name: Corrosive Liquid, Acidic, Organic, N.O.S. (Contains Glutaraldehyde)
Transport Hazard Class(es): 8
Packing Group: III

IMDG/IMO

UN Number: UN3265
UN Proper Shipping Name: Corrosive Liquid, Acidic, Organic, N.O.S. (Contains Glutaraldehyde)
Transport Hazard Class(es): 8
Packing Group: III
Environmental Hazards: Not applicable
EMS: EmS F-A, S-B

IATA/ICAO

UN Number: UN3265
UN Proper Shipping Name: Corrosive Liquid, Acidic, Organic, N.O.S. (Contains Glutaraldehyde)
Transport Hazard Class(es): 8
Packing Group: III

Special Precautions for User: None

Transport in bulk according to Annex II of MARPOL 73/78 and the IBC Code: Not applicable

15. REGULATORY INFORMATION

Chemical Inventories

Australian AICS Inventory All components listed on inventory or are exempt.
New Zealand Inventory of Chemicals All components listed on inventory or are exempt.
US TSCA Inventory All components listed on inventory or are exempt.
EINECS Inventory This product, and all its components, complies with EINECS

Classification	C - Corrosive. Xn - Harmful. N - Dangerous For The Environment.
Risk Phrases	R34 Causes burns. R20/22 Harmful by inhalation and if swallowed. R42/43 May cause sensitization by inhalation and skin contact. R50/53 Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.
Safety Phrases	S23 Do not breathe gas, fumes, vapour or spray. S26 In case of contact with eyes, rinse immediately with plenty of water and seek medical advice. S45 In case of accident or if you feel unwell, seek medical advice immediately. S1/2 Keep locked up and out of reach of children. S36/37/39 Wear suitable protective clothing, gloves and eye/face protection.

16. OTHER INFORMATION

The following sections have been revised since the last issue of this SDS
Not applicable

Contact

Australian Poisons Information Centre
24 Hour Service: - 13 11 26
Police or Fire Brigade: - 000 (exchange): - 1100

New Zealand National Poisons Centre
0800 764 766

Additional information	For additional information on the use of this product, contact your local Halliburton representative. For questions about the Safety Data Sheet for this or other Halliburton products, contact Chemical Compliance at 1-580-251-4335.
Disclaimer Statement	This information is furnished without warranty, expressed or implied, as to accuracy or completeness. The information is obtained from various sources including the manufacturer and other third party sources. The information may not be valid under all conditions nor if this material is used in combination with other materials or in any process. Final determination of suitability of any material is the sole responsibility of the user.

*****END OF MSDS*****

HALLIBURTON

SAFETY DATA SHEET

BE-9

Revision Date: 13-Oct-2017 **Revision Number:** 20

1. Product Identifier & Identity for the Chemical

Statement of Hazardous Nature Hazardous according to the criteria of the 3rd Revised Edition of the Globally Harmonised System of Classification and Labelling of Chemicals (GHS), Dangerous Goods according to the criteria of ADG.

1.1. Product Identifier

Product Name BE-9

Other means of Identification

Synonyms None

Hazardous Material Number: HB006583

Recommended use of the chemical and restrictions on use

Recommended Use Biocide

Uses advised against No information available

Supplier's name, address and phone number

Manufacturer/Supplier Halliburton Australia Pty. Ltd.
15 Marriott Road, Jandakot, WA 6164
Australia
ACN Number: 009 000 775
Telephone Number: + 61 1 800 686 951
Fax Number: 61 (08) 9455 5300

E-mail Address fdunexchem@halliburton.com

Emergency phone number

+ 61 1 800 686 951
Global Incident Response Access Code: 334305
Contract Number: 14012

Australian Poisons Information Centre
24 Hour Service: - 13 11 26
Police or Fire Brigade: - 000 (exchange): - 1100

2. Hazard Identification

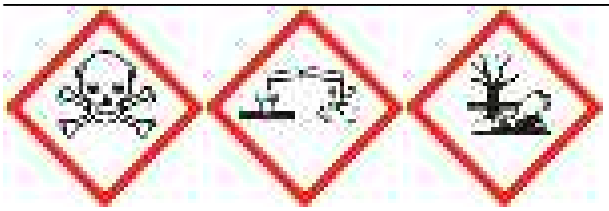
Statement of Hazardous Nature Hazardous according to the criteria of the 3rd Revised Edition of the Globally Harmonised System of Classification and Labelling of Chemicals (GHS), Dangerous Goods according to the criteria of ADG.

Classification of the hazardous chemical

Skin Corrosion/Irritation	Category 1 - H314
Serious Eye Damage/Irritation	Category 1 - H318
Acute Aquatic Toxicity	Category 1 - H400
Chronic Aquatic Toxicity	Category 2 - H411

Label elements, including precautionary statements

Hazard Pictograms



Signal Word DANGER

Hazard Statements:
H314 - Causes severe skin burns and eye damage
H318 - Causes serious eye damage
H400 - Very toxic to aquatic life
H411 - Toxic to aquatic life with long lasting effects

Precautionary Statements

Prevention
P260 - Do not breathe dust/fume/gas/mist/vapors/spray
P273 - Avoid release to the environment
P280 - Wear protective gloves/protective clothing/eye protection/face protection

Response
P301 + P330 + P331 - IF SWALLOWED: rinse mouth. Do NOT induce vomiting
P303 + P361 + P353 - IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water [or shower].
P363 - Wash contaminated clothing before reuse
P304 + P340 - IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing
P310 - Immediately call a POISON CENTER or doctor/physician
P305 + P351 + P338 - IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing
P391 - Collect spillage

Storage
P405 - Store locked up

Disposal
P501 - Dispose of contents/container in accordance with local/regional/national/international regulations

Contains

Substances	**CAS Number**
Tributyl tetradecyl phosphonium chloride	81741-28-8

Other hazards which do not result in classification
None known

For the full text of the H-phrases mentioned in this Section, see Section 16

3. Composition/information on Ingredients

Substances	CAS Number	PERCENT (w/w)	GHS Classification - Australia
Tributyl tetradecyl phosphonium chloride	81741-28-8	5 - 10%	Acute Tox. 4 (H302) Acute Tox. 2 (H330) Skin Corr. 1B (H314) Eye Corr. 1 (H318) Aquatic Acute 1 (H400) Aquatic Chronic 1 (H410)

4. First aid measures

Description of necessary first aid measures

Inhalation If inhaled, move victim to fresh air and seek medical attention.

Eyes Immediately flush eyes with large amounts of water for at least 30 minutes. Seek prompt medical attention.

Skin In case of contact, immediately flush skin with plenty of soap and water for at least 30 minutes and remove contaminated clothing, shoes and leather goods immediately. Get medical attention immediately.

Ingestion Do NOT induce vomiting. Give nothing by mouth. Obtain immediate medical attention.

Symptoms caused by exposure

Causes severe eye irritation which may damage tissue. Causes severe skin irritation with tissue destruction.

Medical Attention and Special Treatment

Notes to Physician Treat symptomatically

5. Fire Fighting Measures

Suitable extinguishing equipment

Suitable Extinguishing Media

Water fog, carbon dioxide, foam, dry chemical.

Extinguishing media which must not be used for safety reasons

None known.

Specific hazards arising from the chemical

Special exposure hazards in a fire

Decomposition in fire may produce harmful gases. Do not allow runoff to enter waterways. Use water spray to cool fire exposed surfaces.

Special protective equipment and precautions for fire fighters

Special protective equipment for firefighters

Full protective clothing and approved self-contained breathing apparatus required for fire fighting personnel.

6. Accidental release measures

6.1. Personal precautions, protective equipment and emergency procedures

Use appropriate protective equipment.

6.2. Environmental precautions

Prevent from entering sewers, waterways, or low areas.

6.3. Methods and material for containment and cleaning up

Isolate spill and stop leak where safe. Contain spill with sand or other inert materials. Scoop up and remove.

7. Handling and storage

7.1. Precautions for safe handling

Handling Precautions

Avoid contact with eyes, skin, or clothing. Wash hands after use. Launder contaminated clothing before reuse. Do NOT consume food, drink, or tobacco in contaminated areas.

Hygiene Measures

Handle in accordance with good industrial hygiene and safety practice.

7.2. Conditions for safe storage, including any incompatibilities

Storage Information

Store in a cool well ventilated area. Keep container closed when not in use. Store away from direct sunlight. Store in a dry location. Store in a manner to prevent commingling with incompatible materials. Store away from alkalis. Store away from reducing agents. Store locked up.

Other Guidelines

No information available

8. Exposure Controls/Personal Protection

Control parameters - exposure standards, biological monitoring

Exposure Limits

Substances	CAS Number	Australia NOHSC	ACGIH TLV-TWA
Tributyl tetradecyl phosphonium chloride	81741-28-8	Not applicable	Not applicable

Appropriate engineering controls

Engineering Controls Use in a well ventilated area. Local exhaust ventilation should be used in areas without good cross ventilation.

Personal protective equipment (PPE)

Personal Protective Equipment If engineering controls and work practices cannot prevent excessive exposures, the selection and proper use of personal protective equipment should be determined by an industrial hygienist or other qualified professional based on the specific application of this product.

Respiratory Protection If engineering controls and work practices cannot keep exposure below occupational exposure limits or if exposure is unknown, wear a NIOSH certified, European Standard EN 149, AS/NZS 1715:2009, or equivalent respirator when using this product. Selection of and instruction on using all personal protective equipment, including respirators, should be performed by an Industrial Hygienist or other qualified professional.
Dust/mist respirator. (N95, P2/P3)

Hand Protection Chemical-resistant protective gloves (EN 374) Suitable materials for longer, direct contact (recommended: protection index 6, corresponding to > 480 minutes permeation time as per EN 374): Neoprene gloves. (>= 0.75 mm thickness)
This information is based on literature references and on information provided by glove manufacturers, or is derived by analogy with similar substances. Please note that in practice the working life of chemical-resistant protective gloves may be considerably shorter than the permeation time determined in accordance with EN 374 as a result of the many influencing factors (e.g. temperature). If signs of wear and tear are noticed then the gloves should be replaced. Manufacturer's directions for use should be observed because of great diversity of types.

Skin Protection Wear impervious protective clothing, including boots, gloves, lab coat, apron, rain jacket, pants or coverall, as appropriate, to prevent skin contact.

Eye Protection Chemical goggles; also wear a face shield if splashing hazard exists.

Other Precautions Eyewash fountains and safety showers must be easily accessible.

Environmental Exposure Controls No information available

9. Physical and Chemical Properties

9.1. Information on basic physical and chemical properties

Physical State: Liquid
Color Clear colorless
Odor: Slight
Odor Threshold: No information available

Property Remarks/ - Method	Values
pH:	6-8
Freezing Point / Range	-8 - -10 °C
Melting Point / Range	No data available
Boiling Point / Range	100 °C / 212 °F
Flash Point	No data available
Evaporation rate	No data available
Vapor Pressure	No data available
Vapor Density	No data available
Specific Gravity	0.95 - 1.0
Water Solubility	Miscible with water
Solubility in other solvents	No data available
Partition coefficient: n-octanol/water	No data available
Autoignition Temperature	No data available
Decomposition Temperature	No data available
Viscosity	No data available
Explosive Properties	No information available
Oxidizing Properties	No information available

9.2. Other information

VOC Content (%) No data available

10. Stability and Reactivity

10.1. Reactivity

Not expected to be reactive.

10.2. Chemical stability

Stable

10.3. Possibility of hazardous reactions

Will Not Occur

10.4. Conditions to avoid

None anticipated

10.5. Incompatible materials

Reducing agents. Strong alkalis.

10.6. Hazardous decomposition products

Chlorine. Phosphorus acids. Carbon monoxide and carbon dioxide.

11. Toxicological Information

Information on routes of exposure

Principle Route of Exposure Eye or skin contact, inhalation.

Symptoms related to exposure

Most Important Symptoms/Effects

Causes severe eye irritation which may damage tissue. Causes severe skin irritation with tissue destruction.

Toxicology data for the components

Substances	CAS Number	LD50 Oral	LD50 Dermal	LC50 Inhalation
Tributyl tetradecyl phosphonium chloride	81741-28-8	= 611 mg/kg (rat)	No data of sufficient quality are available	> 0.908 mg/L (rat, 4hr, mist)

Immediate, delayed and chronic health effects from exposure

Inhalation May cause respiratory irritation.

Eye Contact Causes severe eye irritation which may damage tissue. May cause eye burns.

Skin Contact Causes severe skin irritation with tissue destruction.

Ingestion Irritation of the mouth, throat, and stomach. May cause abdominal pain, vomiting, nausea, and diarrhea.

Chronic Effects/Carcinogenicity No data available to indicate product or components present at greater than 0.1% are chronic health hazards.

Exposure Levels

No data available

Interactive effects

Lung disorders. Skin disorders.

Data limitations

No data available

Substances	CAS Number	Skin corrosion/irritation
Tributyl tetradecyl phosphonium chloride	81741-28-8	Causes burns (Rabbit)

Substances	CAS Number	Serious eye damage/irritation
Tributyl tetradecyl phosphonium chloride	81741-28-8	Causes severe eye irritation which may damage tissue. (Rabbit)

Substances	CAS Number	Skin Sensitization
Tributyl tetradecyl phosphonium chloride	81741-28-8	No information available

Substances	CAS Number	Respiratory Sensitization
Tributyl tetradecyl phosphonium chloride	81741-28-8	No information available

Substances	CAS Number	Mutagenic Effects
Tributyl tetradecyl phosphonium chloride	81741-28-8	No data of sufficient quality are available.

Substances	CAS Number	Carcinogenic Effects
Tributyl tetradecyl phosphonium chloride	81741-28-8	No information available

Substances	CAS Number	Reproductive toxicity
Tributyl tetradecyl phosphonium chloride	81741-28-8	No information available

Substances	CAS Number	STOT - single exposure
Tributyl tetradecyl phosphonium chloride	81741-28-8	No information available

Substances	CAS Number	STOT - repeated exposure
Tributyl tetradecyl phosphonium chloride	81741-28-8	No data of sufficient quality are available.

Substances	CAS Number	Aspiration hazard
Tributyl tetradecyl phosphonium chloride	81741-28-8	No information available

12. Ecological Information

Ecotoxicity

Substance Ecotoxicity Data

Substances	CAS Number	Toxicity to Algae	Toxicity to Fish	Toxicity to Microorganisms	Toxicity to Invertebrates
Tributyl tetradecyl phosphonium chloride	81741-28-8	No information available	LC50 (96 h) 0.46 mg/L (Oncorhynchus mykiss) LC50 (96 h) 0.06 mg/L (Lepomis macrochirus)	No information available	EC50 (48 h) 0.025 mg/L (Daphnia sp.)

12.2. Persistence and degradability

Substances	CAS Number	Persistence and Degradability
Tributyl tetradecyl phosphonium chloride	81741-28-8	(0% @ 28d)

12.3. Bioaccumulative potential

Substances	CAS Number	Log Pow
Tributyl tetradecyl phosphonium chloride	81741-28-8	< 3

12.4. Mobility in soil

Substances	CAS Number	Mobility
Tributyl tetradecyl phosphonium chloride	81741-28-8	No information available

12.6. Other adverse effects

Endocrine Disruptor Information

This product does not contain any known or suspected endocrine disruptors

13. Disposal Considerations

Safe handling and disposal methods
Disposal should be made in accordance with federal, state, and local regulations. Incineration recommended in approved incinerator according to federal, state, and local regulations. Substance should NOT be deposited into a sewage facility.

Disposal of any contaminated packaging
Follow all applicable national or local regulations.

Environmental regulations
Not applicable

14. Transport Information

Transportation Information

Australia ADG

UN Number	UN2922
UN proper shipping name:	Corrosive Liquid, Toxic, N.O.S. (contains Tributyl Tetradecyl Phosphonium Chloride)
Transport Hazard Class(es):	8, (6.1)
Packing Group:	II
Environmental Hazards:	Marine Pollutant

IMDG/IMO

UN Number	UN2922
UN proper shipping name:	Corrosive Liquid, Toxic, N.O.S. (contains Tributyl Tetradecyl Phosphonium Chloride)
Transport Hazard Class(es):	8, (6.1)
Packing Group:	II
Environmental Hazards:	Marine Pollutant
EMS:	EmS F-A, S-B

IATA/ICAO

UN Number	UN2922
UN proper shipping name:	Corrosive Liquid, Toxic, N.O.S. (contains Tributyl Tetradecyl Phosphonium Chloride)
Transport Hazard Class(es):	8, (6.1)
Packing Group:	II
Environmental Hazards:	Marine Pollutant

Special precautions during transport
None

HazChem Code
2X

15. Regulatory Information

Safety, health and environmental regulations specific for the product

International Inventories

Australian AICS Inventory	All components are listed on the AICS or are subject to a relevant exemption, permit, or assessment certificate.
New Zealand Inventory of Chemicals	All components are listed on the NZIoC or are subject to a relevant exemption, permit, or assessment certificate.
EINECS (European Inventory of Existing Chemical Substances)	This product, and all its components, complies with EINECS
US TSCA Inventory	All components listed on inventory or are exempt.
Canadian Domestic Substances List (DSL)	All components listed on inventory or are exempt.

Poisons Schedule number

None Allocated

International Agreements

Montreal Protocol - Ozone Depleting Substances:	Does not apply
Stockholm Convention - Persistent Organic Pollutants:	Does not apply
Rotterdam Convention - Prior Informed Consent:	Does not apply
Basel Convention - Hazardous Waste:	Does not apply

16. Other information

Date of preparation or review

Revision Date: 13-Oct-2017

Revision Note
SDS sections updated:
2

Full text of H-Statements referred to under sections 2 and 3
H302 - Harmful if swallowed
H314 - Causes severe skin burns and eye damage
H318 - Causes serious eye damage
H330 - Fatal if inhaled
H400 - Very toxic to aquatic life
H401 - Toxic to aquatic life
H410 - Very toxic to aquatic life with long lasting effects
H411 - Toxic to aquatic life with long lasting effects

Additional information

For additional information on the use of this product, contact your local Halliburton representative.

For questions about the Safety Data Sheet for this or other Halliburton products, contact Chemical Stewardship at 1-580-251-4335.

Key abreviations or acronyms used
bw – body weight
CAS – Chemical Abstracts Service
EC50 – Effective Concentration 50%
LC50 – Lethal Concentration 50%
LD50 – Lethal Dose 50%
LL50 – Lethal Loading 50%
mg/kg – milligram/kilogram
mg/L – milligram/liter
NOEC – No Observed Effect Concentration
OEL – Occupational Exposure Limit
PBT – Persistent Bioaccumulative and Toxic
ppm – parts per million
STEL – Short Term Exposure Limit
TWA – Time-Weighted Average
vPvB – very Persistent and very Bioaccumulative
h - hour
mg/m^3 - milligram/cubic meter
mm - millimeter
mmHg - millimeter mercury
w/w - weight/weight
d - day

Key literature references and sources for data
www.ChemADVISOR.com/
NZ CCID

Disclaimer Statement

This information is furnished without warranty, expressed or implied, as to accuracy or completeness. The information is obtained from various sources including the manufacturer and other third party sources. The information may not be valid under all conditions nor if this material is used in combination with other materials or in any process. Final determination of suitability of any material is the sole responsibility of the user.

End of Safety Data Sheet

Appendix 3

Toxicity Profile

Glutaraldehyde
(CAS No. 111-30-8)

Acute Toxicity

The oral LD_{50} values are: 134 to 820 mg/kg in rats; 100 to 350 mg/kg in mice; and 50 mg/kg in guinea pigs (OECD 1995). The dermal LD_{50} values are: 640 to 2,000 mg/kg in rabbits; and >2,500 mg/kg in rats and mice (OECD 1995). The inhalation 4-hour LC_{50} values have been reported to be 23.5 and 40.1 ppm for male and female rats, respectively (NICNAS 1994).

Irritation

Glutaraldehyde is corrosive to the skin and eyes of rabbits (NICNAS 1994). Signs of irritation occur at a concentration of 2% for skin and 0.2% for eyes (NICNAS 1994). Nasal irritation and respiratory difficulty in rats occurred from inhalation to glutaraldehyde vapors (NICNAS 1994).

Sensitization

Glutaraldehyde is a skin sensitizer to guinea pigs and humans (NICNAS 1994).

Repeated Dose Toxicity

Oral

Male and female Wistar rat were given in their drinking water 0, 100, 500 or 2,000 ppm glutaraldehyde for 90 days. The approximate daily intakes were 0, 3, 15 or 53 mg/kg-day for males, and 0, 4, 19 or 72 mg/kg-day for females. There were no signs of neurotoxicity at any dose level. There was slight impairment of food consumption in the 2,000 ppm animals, as well as slight impairment of body weight and body weight gain. Impaired water consumption was seen in the 100 and 500 ppm females. The NOAEL for both males and females is 100 ppm, since the impaired water consumption in the 100 ppm females was considered a palatability problem and not an adverse effect (ECHA).

Male and female Wistar rats were given in their drinking water 0, 100, 500 or 2000 ppm glutaraldehyde for 12 months. The approximate daily intakes were 0, 6.4, 30.5 or 116.6 mg/kg-day for males, and 0. 9.6, 46 or 153 mg/kg-day for females. There was no treatment-related mortality. At 2,000 ppm, treatment-related effects included respiratory sounds (both sexes), decrease in body weight (males), decrease in body weight gain (both sexes), decrease in food consumption (both sexes), reduced water consumption (both

sexes), lesions within the glandular stomach (both sexes showed erosion/ulceration of the glandular stomach), increased incidence of clear cell foci in the liver (males), and a single case of slight diffuse squamous metaplasia in the epithelium of the larynx (male). At 500 ppm, water consumption was reduced in males which was considered to be a palatability (bad taste) problem and not an adverse effect. No treatment-related effects were seen in the 100 ppm animals (ECHA).

Male and female F344 rats were given in their drinking water 0, 50, 250 or 1,000 ppm glutaraldehyde for 13 weeks. Additional groups of animals were given in their drinking water 0 or 1000 ppm glutaraldehyde for 13 weeks followed by a 4-week recovery period. The approximate daily intakes were 0, 5, 25 or 100 mg/kg-day for males, and 0, 7, 35 or 120 mg/kg-day for females. Water consumption was reduced in a dose-dependent manner in the $\geq$250 ppm males and 1,000 ppm females, which was attributed to an aversion to the taste and/or odor of glutaraldehyde in the water. There was also a reduction in food consumption in the 1,000 ppm animals with a parallel reduction in body weights. It is unclear whether the reduction in food consumption was related to the decreased water consumption. Urine volume was decreased with an increase in specific gravity, along with a slight increase in protein and ketone concentration, in the $\geq$250 ppm animals, which was probably related to the decreased water consumption. There were no treatment-related changes in the hematology parameters measured. Blood urea nitrogen was increased in a dose-related manner in the $\geq$250 ppm females at the 6-week time point, but at the 13-week or 17-week time points. Relative kidney weights were increased in a dose-related manner in the $\geq$250 ppm males and females, and increased absolute kidney weights in the females. Histopathological examination showed no treatment-related effects. The NOAEL is 50 ppm (5 and 7 mg/kg-day for males and females, respectively) based on dose-related increase in kidney weights at $\geq$250 ppm (NICNAS 1994).

Male and female Fischer 344 rats were given in their drinking water 0, 50, 250 or 1000 ppm glutaraldehyde for 104 weeks. The mean glutaraldehyde consumption was 0, 4, 17 and 64 mg/kg-day for males and 0, 6, 25 and 86 mg/kg-day for females. There were no treatment-related mortalities or clinical symptoms of toxicity. In the 250 and 1,000 ppm groups, there was reduction in body weight and body weight gain; reduction in food and water consumption; increased statistically significant incidence of nucleated erythrocytes and of large monocytes; decreases in alanine aminotransferase (ALT), aspartate aminotransferase (AST), and glutamate dehydrogenase; dose-related decrease in urine volume accompanied by a dose-related increase in osmolality; changes in absolute and relative kidney weight; gastric irritation; increases in bone marrow hyperplasia; and increased incidence of renal tubular pigmentation. The decreased water consumption was considered to be due to the bad taste , smell and/or irritancy of the test substance in the drinking water; thus, it is of no toxicological relevance. As a result of reduced water intake, there are renal physiological adaptation ,such as decreased urine, increased osmolality and changes in kidney weight. The hematological and clinical chemistry parameter changes were marginal and were considered to be of not toxicological relevance. The main hematological finding seen at the end of the study and which consisted of the appearance of nucleated erythrocytes and large monocytes in all treated groups (statistically significant for the $\geq$250 ppm males) was related to the incidence of

large granular lymphocytic leukemia (LGLL) in the spleen. The bone marrow hyperplasia and renal tubular pigmentation are related to the occurrence/incidence of large granular lymphocytic leukemia (LGLL), and were considered by the authors of the study as being secondary to a low grade hemolytic anemia in animals with LGLL. The NOAEL for this study is 50 ppm which corresponds to 4 and 6 mg/kg-day for males and females, respectively (Van Miller *et al.* 2002).

Inhalation

Male and female F344 rats were exposed by inhalation to 0, 0.0625, 0.125, 0.25, 0.5 or 1.0 ppm glutaraldehyde for 6.5 hours/day, 5 days/week for 13 weeks. The study focused on the respiratory tract, using histopathology and epithelial cell labeling index as end points. Histopathological lesions in the nasal passages and turbinates were seen at $\geq$0.25 ppm. Treatment-related effects were primarily the respiratory mucosa (nasal cavity and tips of the turbinates) and the olfactory epithelium (dorsal meatus). Hyperplasia, squamous metaplasia, olfactory degeneration, squamous exfoliation (accumulation of keratin, cell debris and bacteria in the lumen of the nasal vestibule) and focal erosions were reported for both sexes, and the severity and incidence of the findings increased with increasing concentration of glutaraldehyde. The NOAEL for this study is 0.125 ppm (Gross *et al.* 1994).

Male and female B6C3F$_1$ mice were exposed by inhalation to 0, 0.0625, 0.125, 0.25, 0.5 or 1.0 ppm glutaraldehyde for 6.5 hours/day, 5 days/week for 13 weeks. The study focused on the respiratory tract, using histopathology and epithelial cell labeling index as end points. Histopathologic lesions in the nasal passages and turbinates were seen at all exposure concentrations ($\geq$0.0625 ppm). Treatment-related lesions were primarily the respiratory mucosa (nasal cavity and tips of the turbinates) and the olfactory epithelium (dorsal meatus). Hyperplasia, squamous metaplasia, olfactory degeneration, squamous exfoliation (accumulation of keratin, cell debris and bacteria in the lumen of the nasal vestibule) and focal erosions were reported for both sexes, and the severity and incidence of the findings increased with increasing test concentration. Furthermore, neutrophilic inflammation was seen at $\geq$0.062 ppm, and squamous metaplasia as well as necrosis were seen in the larynx at 1 ppm). The LOAEL for this study is 0.0625 ppm; a NOAEL was not established (Gross *et al.* 1994).

Male and female B6C3F$_1$ mice were exposed by inhalation to 0 or 0.1 ppm glutaraldehyde for 6 hours/day, 5 days/week for 52 and 78 weeks. Survival was similar between treated and control groups. Hyperplasia of the squamous epithelium lining of the dorsal wall of the nasal passages and the lateral aspect of the atrioturbinate was seen in a greater number of exposed females than in controls. Epidermal erosion and ulceration as well as squamous and inflammatory exfoliation were also seen in the nasal lumens. All of these changes were dependent on the length of glutaraldehyde exposure. The authors concluded that, since the induced lesions occurred at the more anterior part of the nasal passages, that they were likely the result of an irritation mechanism (Zissu *et al.* 1998).

Male and female Fischer 344 rats were exposed by inhalation to 0, 0.25, 0.5, or 0.75 ppm glutaraldehyde for 6 hours/day, 5 days/week for two years. Survival in the mid- and high-dose females was statistically significantly decreased compared to controls. Mean body weights of all exposed males and the mid- and high-dose females were generally less than those of the controls. Non-neoplastic lesions were limited primarily to the most anterior region of the nasal cavity. Effects included hyperplasia and inflammation of the squamous epithelium; hyperplasia, goblet cell hyperplasia, inflammation, and squamous metaplasia of the respiratory epithelium; and hyaline degeneration of the olfactory epithelium. The LOAEL for this study is 0.25 ppm based on hyperplasia and inflammation of the squamous epithelium of the nose in both sexes. A NOAEL was not established (van Birgelen *et al.* 2000).

Male and female $B6C3F_1$ mice were exposed by inhalation to 0, 0.0625, 0.125, or 0.25 ppm glutaraldehyde for 6 hours/day, 5 days/week for two years. Survival of the treated animals was similar to controls. Mean body weights of the high-dose females were generally lower than the controls. Non-neoplastic lesions were limited primarily to the anterior region of the nasal cavity; the effects were qualitatively similar to those seen in the rats (see accompanying summary on the two-year rat study by van Birgelen *et al.* 2000). Squamous metaplasia of the respiratory epithelium was observed in both sexes of mice while female mice also had inflammation and hyaline degeneration of the respiratory epithelium. The incidence and severity grade (in parentheses) of the hyaline degeneration were: 16/50 (1.4), 35/49 (1.4), 32/50 (1.3), and 30/50 (1.1) for the 0, 0.0625, 0.125, and 0.25 ppm dose groups, respectively. The LOAEL for this study is 0.0625 ppm based on hyaline degeneration of the respiratory epithelium in female mice. A NOAEL was not established (van Birgelen *et al.* 2000).

Genotoxicity

Glutaraldehyde has been shown to be mutagenic in some, but not all, *in vitro* bacterial mutation assays with or without metabolic activation. Glutaraldehyde has also been shown to produce mutations, sister chromatid exchanges and chromosomal aberrations in mammalian cells *in vitro*, with and without metabolic activation (NICNAS 1994).

Glutaraldehyde did not induce micronuclei in peripheral blood of mice given a single dose of a 50% w/w aqueous solution of glutaraldehyde up to 250 mg/kg (NICNAS 1994). Sprague-Dawley rats were given a single oral gavage dose of a 50% w/w aqueous solution of glutaraldehyde. The dose levels were 25, 60 and 120 mg/kg for males, and 15, 40 and 80 mg/kg for females. There were no increases in chromosomal aberrations in bone marrow cells in either sex at any dose level (NICNAS 1994). Glutaraldehyde was inactive in a sex-linked recessive lethal mutation assay of germ cells of *Drosophila melanogaster* (NICNAS 1994).

Carcinogenicity

Oral

Male and female Fischer 344 rats were given in their drinking water 0, 50, 250 or 1,000 ppm glutaraldehyde for 104 weeks. The mean glutaraldehyde consumption was 0, 4, 17 and 64 mg/kg-day for males and 0, 6, 25 and 86 mg/kg-day for females. Mortality rates were 25-30% and 19-23% for males and females, respectively, with no dose-related increase. The major cause of death in all dose groups including the controls was large granular cell lymphatic leukemia (LGLL). There was an increased incidence of LGLL in the liver and spleen in all treated females ($\geq$50 ppm). No other treatment-related increased incidence of tumors were seen (Van Miller *et al.* 2002).

Male and female Wistar rats were given in their drinking water 0, 100, 500 or 2,000 ppm glutaraldehyde for two years. The mean glutaraldehyde consumption was 0, 6.1, 31.9, and 120.7 mg/kg-day for males and 0, 10.5, 48.5 and 176.4 mg/kg-day for females. In the high-dose animals, there was mortality (2 males and 9 females) from asphyxia and mean terminal body weights were significantly decreased compared to the controls. There were no treatment-related neoplastic effects (ECHA).

Inhalation

Male and female B6C3F_1 mice were exposed by inhalation to 0 or 0.1 ppm glutaraldehyde for 6 hours/day, 5 days/week for 52 and 78 weeks. No exposure-related neoplastic lesions were observed in either males or females (Zissu *et al.* 1998).

Male and female Fischer 344 rats were exposed by inhalation to 0, 0.25, 0.5, or 0.75 ppm glutaraldehyde for 6 hours/day, 5 days/week for two years. Survival in the mid- and high-dose females was statistically significantly decreased compared to controls. Survival of the treated males was similar to controls. No exposure-related neoplastic lesions were observed in either males or females (van Birgelen *et al.* 2000).

Male and female B6C3F_1 mice were exposed by inhalation to 0, 0.0625, 0.125, or 0.25 ppm glutaraldehyde for 6 hours/day, 5 days/week for two years. Survival of the treated animals was similar to controls. No exposure-related neoplastic lesions were observed in either males or females (van Birgelen *et al.* 2000).

Reproductive Toxicity

A two-generation reproductive toxicity study was conducted in Wistar rats given 0, 100, 500 and 2000 ppm glutaraldehyde in their drinking water. The approximately mean daily intake is 0, 12, 58 and 199 mg/kg-day for the parental males and females of the F_0 and F_1 generation during premating. There were no adverse effects on reproductive performance or fertility. Estrous cycle data, mating behavior, conception, gestation, parturition, lactation and weaning as well as sperm parameters, sexual organ weights, gross and histopathological findings of these organs were similar between treated and control groups. In the high-dose animals, there was decreased water and/or food consumption;

and decreased body weights and/or reduced body weight gains during the premating periods in the F_0 and F_1 parental females during premating, gestation and/or lactation. The high-dose F_1 parental females also had increased number of erosions/ulcers with microscopic erosion(s) or inflammatory edema in the mucosa/submucosa of the glandular stomach. There were no adverse effects in the 500 ppm animals except for slight decreases in water consumption due to a palatability (bad taste) problem. Treatment-related signs of developmental toxicity were seen in the progeny of the high-dose F_0 and F_1 parental generation, and included impairment in body weight and consequently in organ weights in the respective F1 and F2 pups. The NOAEL for reproductive toxicity is 2,000 ppm, the highest dose tested. The NOAEL for parental system toxicity is 500 ppm. The NOAEL for developmental toxicity is 500 ppm (ECHA).

A two-generation reproductive toxicity study was conducted in Crj: CD(SD) rats given 0, 50, 250 and 1,000 ppm glutaraldhyde in their drinking water. Parental body weights and body weight gains were significantly reduced at 1,000 ppm at some periods, particularly during pre-mating. Food consumption was significantly reduced at 1,000 ppm for the F_0 and F_1 parental animals during pre-mating and gestation, and F_1 females during lactation. Water consumption was reduced throughout the pre-mating period for the F_0 and F_1 250 and 1,000 ppm parental animals. There was no indication of adverse effects on reproductive performance or fertility at any dose level. For the F_1 1,000 ppm offspring, body weights were reduced from lactation days 21-28. The NOAEL for reproductive toxicity is 1,000 ppm, the highest dose tested. The NOAEL for parental systemic toxicity is 50 ppm. The NOAEL for developmental toxicity is 250 ppm (Neeper-Bradley and Ballantyne 2000).

Developmental Toxicity

Pregnant Wistar rats were given in their drinking water 0, 50, 250 or 750 ppm (0, 5, 26 or 68 mg/kg) glutaraldehyde from GD 6 to 16. Water consumption was reduced in a dose-related manner in the $\geq$26 mg/kg dams, and was considered to be a toxic response but due to the palatability (bad taste) of the drinking test solution. No other maternal effects were seen in the study. There were no significant differences between treated and controls in the sex distribution, placental weights, fetal weights, malformations or variations. The NOELs for maternal and developmental toxicity are 5 and 68 mg/kg-day, respectively (NICNAS 1994).

Pregnant Himalayan rabbits were dosed by oral gavage with 0, 5, 15 or 45 mg/kg glutaraldehyde on GD 7 to 19. In the high-dose group, 5/15 died on GD 9-11. Food consumption and body weight gain were also significantly reduced in the high-dose group. Clinical observations in 12/15 high-dose does included soft feces, diarrhea, an blood in the bedding. At necropsy, gastrointestinal irritation was observed and uterus weight was significantly reduced. 9/10 of the remaining high-dose does did not produce live fetuses. There were reduced placental and fetal body weights in the only four fetuses. No significant maternal or developmental effects were seen in the mid- and low-dose

groups. The NOAELs for maternal and developmental toxicity are 15 mg/kg-day (NICNAS 1994).

Pregnant Charles River albino rats were dosed by oral gavage with a 25% glutaraldehyde solution on GD 6 to 15. The dose levels were 0, 25 or 50 mg/kg glutaraldehyde. One 25 mg/kg dam died during the study from injury. Body weight gain was significantly reduced in the 50 mg/kg dams. The number of corpora lutea, implantation sites, resorption sites and fetuses were similar between treated and control groups. There was no treatment-related effects on fetal body weights or skeletal or internal development of the fetuses. The NOAELs for maternal and developmental toxicity were 25 and 50 mg/kg-day, respectively (NICNAS 1994).

Key Study/Critical Effect for Screening Criteria

Oral

The NOAEL from the two-year drinking water study in rats (Van Miller *et al.* 2002) is 50 ppm, which corresponds to 4 and 6 mg/kg-day for males and females, respectively .

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability)

Oral RfD = 4/100 = 0.04 mg/kg-day

Drinking water guidance value = 0.14 ppm

Inhalation

The LOAEL from the two-year inhalation study in mice (van Birgelen *et al.* 2000) is 0.0625 ppm or 62.5 ppb. Exposures were for 6 hours/day, 5 days/week and the critical effect is hyaline degeneration of the respiratory epithelium in female mice. This effect is considered a result of direct irritation of nasal cavity from glutaraldehyde exposure.

For a worker exposed for an 8-hour work day, the LOAEL from the mouse study is converted to 46.9 ppb.

For the general public exposed continuously, the LOAEL from the mouse study is converted to 11.2 ppb.

Uncertainty factors: 1 (interspecies variability); 1 (intraspecies variability); 10 (LOAEL to NOAEL)

Worker [8-hour exposure] RfC = 46.9/10 = 4.7 ppb
General population [continuous exposure] = 11.2/10 = 1.1 ppb

References

ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances

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Toxicity Profile

Potassium chloride
(CAS No. 7447-40-7)

Potassium chloride (KCl) has been reviewed in the OECD-SIDS program (OECD, 2001).

Potassium chloride (KCl) is an inorganic salt that readily dissociates in aqueous media to K^+ and Cl^-.

Acute Toxicity

The oral LD_{50} in rats has been reported to be 3,020 mg/kg (Boyd and Shanas, 1961).

Irritation

Potassium chloride did not produce an irritant response in an *in vitro* skin irritation OECD 439 test or an *in vitro* eye irritation test (ECHA).

Repeated Dose Toxicity

Fourteen female rats were given KCl in their drinking water (approximately 5,250 mg/kg/day) for 105 days. Ten rats were sacrificed after 105 days of exposure for examination of the heart, kidneys and the adrenals; four rats (recovery group) were kept for an additional month. KCl exposure resulted in decreased heart weight, increased kidney weight, and enlargement of part of the adrenals. All changes were reversible within one month of exposure (Bacchus, 1951).

F344/Slc male rats were given 0, 110, 450 or 1,820 mg/kg/day KCl in feed for two years. At the end of the study, survival rates were 48%, 64%, 58% and 84% in the controls, 110, 45 and 1,820 mg/kg/day groups. Nephritis was reported to be predominant in all groups, including the controls. The only treatment-related effect observed was gastritis (inflammation of the stomach lining). The incidence of gastritis and ulcers were 6%, 18%, 18% and 30% in the controls, 110, 450 and 1,820 mg/kg/day groups (Imai *et al.*, 1968).

Male and female Wistar rats were fed diets containing 0 or 3% KCl over a total period of 30 months: Examination after 13 weeks (10 rats/sex/group), after 18 months (15 rats/sex/group) and after 30 months (50 rats/sex /group). Due to the reduction of feed intake the mean test substance intake and mean body weight decreased in time. After 30 months of treatment, there was hypertrophy of the zona glomerulosa in the adrenals (24/50 treated rats versus 4/50 in controls); and cystitis in the urinary bladder (males: 3/59; females 3/50) and single epithelial hyperplasia of the bladder (males 3/50; females

2/50) (Lina *et al.*, 1994; Lina and Kuijpers, 2004)**.**

Genotoxicity

Potassium chloride was not mutagenic to *Salmonella typhimurium* strains TA100, TA 1535, TA 1537 and TA 98 strains in an *in vitro* bacterial mutation assay in the presence or absence of metabolic activation (Mortelmans *et al.*, 1986). KCl was also not mutagenic to *E. coli* in a SOS chromotest (Olivier and Marzin, 1987).

In two different studies, KCl was found to be weakly mutagenic to mouse lymphoma L5178Y cells at high concentrations (Myhr and Caspary, 1988; Mitchell *et al.*, 1988).

Potassium chloride induced a significant increase in chromosomal aberrations in Chinese Hamster lung fibroblasts (V79) cells only at the highest test dose (12,000 µg/ml) in the absence of a metabolic activation system. Measurements of the osmotic pressure of the medium revealed a two-fold increase at this test compound concentration when compared to the normal medium (530 mOsmol/ kg versus 253 mOsmol/kg (Hasegawa *et al.*, 1984). There are two other reports on the effect of KCl on formation of chromosome aberrations in Chinese hamster ovary cells (CHO). In these studies KCl concentrations of 75 and 80 mM (approximately 5500 and 6000 µg/ml) resulted in 19% and 28% aberrant cells respectively. Increased number of chromosome aberrations was observed with KCl concentrations that reduced cell survival 40% and more. It is reasonable to conclude that the increases in mutagenicity and chromosome aberrations observed in these studies are related to cytotoxicity resulting from the high KCl concentrations used. This argument is supported by the studies on the effect of increased osmolarity on genotoxicity in cultured mammalian cells.

The reported mutagenic effect of KCl most probably results from a disruption of osmotic balance of cells with a subsequent interference with chromosomal stability. This may result in the clastogenic effects (DNA breakage and chromosome structural instability) due to K^{+} effects on sequestering of Mg^{++} ions required for normal maintenance of chromatin integrity. Other chemicals may also exert such effect (*e.g.*, NaCl, sucrose).

Carcinogenicity

F344/Slc male rats were given 0, 110, 450 or 1,820 mg/kg/day KCl in feed for two years. At the end of the study, survival rates were 48%, 64%, 58% and 84% in the controls, 110, 45 and 1,820 mg/kg/day groups. There was no increased incidence of tumors that were considered to be treatment-related (Imai *et al.*, 1968).

Reproductive/Developmental Toxicity

Pregnant female Wistar rats were given by oral gavage 3.1 to 310 mg/kg KCl during gestation days 5 through 15, and sacrificed on gestation day 20. There were no effects on

survival, total number of corpora lutea, implant sites, resorptions, soft tissue observations (urogenital tract), or live offspring. No treatment-related effects were seen in the offspring with regards to survival, sex ratio, average offspring weight, external congenital abnormalities, soft tissue or skeletal defects. The maternal and developmental NOAELs were 310 mg/kg/day (FDRL, 1975).

Female CD-1 mice were given by oral gavage 2.35 to 235 mg/kg KCL during gestation days 5 through 15, and sacrificed on gestation day 17. There were no effects on survival, total number of corpora lutea, implant sites, resorptions, soft tissue observations (urogenital tract), or live offspring. No treatment-related effects were seen in the offspring with regards to survival, sex ratio, average offspring weight, external congenital abnormalities, soft tissue or skeletal defects. The maternal and developmental NOAELs were 235 mg/kg/day (FDRL, 1975).

Key Study/Critical Effect for Screening Criteria

In a two-year rat feeding study, there was an increased incidence of gastritis and ulcers at dose levels of ≥110 mg/kg/day (Imai *et al.*, 1968). There was no NOAEL. Thus, the LOAEL for this study is 110 mg/kgday. Since the gastritis and ulcers are the result of a localized irritation effect of the test substance (site of contact) in the gastrointestinal tract, an uncertainty factor for interspecies variability is deemed unnecessary.

For systemic effects, the NOAEL for the two-year rat feeding study is considered to be 1,820 mg/kg/day, the highest dose tested.

Uncertainty factors: 10 (intraspecies variability); 10 (interspecies variability); 1 (intraspecies variability)

Oral Reference Dose = 1,820/100 = 18.2 mg/kg/day

Drinking water guideline: 64 ppm

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Toxicity Profile

Shellac, Ammonium salt
(CAS No. 68308-35-8)

Lac is the hardened resinous secretion of the insesct *Kerria lacca* (Douglas, 1971; CIR, 1986). The secreted lac or sticklac contains lac resin, erythrolaccin, wax, inset debris, wood materials, sand, dust and water-soluble impurities. The semirefined seedlac of commerce is the yellowish granular material obtained from the processing of sticklac (Douglas, 1971; Misra and Sengupta, 1970; CIR, 1986).

Unrefined shellac can contain shellac wax and erythrolaccin (the yellow material), which both comprise about 6% of Shellac (CIR, 1986). The removal of these constituents yields lac resin that has a soft (30%) and hard (70%) components (CIR, 1986). Mild alkaline hydrolysis of this resin results in a complex mixture of hydroxyaliphatic and alicyclic acids and their polyesters. The composition of the mixture varies with the lac source and the time of collection (CIR, 1986).

The major component of the aliphatic fraction is aleuritic acid. The alicyclic fraction consists of sesquiterpenic acids, primarily jalaric acid and its derivatives. The native form of the pure lac resin molecule has a molecular weight of 2,095, which contains four terpene acids (mostly jalaric acid) and four aleuritic acid units in repeating ester linkage (Singh *et al.*, 1974). The proposed structure for lac resin respresents an average situation since the molecule may not always be homogenous with respect to sequence or ratio of jalaric acid to other sesquiterpenic acid substitutes (Singh *et al.*, 1974). The sesquiterpenic acids in lac resin are jalaric acid, shellolic acid, epishellolic acid, laksholic acid, and epilaksholic acid.

Aqueous shellac solutions can be prepared by neutralization with ethanolamines, alkalies, or borax (CIR, 1986).

Acute Toxicity

The acute oral LD_{50} in rats is >5,000 mg/kg (CIR, 1986).

Irritation

No data were located.

Sensitization

No data were located.

Toxicity Profile

Tributyl Tetradecyl Phosphonium Chloride [TTPC]
(CAS No. 81741-28-8)

Acute Toxicity

An oral LD_{50} in rats was reported to be 1,002 mg/kg. The 4-hour LC_{50} to rats is <0.9 mg/L (aerosol) (MSDS for Bellecide 350).

Irritation

TTPC is corrosive to the skin and eyes (MSDS for Bellecide 350).

Sensitization

TTPC is not a skin sensitizer (MSDS for Bellecide 350).

Repeated Dose Toxicity

A 90-day rat drinking water study has been conducted on a product containing TTPC. The LOAEL for the active ingredient (TTPC) is 27.2 and 32.3 mg/kg-day in males and females, respectively, based on various clinical signs and significantly reduced body weights, feed and water consumption. The NOAEL for TTPC is 8.66 mg/kg-day (EPA 2006).

Genotoxicity

TTPC tested negative in an Ames test (MSDS for Bellecide 350).

Carcinogenicity

No data were found.

Reproductive Toxicity

No data were found.

Developmental Toxicity

Female Tif:RAIf(SPF) rats were dosed by oral gavage with 0, 20, 60, or 120 mg/kg Belclene® [50% active ingredient: TTPC] during gestational days (GD) 6 through 15. In the high-dose dams, there were two possible treatment-related spontaneous deaths (GD 9 and 14) and another death on GD 15 due to an intubation error. Clinical signs included dyspnea in one mid-dose and 4 high-dose animals, and vaginal bleeding in one mid-dose female on GD 15. In the high-dose dams, maternal body weight gain was significantly lower during the treatment period (GD 6-15) and throughout the gestational period (GD 0-20). Mean food consumption was significantly reduced during GD 6-11 for both the mid- and high-dose animals. The number of females with implantations and the number of implantations/females were similar across all groups. Embryonic and fetal deaths were similar between treated and control groups. There were no soft tissue changes. There was an increased incidence of incomplete ossification of the 5th sternebra in the mid- and high-dose groups. The NOAELs for maternal and developmental toxicity for the active ingredient TTPC in this study is 30 and 10 mg/kg-day (EPA 2006).

Female chinchilla rabbits were dosed by oral gavage with 0, 7.5, 22.5, or 45 mg/kg Belclene® [50% active ingredient: TTPC] during gestational days (GD) 6 through 18. In the mid- and high-dose groups, body weight gain was significantly reduced during GD 6-18 and feed consumption was reduced during GD 6-11. Fetal body weights were significantly reduced in the mid-(males only) and high-dose dose groups. There was also an increased incidence of delayed ossification of the hindlimb phalangeal nuclei in the mid- and high-dose groups. The NOAELs for maternal and developmental toxicity for the active ingredient TTPC in this study are 3.75 mg/kg-day (EPA 2006).

Key Study/Critical Effect for Screening Criteria

The NOAEL from the rat 90-day drinking water study with TTPC as the active ingredient is 8.66 mg/kg-day.

Oral

Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (subchronic to chronic)

Oral RfD = 8.66/1000 = 0.009 mg/kg-day

Drinking water guidance value = 0.03 ppm

Inhalation

For a worker exposed for an 8-hour work day, the ventilation rate for heavy (male) workers, *i.e.*, farm workers, is 13.5 m^3/8-hour work day; the average lifetime adult body

weight is 70 kg (Commonwealth of Australia 2012). It is also assumed that inhalation absorption is 100%.

Note that this equation is for a heavy worker exposed continuously:
$NOAEC_{worker\ cont.}$ [mg/m^3] = $NOAEL_{oral\ rat}$ x human body weight x (1/ventilation rate) x 8/24

$NOAEC_{worker\ cont.}$ = 8.66 x 70 x 1/13.5 x 8/24 = 15 mg/m^3 or 0.84 ppm

[molecular weight of TTPC: 435.13]

Inhalation RfC for a continuously exposed heavy worker = 0.84 ppm/1000 = 0.00084 ppm or 0.84 ppb

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Material Safety Data Sheet for Bellacide 350, BWA Water Additives, SDS No. 10794, Report Date: 10/03/2009.

Appendix 4

Santos
GLNG Project

Appendix 4 Comparison of Theoretical Scenario in Initial Flowback for Scotia System to Human Health Drinking Water Standards

Constituent Name	CAS No.	Scenario	Estimated concentration in tank (mg/L)	Fate and Transport Properties	Estimated Tank Concentration after application of Biodegradation (half life)			
					Temporal Scenario (days)			
				Half-Life (days)	0	30	150	300
Tributyl Tetradecyl Phosphonium Chloride	81741-28-8	1A - Maximum	24	NA	2.4E+01	2.4E+01	2.4E+01	2.4E+01
Glutaraldehyde	111-30-8	1B - Maximum	80	15	8.0E+01	2.0E+01	7.8E-02	7.6E-05
Tributyl Tetradecyl Phosphonium Chloride	81741-28-8	1A - Minimum	8	NA	8.0E+00	8.0E+00	8.0E+00	8.0E+00
Glutaraldehyde	111-30-8	1B - Minimum	28	15	2.8E+01	7.0E+00	2.7E-02	2.7E-05
Tributyl Tetradecyl Phosphonium Chloride	81741-28-8	2A - Maximum	12	NA	1.2E+01	1.2E+01	1.2E+01	1.2E+01
Glutaraldehyde	111-30-8	2B - Maximum	40	15	4.0E+01	1.0E+01	3.9E-02	3.8E-05
Tributyl Tetradecyl Phosphonium Chloride	81741-28-8	2A - Minimum	4	NA	4.0E+00	4.0E+00	4.0E+00	4.0E+00
Glutaraldehyde	111-30-8	2B - Minimum	14	15	1.4E+01	3.5E+00	1.4E-02	1.3E-05

Appendix 5

Environmental Assessment

Potassium chloride
(CAS No. 7447-40-7)

Potassium chloride (KCl) has been reviewed in the OECD-SIDS program (OECD, 2001a,b).

Environmental Fate

KCl is a solid inorganic salt that is highly soluble in water (342 g/L at 20° C). Potassium chloride fully dissociates in aqueous solutions to K^+ and Cl^- ions.

KCl, either as an inorganic salt or as K^+ and Cl^- ions, is ubiquitous in the environment. There is no potential for bioaccumulation or bioconcentration. Potassium and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated.

Aquatic Toxicity

In a guideline study, the 96-hour LC_{50} in *Pimephales promelas* was reported to be 880 mg/L (Mount *et al.*, 1997). The 48-hour LC_{50} values from two studies on *Lepomis macrochirus* (Patrick *et al.*, 1968; Trama, 1954), and one study each on *Oncorhyncus mykiss* and *Ictalurus punctatus* (Waller *et al.*, 1993) ranged from 720 to 2,010 mg/L.

In a guideline study, the 48-hour EC_{50}s in *Daphnia magna* and *Ceriodaphnia dubia* were 660 and 630 mg/L, respectively (Mount *et al.*, 1997; ECHA REACH database). The 48-hour EC_{50} in *Daphnia magna* in another study was also reported to be 177 mg/L (Biesinger and Christensen, 1972).

The toxicity of KCl has been investigated in one algae species (*Nitzschia linearis*), showing 120 hour-EC_{50} (growth rate) of 1,337 mg/L (Patrick *et al.*, 1968). The 72-hour EC_{50} to *Scenedesmus subspicatus* is >100 mg/L (growth rate), with a NOEC of $\geq$100 mg/L (ECHA REACH database).

In a fish early-life-stage test with the fathead minnow (*Pimephales promelas*), the 7-day NOEC is 500 mg/L (ECHA REACH database). A long term (21-day) study has been performed on *Daphnia magna* where effects on reproduction were investigated for several metals. A 16% impairment of reproduction (LOEC) was observed at a concentration of 53 mg/L of K +, equal to KCl concentration of 101 mg/L (Biesinger and Christensen, 1972).

Toxicity to Terrestrial Organisms

Potassium is one of the three major nutrients and chloride is an essential micronutrient for plants. No data could be located on the toxicity to terrestrial organisms.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (720 mg/L), Daphnia (177 mg/L), and algae (>100 mg/L). Although chronic studies has been conducted on fish and invertebrates, these tests are not valid for deriving PNECs (ECHA REACH database). On the basis of the short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 100 mg/L for algae. The $PNEC_{aquatic}$ is determined to be 0.1 mg/L.

$PNEC_{sediment}$: No reliable experimental toxicity data on sediment organisms are available. Potassium chloride dissociates completely in water with its environmental distribution is dominated by its high water solubility. Kow and Koc parameters do not readily apply to inorganics, such as potassium chloride. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{sediment}$. Based on the its properties, no adsorption of potassium chloride to sediment is to be expected, and the assessment of this compartment will be covered by the aquatic assessment.

$PNEC_{soil}$: No reliable experimental toxicity data on terrestrial organisms are available. The environmental distribution of potassium chloride is dominated by its water solubility. Sorption of potassium chloride should probably be regarded as a reversible situation, *i.e.*, the substance is not tightly nor permanently bound. Koc and Kow parameters do not readily apply to inorganics, such as potassium chloride. Thus, the equilibrium partitioning method cannot be used to calculate the $PNEC_{soil}$. Based on the its properties, potassium chloride is not expected to significantly adsorb to soil, and the assessment of this compartment will be covered by the aquatic assessment.

PBT Assessment

Potassium chloride is an organic salt that dissociates completely to potassium and chloride ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both potassium and chloride ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria is not considered applicable to this inorganic salt.

Potassium and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, potassium chloride is not expected to bioaccumulate.

No chronic toxicity data exist on potassium chloride; however, the acute $EC(L)_{50}$s are >0.1 mg/L in fish, invertebrates and algae. Thus, potassium chloride does not meet the screening criteria for toxicity.

The overall conclusion is that potassium chloride is not a PBT substance.

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Environmental Assessment

Shellac, Ammonium salt
(CAS No. 68308-35-8)

Lac is the hardened resinous secretion of the insesct *Kerria lacca* (Douglas, 1971; CIR, 1986). The secreted lac or sticklac contains lac resin, erythrolaccin, wax, inset debris, wood materials, sand, dust and water-soluble impurities. The semirefined seedlac of commerce is the yellowish granular material obtained from the processing of sticklac (Douglas, 1971; Misra and Sengupta, 1970; CIR, 1986).

Unrefined shellac can contain shellac wax and erythrolaccin (the yellow material), which both comprise about 6% of Shellac (CIR, 1986). The removal of these constituents yields lac resin that has a soft (30%) and hard (70%) components (CIR, 1986). Mild alkaline hydrolysis of this resin results in a complex mixture of hydroxyaliphatic and alicyclic acids and their polyesters. The composition of the mixture varies with the lac source and the time of collection (CIR, 1986).

The major component of the aliphatic fraction is aleuritic acid. The alicyclic fraction consists of sesquiterpenic acids, primarily jalaric acid and its derivatives. The native form of the pure lac resin molecule has a molecular weight of 2,095, which contains four terpene acids (mostly jalaric acid) and four aleuritic acid units in repeating ester linkage (Singh *et al.*, 1974). The proposed structure for lac resin respresents an average situation since the molecule may not always be homogenous with respect to sequence or ratio of jalaric acid to other sesquiterpenic acid substitutes (Singh *et al.*, 1974). The sesquiterpenic acids in lac resin are jalaric acid, shellolic acid, epishellolic acid, laksholic acid, and epilaksholic acid.

Aqueous shellac solutions can be prepared by neutralization with ethanolamines, alkalies, or borax (CIR, 1986).

Biodegradation

No data were found. As a natural resin, it is expected to be resistant to biodegradation.

Aquatic Toxicity

No data were found. Given that the molecular weight of the pure lac resin molecule is on average ~2,000 and that it is insoluble in water at environmentally relevant pHs, it is not expected to be bioavailable; this resin is thus expected to be non-toxic to aquatic organisms.

Environmental Assessment

Glutaraldehyde
(CAS No. 111-30-8)

Hydrolysis

In an OECD TG 111 test (hydrolysis as a function of pH), glutaraldehyde was found to be hydrolytically stable at pH 4 and pH 7, but decomposed at pH 9 (ECHA).

Phototransformation in Water

Glutaraldehyde was tested in photodegradation studies in water using EPA Guideline Subdivision N pesticide guideline161-2. Under sensitized conditions equivalent to 36 days of natural sunlight (12 hours/day; sensitized acetone system) and to 34 of natural sunlight (12 hours/day; sensitized acetonitrile system), glutaraldehyde was subjected to photolytic degradation with a half-life of 18 and 49 days, respectively. No photodegradation of glutaraldehyde occurred under darkness, and no photodegradation occurred under non-sensitized conditions (ECHA).

Biodegradation

Glutaraldehyde was considered readily biodegradable in a OECD 301A (DOC die away test). Degradation was 90-100% in 28 days (ECHA). The results of the ready biodegradation test on glutaraldehyde indicate that its half-life in water can be estimated to be 15 days (AEA 2009).

In an simulation test involving aerobic sewage treatment [activated sludge units] (OECD TG 303), glutaraldehyde degraded 97% after 73 days based on DOC removal (ECHA).

Glutaraldehyde was evaluated in an aerobic aquatic metabolism test using EPA Subdivision N pesticide guideline 162-3. The total ^{14}C residues from [^{14}C]-glutaraldehyde in pond water declined in a logarithmic fashion from about 103% (day 0) to about 9% over the complete test period of 30 days. Most of the radioactivity in the sediment was bound, with extractable ^{14}C residues being 3%. There was a major capture of radioactivity in the KOH solutions, especially for the first KOH solution, indicating$^{14}CO_2$ production; peaks in radioactivity were seen after 7 and 16 days. The total mass balance accountability decreased over the complete period, reaching about 48% of the initial dose on day 30. A half-life of 8.4 days was calculated for the decline of total radioactivity in pond water. The half-life of the degradation of [^{14}C]-glutaraldehyde was determined to be 0.5 days (ECHA).

Glutaraldehyde was evaluated in an anaerobic aquatic metabolism test using EPA Subdivision N pesticide guideline 162-3. The total ^{14}C residues from [^{14}C]-glutaraldehyde in pond water declined from about 92% to about 16% over the complete test period of 90 days. A thin layer chromatograph (TLC) of pond water samples showed that the parent compound had already disappeared on day 0. An increase in ^{14}C residues was observed in the sediment during the three first days (31%) of the test, which was followed by a decrease (13% on day 7). Most of the radioactivity in the sediment was bound, with extractable ^{14}C residues being 3%. A total of 7.12% of the initial ^{14}C dose was recovered in the trapping solutions, with 7.11% having been trapped in the first KOH trap, indicating $^{14}CO_2$ production. The ^{14}C residue half-life was reported to be 5.6 days (ECHA).

Glutaraldehyde was evaluated in an aerobic soil metabolism test using EPA Subdivision N pesticide guideline 162-1. The total ^{14}C residues from [^{14}C]-glutaraldehyde in soil decreased exponentially from day 0 to day 21, reaching 40% of the initial dose. The ^{14}C residues were constant at 40% from day 21 until the end of the experimental period on day 120. The extractable ^{14}C residues were 25% of the initial dose on day 0 and decreased to 2% by day 3 to 7; these residues remained <2% until the end of the study. The bound ^{14}C residues ranged from 76 to 121% of total ^{14}C residues throughout the study period. Thin layer chromatographs (TLC) showed that about 20% of the extracted radioactivity at day 0 was due to the parent compound glutaraldehyde. Up to day 3, no parent compound could be identified; but, on day 7 the TLC showed that about 20% of extracted radioactivity was due to the parent compound. The half-life of the degradation of [^{14}C]-glutaraldehyde was calculated to be 1.7 days (ECHA).

Bioaccumulation

Glutaraldehyde is not expected to bioaccumulate. The measured log Kow at pH 5, 7 and 9 are -0.41, -0.36 and -0.80, respectively (ECHA).

Aquatic Toxicity

The 96-hour LC_{50} values to bluegill sunfish and *Oncorhynchus mykiss* are 13 and 10 mg/L, respectively (ECHA). The 48-hour LC_{50} values to *Daphnia magna* from two different studies are 14.87 and 14 mg/L (ECHA).

The 72-hour EC_{50} values to algae *Scenedesmus subspicatus* are 0.375 mg/L [biomass] and 0.6 mg/L [growth rate]; the NOEC based on growth rate is 0.025 mg/L (ECHA). In another study, the 72-hour EC_{50} value to algae *Scenedesmus subspicatus* was reported to be 0.6 mg/L based on growth rate (ECHA).

A 97-day fish, early-life stage toxicity test has been conducted with *Oncorhynchus mykiss*. The LOEC and NOEC from this study are 5 and 1.6 mg/L, respectively (ECHA). The NOEC from a 21-day *Daphnia magna* reproduction study is 5 mg/L (ECHA).

Terrestrial Toxicity

In an acute toxicity study on earthworm *Eisenia fetida* (OECD TG 207), the 14-day LC_{50} value for glutaraldehyde is >500 mg/kg (ECHA).

Glutaraldehyde has been evaluated in a terrestrial plants test: seedling emergence and seedling growth test (OECD TG 208). The test material contained 48.9% glutaraldehyde. The 19-day EC_{50} value is >1,000 mg/kg soil dry weight for *Avena sativa* (oats) based on emergence rate, dry weight and shoot length. The 19-day EC_{50} for *Brassica napus* (rapeseed oil) is >1,000 mg/kg soil dry weight based on emergence rate and shoot length and 994 mg/kg soil dry weight based on dry weight. The 19-day EC_{50} for *Vicia sativa* (vetch) is >1,000 mg/kg soil dry weight based on emergence rate and shoot length and 901 mg/kg soil dry weight based on dry weight. The NOECs for *Avena sativa* (oats) were $\geq$1,000 mg/kg dry weight on all three parameters tested. The NOECs for *Brassica napus* (rapeseed oil) were $\geq$1,000, 500, and 250 mg/kg soil dry weight for emergence rate, dry matter, and shoot length, respectively. The NOECs for *Vicia sativa* (vetch) were $\geq$1,000, 125, and 125 mg/kg soil dry weight for emergence rate, dry matter, and shoot length, respectively (ECHA).

The 28-day EC_{50} value of glutaraldehyde to soil microorganisms in a nitrogen transformation test (OECD TG 216) was reported to be 360 mg/kg soil dry weight (ECHA).

The 28-day EC_{50} value of glutaraldehyde to soil microorganisms in a carbon transformation test (OECD TG 217) is >593 mg/kg soil dry weight (ECHA).

The 14-day LD_{50} value of glutaraldehyde to mallard ducks (*Anas platyrhynchos)* is 206 mg/kg (ECHA). The 5-day LC_{50} to (*Anas platyrhynchos)* was reported to be >2,500 ppm in feed; there was no mortality (ECHA).

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (10 mg/L), Daphnia (14 mg/L), and algae (0.375 mg/L). Results from chronic studies are also available for all three trophic levels, with the lowest NOEC being 0.025 mg/L for algae. On the basis that the data consists of short-term and long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported long-term NOEC of 0.025 mg/L for algae. The $PNEC_{aquatic}$ is 0.0025 mg/L.

PBT Assessment

Glutaraldehyde is readily biodegradable and thus does not meet the screening criteria for persistence.

The log Pow for glutaraldehyde at different pH values ranges from -0.36 to -0.80. Thus, glutaraldehyde does not meet the screening criteria for bioaccumulation.

Chronic NOECs for fish, daphnia and algae are available for glutaraldehyde and the NOEC values are >0.01 mg/L. Thus, glutaraldehyde does not meet the screening criteria for toxic.

The overall conclusion is that glutaraldehyde is not a PBT substance.

References

AEA (2009) Environmental Risk Assessment Guidance Manual for Industrial Chemicals. Prepared by Chris Lee-Steere, Australian Environment Agency Pty Ltd.

ECHA REACH database: http://echa.europa.eu/information-on-chemicals/registered-substances

Environmental Assessment

Tributyl Tetradecyl Phosphonium Chloride [TTPC]
(CAS No. 81741-28-8)

Limited information was located for this alkyl phosphonium salt.

Hydrolysis
TTPC is stable in water over a wide range of pH values (BuruEnergy).

Photolysis
TTPC is not susceptible to photolysis (BuruEnergy).

Biodegradation
TTPC was not readily biodegradable in an OECD 301 test (BuruEnergy).

In a die-away [simulation] test (using activated sludge) with radiolabelled TTPC for 168 hours at 0.31 mg/L, the first-order rate constant was 0.69/hour and the half-life was 6.6 hours. After 24 and 168 hours, degradation was >81% and >98%, respectively (BuruEnergy).

TTPC was evaluation in simulation tests over a 40-day period using double ^{14}C labeled TTPC. In activated sludge, there was >40% degradation after 30 days with 50 ppb TTPC and >30% degradation after 7 days with 5 ppb TTPC. In river water, there was >20% after 35 days with 5 ppb TTPC. In sea water, there was >30% degradation after 35 days with 5 ppb TTPC (BuruEnergy).

Adsorption/Desorption
The soil adsorption/desorption of TTPC was tested with three soils differing in sand/silt/clay content, by running an aqueous solution of radiolabelled TTPC through a column of soil. Soil adsorption ranged from 93-96% (BuruEnergy).

Bioaccumulation
The octanol-water coefficient (K_{ow}) was determined experimentally to be 2.45 from an OECD 107 test (BuruEnergy).

Aquatic Toxicity

Bellacide 350 MSDS: The 96-hour LC_{50}s in rainbow trout and Bluegill sunfish were reported to be 0.46 mg/L and 0.06 mg/L, respectively. The 48-hour EC_{50} in *Daphnia* was reported to be 0.025 mg/L.

U.S. EPA OPP Pesticide Ecotoxicity Database (wit study details): The 96-hour LC_{50}s in

rainbow trout are 0.49 and 0.2 mg/L. The 96-hour LC_{50}s in Bluegill sunfish and common carp (*Cyprinus carpio*) are 0.06 and 0.09 mg/L, respectively. The 48-hour EC_{50} in *Daphnia* is 0.025 mg/L.

Environmental Properties of Proposed Biocide BE-9 (Document from BuruEnergy)
The 96-hour LC_{50}s in rainbow trout and Bluegill sunfish were reported to be 0.46 mg/L and 0.06 mg/L, respectively. The 48-hour EC_{50} in *Daphnia* was reported to be 0.025 mg/L. The 72-hour EC_{50} in green algae *Selenastrum capricornutum* was reported to be 0.019 mg/L.

Toxicity to Sediment Organisms

No data were found.

Toxicity to Terrestrial Organisms

U.S. EPA OPP Pesticide Ecotoxicity Database: The 8-day dietary LC_{50} in Bobwhite Quail is 4,215 ppm, with a NOEL of 1,980 ppm. The 8-day dietary LC_{50} in Mallard Duck is 3,663 ppm, with a NOEL of 1,780 ppm. The 14-day oral gavage LD_{50} in Mallard Duck is 232 mg/kg, with a NOEL of 178 mg/kg.

Determination of PNECs

$PNEC_{aquatic}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (0.2 mg/L), Daphnia (0.025 mg/L), and algae (0.019 mg/L). While the lowest acute value is 0.019 mg/L, it has only been reported in summary document from BuruEnergy and needs to be substantiated. For the purposes of PNEC determination, the acute EC_{50} value for Daphnia will be used. It should be noted that the two values are very similar.

On the basis that the data consists of short-term results from three trophic levels, an assessment factor of 1,000 has been applied to the effect concentration of 0.025 mg/L for *Daphnia*. The $PNEC_{aquatic}$ is calculated to be 2.5×10^{-5} mg/L (0.025 μg/L).

PBT Assessment

TTPC is not readily biodegradable. In a simulation test using river water, there was >20% after 35 days. Thus, TTPC appears to meet the screening criteria for persistence.

The octanol-water coefficient (K_{ow}) for TTPC is 2.45. Thus, TTPC does not meet the screening criteria for bioaccumulation.

No chronic toxicity data are available for TTPC. The lowest acute $EC(L)_{50}$ of TTPC is 0.025 mg/L in invertebrates. Since this value is <0.1 mg/L, TTPC does meet the screening criteria for toxicity.

References

Environmental Properties of Proposed Biocide BE-9. BuruEnergy. Accessed at: http://www.buruenergy.com/wp-content/uploads/BE-Environmental-Properties-of-Proposed-Biocide-BE-91.pdf

Material Safety Data Sheet for Bellacide 350, BWA Water Additives, SDS No. 10794, Report Date: 10/03/2009.

U.S. EPA OPP Pesticide Ecotoxicity Database: National Information System of the Regional Integrated Pest Management (IPM) Centers, U.S. Department of Agriculture and National Institutes of Food and Agriculture (www.ipmcenters.org).

Appendix 6

Appendix 6 Comparison of Estimated Theoretical Scotia System Concentrations to Aquatic Life Water Guidelines

Constituent Name	CAS No.	Scenario	Estimated concentration in tank (mg/L)	Fate and Transport Properties	Estimated Tank Concentration after application of Biodegradation (half life)			
					Temporal Scenario (days)			
				Half-Life (days)	0	30	150	300
Tributyl Tetradecyl Phosphonium Chloride	81741-28-8	1A - Maximum	24	NA	2.4E+01	2.4E+01	2.4E+01	2.4E+01
Glutaraldehyde	111-30-8	1B - Maximum	80	15	8.0E+01	2.0E+01	7.8E-02	7.6E-05
Tributyl Tetradecyl Phosphonium Chloride	81741-28-8	1A - Minimum	8	NA	8.0E+00	8.0E+00	8.0E+00	8.0E+00
Glutaraldehyde	111-30-8	1B - Minimum	28	15	2.8E+01	7.0E+00	2.7E-02	2.7E-05
Tributyl Tetradecyl Phosphonium Chloride	81741-28-8	2A - Maximum	12	NA	1.2E+01	1.2E+01	1.2E+01	1.2E+01
Glutaraldehyde	111-30-8	2B - Maximum	40	15	4.0E+01	1.0E+01	3.9E-02	3.8E-05
Tributyl Tetradecyl Phosphonium Chloride	81741-28-8	2A - Minimum	4	NA	4.0E+00	4.0E+00	4.0E+00	4.0E+00
Glutaraldehyde	111-30-8	2B - Minimum	14	15	1.4E+01	3.5E+00	1.4E-02	1.3E-05

Santos

APPENDIX H.7 CHEMICAL FRACTURING TRACERS (CFTS) TRACER ADDITIVE PBT ASSESSMENT AND SCREENING EVALUATION

MEMO

To: Santos GLNG

From: Tom Biksey and Chris Bevan

CC: Nigel Goulding

Date: October 26, 2016

Re: **Chemical Fracturing Tracers (CFTs) Tracer Additive PBT Assessment and Screening Evaluation**

Introduction

Santos GLNG (Santos) is looking to use new water soluble tracer additives in their hydraulic fracturing process. The use of Chemical Fracturing Tracers (CFTs), is being proposed to evaluate produced water profiles and water movement within the gas reservoir. A unique CFT tracer is injected into each fracturing stage. Following the completion when the well is put on production, water samples are collected and analysed for the presence and concentration of the CFTs in each sample. The injection technique used in the field for all of the tracers is very similar. The injection of the tracers requires an electric pump, and the tracers can be injected at any suitable point on the low pressure treatment line, normally at the suction side of the high pressure fracturing pumps. Expected tracer concentration injected is expected to be 1.5 ppm. **Attachment 1** includes the Safety Data Sheets for the CFTs.

For the environmental hazard assessment, a PBT (persistence, bioaccumulative, toxic) assessment was conducted in accordance with the guidance developed by DEWHA (2009), as presented in the RA Compendium. The PBT assessment is conducted because of specific concerns for substances that can be shown to persist for long periods in the environment, to bioaccumulate in food chains, and can give rise to toxic effects after a longer time and over a greater spatial scale than chemicals without these properties. These effects may be difficult to detect at an early stage because of long-term exposures at normally low concentration levels and long life-cycles of species at the top of the food chain.

In addition, where applicable, the tracers will be assessed based on risk-based screening values for comparison to the sample analyses of the tracers. The risk-based screening values will be based on the availability of toxicological data; there is a paucity of experimental data on the 16 new chemicals, therefore, toxicological modeling will be used including EPI SUITE™ or similar QSAR modeling software (e.g., OECD); the SMILES notation will be obtained from TOXNET database. Where appropriate, surrogates may be used for human health and ecological toxicological endpoints.

PBT Assessment

The QSAR Modelling (EPISUITE) data for the PBT assessment are presented in **Tables 1** and **2**. The results of the PBT assessment for the chemical constituents in the CRT tracers are summarised in **Table 3**. There were no tracers that were considered at PBTs.

Comparison to Risk-Based Screening Criteria

The determination of risk-based screening criteria will be conducted according to the predicted no-effects concentration (PNEC) guidance in the Environmental Risk Assessment Guidance Manual for Industrial Chemicals prepared by the Australian Environmental Agency (AEA, 2009).

The PNECs are determined by dividing the lowest toxicity value from a laboratory test by the relevant assessment factor. Results of long-term tests (expressed as the 10 percent effective concentration [EC10] or no observable effects concentration [NOEC]) are preferred to those of short-term tests (50 percent effective concentration/lethal concentration [EC/LC50]) because the results give a more realistic picture of effects on the organisms during their entire life cycle.

It is preferable to use actual measured data in effects assessment and in estimation of PNECs. However, when limited or no data were available (e.g. data for only one test species) or when the measured data for a species were unacceptable, then estimation using QSARs was considered. With the exception of the $PNEC_{aquatic}$ value for nitrate (used for magnesium nitrate), the aquatic toxicity data sets for the chemicals were insufficient for using the species sensitivity distribution approach. In the case of nitrate, the ANZECC water quality guideline of 700 µg/L was used for the $PNEC_{aquatic}$; this value had been derived using the statistical distribution method.

Note that there was no human health toxicity information located on the fluorobenzoic acid compounds or on similar compounds. Therefore, no oral reference dose (RfD) or drinking water guidance values were derived.

Based on stimulation flow back monitoring conducted by Santos and the Quantitative Risk Assessment completed for the Schlumberger Fluid Systems (Appendix C of the RA Compendium), 20 percent of the total mass of constituents injected is assumed to be recovered in the flowback water. This mass is diluted within 150 percent of the injected volume (the minimum volume that must be flowed back) to establish an "estimated" concentration (i.e., concentration expected due to full dilution of the back flow water) within the flowback storage ponds. Assessment of the flowback to the CRT tracer PNEC concentrations was based on the concentration of the tracer 1.5 mg/l, divided by 1.5 factor (150 percent of injected fluid volume per coal seam) times 0.2 factor (20 percent mass returned). This results in an exposure point concentration (EPC) of 0.2 mg/l.

Comparing the EPC concentration to the calculated $PNECa_{quatic}$ values in **Table 4**, two tracers, 3-(Trifluoromethyl) benzoic acid and 4-(Trifluoromethyl) benzoic acid, had $PNEC_{aquatic}$ values less than the estimated EPC of 0.2 mg/l used for all the tracer EPCs. The order of magnitude of this exceedance is less than one, indicating that the estimated potential risk to exposed aquatic receptors is within the acceptable range based on the overall conservatism in the $PNEC_{aquatic}$ value derivation.

References

Australian Agency Party Ltd. (2009). Environmental Risk Assessment Guidance Manual for Industrial Chemicals, Commonwealth of Australia.

DEWHA. 2009. Environmental risk assessment guidance manual for industrial chemicals, Department of the Environment, Water, Heritage and the Arts, Commonwealth of Australia.

National Environmental Protection (Assessment of Site Contamination) Measure 1999. (National Environment Protection Council); and Monitoring and Sampling Manual 2009, Environmental Protection (Water) Policy 2009, DERM, Version 1, September 2009.

Santos GLNG Projects. 2016. Santos GLNG. Upstream Hydraulic Fracturing Risk Assessment Compendium of Assessed Fluid Systems

TABLES

Appendix I.7

Table 1

Predicted Log Kow and Biodegradation of Fluorobenzoic Acid Compounds Using QSAR Modelling (EPISUITE)

Substance (CAS No.)	Log Kow	Biowin 2	Biowin 3	Biowin 6
2-(Trifluoromethyl)benzoic acid (433-97-6)	2.49	Does not biodegrade fast	Weeks-months	Does not biodegrade fast
2-Fluorobenzoic acid (445-29-4)	1.24	Biodegrades fast	Weeks	Biodegrades fast
2,3-Difluorobenzoic acid (4519-39-5)	1.93	Does not biodegrade fast	Months	Does not biodegrade fast
2,3,4-Trifluorobenzoic acid (61079-72-9)	2.13	Does not biodegrade fast	Recalcitrant	Does not biodegrade fast
2,3,4,5-Tetrafluorobenzoic acid (1201-31-6)	2.33	Does not biodegrade fast	Recalcitrant	Does not biodegrade fast
2,4-Difluorobenzoic acid (1583-58-0)	1.93	Does not biodegrade fast	Months	Does not biodegrade fast
2,4,5-Trifluorobenzoic acid (446-17-3)	2.13	Does not biodegrade fast	Recalcitrant	Does not biodegrade fast
2,5-Difluorobenzoic acid (2991-28-8)	1.93	Does not biodegrade fast	Months	Does not biodegrade fast
2,6-Difluorobenzoic acid (385-00-2)	1.18	Does not biodegrade fast	Months	Does not biodegrade fast
3-(Trifluoromethyl)benzoic acid (454-92-2)	2.84	Does not biodegrade fast	Weeks-months	Does not biodegrade fast
3-Fluorobenzoic acid (455-38-9)	2.07	Does not biodegrade fast	Weeks-months	Does not biodegrade fast
3,4-Difluorobenzoic acid (455-86-7)	2.28	Does not biodegrade fast	Months	Does not biodegrade fast
3,4,5-Trifluorobenzoic acid (121602-93-5)	2.48	Does not biodegrade fast	Recalcitrant	Does not biodegrade fast
3,5-Difluorobenzoic acid (455-40-3)	2.28	Does not biodegrade fast	Months	Does not biodegrade fast
4-(Trifluoromethyl)benzoic acid (455-24-3)	2.84	Does not biodegrade fast	Weeks-months	Does not biodegrade fast
4-Fluorobenzoic acid (456-22-4)	2.07	Does not biodegrade fast	Weeks-months	Does not biodegrade fast

Appendix I.7

Table 2

Predicted Acute Aquatic Toxicity of Fluorobenzoic Acid Compounds Using QSAR Modelling (EPISUITE)

Substance (CAS No.)	Acute Fish (Predicted mg/L)	Acute Daphnia (Predicted mg/L)	Acute Algae (Predicted mg/L)
2-(Trifluoromethyl)benzoic acid (433-97-6)	561	334	300
2-Fluorobenzoic acid (445-29-4)	553	293	163
2,3-Difluorobenzoic acid (4519-39-5)	1493	842	612
2,3,4-Trifluorobenzoic acid (61079-72-9)	1099	631	495
2,3,4,5-Tetrafluorobenzoic acid (1201-31-6)	800	468	390
2,4-Difluorobenzoic acid (1583-58-0)	1493	842	612
2,4,5-Trifluorobenzoic acid (446-17-3)	1099	631	495
2,5-Difluorobenzoic acid (2991-28-8)	1493	842	612
2,6-Difluorobenzoic acid (385-00-2)	7150	3762	2045
3-(Trifluoromethyl)benzoic acid (454-92-2)	276	170	174
3-Fluorobenzoic acid (455-38-9)	986	564	432
3,4-Difluorobenzoic acid (455-86-7)	735	428	354
3,4,5-Trifluorobenzoic acid (121602-93-5)	541	321	287
3,5-Difluorobenzoic acid (455-40-3)	735	428	354
4-(Trifluoromethyl)benzoic acid (455-24-3)	276	170	174
4-Fluorobenzoic acid (456-22-4)	986	524	432

Appendix I.7

Table 3

Persistence, Bioaccumulation and Toxicity (PBT) Assessment of Fluorobenzoic Acid Compounds

Substance (CAS No.)	P/vP criteria fulfilled?	B/vB criteria fulfilled?	T criteria fulfilled?	Overall Conclusion
2-(Trifluoromethyl)benzoic acid (433-97-6)	No (predicted using QSAR modelling)	No (predicted screening value using QSAR modelling)	No (predicted screening values using QSAR modelling)	Not PBT (based on QSAR modelling)
2-Fluorobenzoic acid (445-29-4)	No (predicted using QSAR modelling)	No (predicted screening value using QSAR modelling)	No (predicted screening values using QSAR modelling)	Not PBT (based on QSAR modelling)
2,3-Difluorobenzoic acid (4519-39-5)	Yes (predicted susing QSAR modelling)	No (predicted screening value using QSAR modelling)	No (predicted screening values using QSAR modelling)	Not PBT (based on QSAR modelling)
2,3,4-Trifluorobenzoic acid (61079-72-9)	Yes (predicted using QSAR modelling)	No (predicted screening value using QSAR modelling)	No (predicted screening values using QSAR modelling)	Not PBT (based on QSAR modelling)
2,3,4,5-Tetrafluorobenzoic acid (1201-31-6)	Yes (predicted using QSAR modelling)	No (predicted screening value using QSAR modelling)	No (predicted screening values using QSAR modelling)	Not PBT (based on QSAR modelling)
2,4-Difluorobenzoic acid (1583-58-0)	Yes (predicted using QSAR modelling)	No (predicted screening value using QSAR modelling)	No (predicted screening values using QSAR modelling)	Not PBT (based on QSAR modelling)
2,4,5-Trifluorobenzoic acid (446-17-3)	Yes (predicted using QSAR modelling)	No (predicted screening value using QSAR modelling)	No (predicted screening values using QSAR modelling)	Not PBT (based on QSAR modelling)
2,5-Difluorobenzoic acid (2991-28-8)	Yes (predicted using QSAR modelling)	No (predicted screening value using QSAR modelling)	No (predicted screening values using QSAR modelling)	Not PBT (based on QSAR modelling)
2,6-Difluorobenzoic acid (385-00-2)	Yes (predicted using QSAR modelling)	No (predicted screening value using QSAR modelling)	No (predicted screening values using QSAR modelling)	Not PBT (based on QSAR modelling)
3-(Trifluoromethyl)benzoic acid (454-92-2)	No (predicted using QSAR modelling)	No (predicted screening value using QSAR modelling)	No (predicted screening values using QSAR modelling)	Not PBT (based on QSAR modelling)
3-Fluorobenzoic acid (455-38-9)	No (predicted using QSAR modelling)	No (predicted screening value using QSAR modelling)	No (predicted screening values using QSAR modelling)	Not PBT (based on QSAR modelling)
3,4-Difluorobenzoic acid (455-86-7)	Yes (predicted using QSAR modelling)	No (predicted screening value using QSAR modelling)	No (predicted screening values using QSAR modelling)	Not PBT (based on QSAR modelling)
3,4,5-Trifluorobenzoic acid (121602-93-5)	Yes (predicted using QSAR modelling)	No (predicted screening value using QSAR modelling)	No (predicted screening values using QSAR modelling)	Not PBT (based on QSAR modelling)
3,5-Difluorobenzoic acid (455-40-3)	Yes (predicted using QSAR modelling)	No (predicted screening value using QSAR modelling)	No (predicted screening values using QSAR modelling)	Not PBT (based on QSAR modelling)
4-(Trifluoromethyl)benzoic acid (455-24-3)	No (predicted using QSAR modelling)	No (predicted screening value using QSAR modelling)	No (predicted screening values using QSAR modelling)	Not PBT (based on QSAR modelling)
4-Fluorobenzoic acid (456-22-4)	No (predicted using QSAR modelling)	No (predicted screening value using QSAR modelling)	No (predicted screening values using QSAR modelling)	Not PBT (based on QSAR modelling)

Appendix I.7
Table 4
Aquatic Toxicity Values (PNECs) of Fluorobenzoic Acid Compounds

Substance (CAS No.)	Endpoint	E(L)C50 (mg/L)	Assessment Factor	PNECaquatic (mg/L)
2-(Trifluoromethyl)benzoic acid (433-97-6)	Acute algae	300	1,000	0.3
2-Fluorobenzoic acid (445-29-4)	Acute algae	163	1,000	0.163
2,3-Difluorobenzoic acid (4519-39-5)	Acute algae	612	1,000	0.612
2,3,4-Trifluorobenzoic acid (61079-72-9)	Acute algae	495	1,000	0.495
2,3,4,5-Tetrafluorobenzoic acid (1201-31-6)	Acute algae	390	1,000	0.39
2,4-Difluorobenzoic acid (1583-58-0)	Acute algae	612	1,000	0.612
2,4,5-Trifluorobenzoic acid (446-17-3)	Acute algae	495	1,000	0.495
2,5-Difluorobenzoic acid (2991-28-8)	Acute algae	612	1,000	0.612
2,6-Difluorobenzoic acid (385-00-2)	Acute algae	2045	1,000	2.045
3-(Trifluoromethyl)benzoic acid (454-92-2)	Acute Daphnia	170	1,000	0.17
3-Fluorobenzoic acid (455-38-9)	Acute algae	432	1,000	0.432
3,4-Difluorobenzoic acid (455-86-7)	Acute algae	354	1,000	0.354
3,4,5-Trifluorobenzoic acid (121602-93-5)	Acute algae	287	1,000	0.287
3,5-Difluorobenzoic acid (455-40-3)	Acute algae	354	1,000	0.354
4-(Trifluoromethyl)benzoic acid (455-24-3)	Acute Daphnia	170	1,000	0.17
4-Fluorobenzoic acid (456-22-4)	Acute algae	432	1,000	0.432

ATTACHMENT 1 - SAFETY DATA SHEETS

SAFETY DATA SHEET

Date-Issued: 05-2015
SDS Ref. No: CFT
Date-Revised: 5/26/2016
Revision No:002

1. PRODUCT AND COMPANY IDENTIFICATION

1.1 Product Identifiers

Product name	:	2,3-Difluorobenzoic acid
Generic name	:	23-DFBA

1.2 Relevant identified used of the substance or mixture and uses advised against

Identified uses	:	Diagnostic
Uses advised against	:	Not available

1.3 Details of the supplier of the safety data sheet

Importer	:	ProTechnics International Division of Core Laboratories 31-35 George St. Thebarton, SA, AUSTRALIA 5031
Telephone	:	(08) 8152 0244

1.4 Emergency telephone number

Poisons Information Centre	:	13 11 26 (24 hour)
Ambulance, Fire, Police	:	000

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

GHS classification in accordance with 29 CFR 1910 (OSHA HCS)
Skin irritation (Category 2), H315
Eye irritation (Category 2), H319
Specific target organ toxicity – single exposure (Category 3), Respiratory system, H335

2.2 GHS Label elements, including precautionary statements

Pictogram



Signal word Warning

Hazard statement(s)

H315	Causes skin irritation.
H319	Causes serious eye irritation.
H335	May cause respiratory irritation.

Precautionary statement(s)

P261	Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray.
P264	Wash skin thoroughly after handling.
P280	Wear protective gloves.
P302 + P352	IF ON SKIN: Wash with plenty of soap and water.
P304 + P340	IF INHALED: Remove affected person into fresh air and keep at rest in a position comfortable for breathing.
P332 + P313	If skin irritation occurs: Get medical advice/ attention.

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

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3. COMPOSITION / INFORMATION ON INGREDIENTS

3.1 Substances

Substance/ mixture Mixture

Ingredient	CAS/Exempt No	Percent	Hazardous
2,3-Difluorobenzoic acid	4519-39-5	10	No
Water	7732-18-5	90	No

---

4. FIRST AID MEASURES

4.1 Description of first aid measures

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance. Move out of dangerous area.

If inhaled
Move person into fresh air. If cough or other symptoms develop, consult a physician.

In case of skin contact
Remove contaminated clothing including shoes and immediately wash affected area with plenty of soap and water. If irritation continues, consult a physician. Wash contaminated clothing and shoes before reuse.

In case of eye contact
Immediately flush eyes with plenty of water for two to three minutes. Remove any contact lenses and continue flushing for 15 minutes. If irritation continues, consult a physician.

If swallowed
Wash out mouth with water and keep at rest. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed

The most important known symptoms and effects are described in the labeling (see Section 2.2) and/or in Section 11.

4.3 Indication of any immediate medical attention and special treatment needed

No data available.

5. FIRE FIGHTING MEASURES

5.1 Extinguishing media

Suitable extinguishing media
Use fire-extinguishing media appropriate for surrounding materials.

5.2 Special hazards arising from the substance or mixture

Carbon oxides, halogenated hydrogen gas.

5.3 Advice for firefighters

As in any fire, wear full protective clothing and equipment.

5.4 Further information

No data available.

6. ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures

Use personal protective equipment. Avoid breathing vapours or mist. Evacuate personnel to safe areas.

6.2 Environmental precautions

Do not let product enter drains, if safe to do so.

6.3 Methods and materials for containment and cleanup

Construct temporary dikes of dirt or any appropriate readily available material to prevent spreading of the material. Cover with appropriate absorbent and sweep or shovel into an appropriate container.

6.4 Reference to other sections

For protective clothing, see Section 8. For disposal, see Section 13.

7. HANDLING AND STORAGE

7.1 Precautions for safe handling

Avoid contact with skin and eyes. Avoid formation of aerosols. Provide adequate exhaust ventilation at places where aerosols are formed. For precautions, see Section 2.2. Handle and use in a manner consistent with good industrial/manufacturing techniques and practices.

7.2 Conditions for safe storage

Keep container tightly closed in a dry, cool, and well-ventilated place. Do not store with, or close to, strong acids.

7.3 Specific end uses(s)

Apart from the uses mentioned in Section 1.2, no other specific uses are stipulated.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

8.1 Control parameters

Components with workplace control parameters
No PELs, TLVs, or OELs for this product or its ingredients are listed in the current issue of ACGIH's Guide to Occupational Exposure Values, nor have they been determined by the manufacturer.

8.2 Exposure controls

Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of the workday.

Personal protective equipment

Eye/face protection
Safety glasses with side-shields conforming to EN166. Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN166 (EU).

Skin protection
Handle with chemical-resistant gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Body protection
Impervious clothing. The type of protective equipment must be selected according to the amount of dangerous substance at the specific workplace.

Control of environmental exposure
Do not let product enter drains.

---

9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: aqueous liquid Color: translucent
b)	Odor Boiling	Odorless
c)	point Freeze	Approximately 100°C
d)	point	0°C
e)	Density	1.05 g/mL
f)	Flash point	Not flammable
g)	pH	Approximately 9
h)	Evaporation factor	Not determined
i)	Solubility	Soluble in water
j)	Vapor pressure	Not determined
k)	Oxidizing properties	Not determined
l)	Vapor density	Not determined
m)	Viscosity	Not determined

9.2 Other safety information

No data available.

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10. STABILITY AND REACTIVITY

10.1 Reactivity

Strong acids. Oxidizing materials.

10.2 Chemical stability

The product is stable under normal ambient conditions of temperature and pressure.

10.3 Possibility of hazardous reactions

Will not polymerize.

10.4 Conditions to avoid

Extreme cold.

10.5 Incompatible materials

Strong acids. Oxidizing materials.

10.6 Hazardous decomposition products

None.

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11. . TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects

Acute toxicity – oral
Based on available data the classification criteria are not met.

Acute toxicity – dermal
Based on available data the classification criteria are not met.

Acute toxicity – inhalation
Based on available data the classification criteria are not met.

Skin corrosion/irritation
Skin irritant 2 – H315 Causes skin irritation.

Serious eye damage/irritation
Eye irritant 2 – H319 May cause severe eye irritation.

Respiratory sensitization
Based on available data the classification criteria are not met.

Skin sensitization
Based on available data the classification criteria are not met.

Germ cell mutagenicity

Genotoxicity – in vitro
Based on available data the classification criteria are not met.

Genotoxicity- in vivo
Based on available data the classification criteria are not met.

Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible, or confirmed human carcinogen by IARC.

ACGIH: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP

OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity

Reproductive toxicity – fertility
Based on available data the classification criteria are not met.

Reproductive toxicity – development
Based on available data the classification criteria are not met.

Specific target organ toxicity – single exposure
STOT SE 3 – H335 May cause respiratory irritation.

Specific target organ toxicity – repeated exposure
Based on available data the classification criteria are not met.

Aspiration hazard
Not anticipated to present an aspiration hazard, based on chemical structure.

Additional information
RTECS: Not available.

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

12. ECOLOGICAL INFORMATION

12.1 Toxicity

No data available.

12.2 Persistence and degradability

Presumed to be persistent.

12.3 Bioaccumulative potential

No data available.

12.4 Mobility in soil

No data available.

12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment are not available as chemical safety assessment not required/ not conducted.

12.6 Other adverse effects

No data available.

13. DISPOSAL CONSIDERATIONS

13.1 Waste treatment methods

Product
Dispose of at a supervised appropriate waste disposal facility according to current applicable laws and regulations and product characteristics at time of disposal.

Contaminated packaging
Contaminated containers should be cleaned and disposed of in the same manner as the product in accordance with applicable regulations.

14. TRANSPORT INFORMATION

DOT (US)
Not dangerous goods.

IMDG
Not dangerous goods.

IATA
Not dangerous goods.

15. REGULATORY INFORMATION

SARA 302 Components
SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

SARA 311/312 Hazards
SAR 311/312: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 311/312.

CERCLA (Comprehensive Response, Compensation, and Liability Act)
Not Applicable.

TSCA (Toxic Substance Control Act)
The components of this product are in compliance with the chemical notification requirements of TSCA.

16. OTHER INFORMATION

HMIS Rating

Health Hazard:	1
Chronic Health Hazard:	
Flammability:	0
Physical Hazard:	0

NFPA Rating

Health Hazard:	1
Fire Hazard:	0
Reactivity Hazard:	0

MANUFACTURER DISCLAIMER: Information given herein is offered in good faith as accurate, but without guarantee. Conditions of use and suitability of the product for particular uses are beyond our control; all risks of use of the product are therefore assumed by the user. Nothing is intended as a recommendation for uses which infringe valid patents or as extending license under valid patents. Appropriate warnings and safe handling procedures should be provided to handlers and users.

Prepared by: ProTechnics Environmental Compliance Department

Contact information: 713-328-2320

SAFETY DATA SHEET

Date-Issued: 05-2015
SDS Ref. No: CFT
Date-Revised: 5/26/2016
Revision No:002

1. PRODUCT AND COMPANY IDENTIFICATION

1.1 Product Identifiers

Product name	:	3,4,5-Trifluorobenzoic acid
Generic name	:	345-TFBA

1.2 Relevant identified used of the substance or mixture and uses advised against

Identified uses	:	Diagnostic
Uses advised against	:	Not available

1.3 Details of the supplier of the safety data sheet

Importer	:	ProTechnics International Division of Core Laboratories 31-35 George St. Thebarton, SA, AUSTRALIA 5031
Telephone	:	(08) 8152 0244

1.4 Emergency telephone number

Poisons Information Centre	:	13 11 26 (24 hour)
Ambulance, Fire, Police	:	000

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

GHS classification in accordance with 29 CFR 1910 (OSHA HCS)
Skin irritation (Category 2), H315
Eye irritation (Category 2), H319
Specific target organ toxicity – single exposure (Category 3), Respiratory system, H335

2.2 GHS Label elements, including precautionary statements

Pictogram



Signal word Warning

Hazard statement(s)

H315	Causes skin irritation.
H319	Causes serious eye irritation.
H335	May cause respiratory irritation.

Precautionary statement(s)

P261	Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray.
P264	Wash skin thoroughly after handling.
P280	Wear protective gloves.
P302 + P352	IF ON SKIN: Wash with plenty of soap and water.
P304 + P340	IF INHALED: Remove affected person into fresh air and keep at rest in a position comfortable for breathing.
P332 + P313	If skin irritation occurs: Get medical advice/ attention.

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

---

3. COMPOSITION / INFORMATION ON INGREDIENTS

3.1 Substances

Substance/ mixture Mixture

Ingredient	CAS/Exempt No	Percent	Hazardous
3,4,5-Trifluorobenzoic acid	121602-93-5	10	No
Water	7732-18-5	90	No

---

4. FIRST AID MEASURES

4.1 Description of first aid measures

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance. Move out of dangerous area.

If inhaled
Move person into fresh air. If cough or other symptoms develop, consult a physician.

In case of skin contact
Remove contaminated clothing including shoes and immediately wash affected area with plenty of soap and water. If irritation continues, consult a physician. Wash contaminated clothing and shoes before reuse.

In case of eye contact
Immediately flush eyes with plenty of water for two to three minutes. Remove any contact lenses and continue flushing for 15 minutes. If irritation continues, consult a physician.

If swallowed
Wash out mouth with water and keep at rest. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed

The most important known symptoms and effects are described in the labeling (see Section 2.2) and/or in Section 11.

4.3 Indication of any immediate medical attention and special treatment needed

No data available.

5. FIRE FIGHTING MEASURES

5.1 Extinguishing media

Suitable extinguishing media
Use fire-extinguishing media appropriate for surrounding materials.

5.2 Special hazards arising from the substance or mixture

Carbon oxides, halogenated hydrogen gas.

5.3 Advice for firefighters

As in any fire, wear full protective clothing and equipment.

5.4 Further information

No data available.

6. ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures

Use personal protective equipment. Avoid breathing vapours or mist. Evacuate personnel to safe areas.

6.2 Environmental precautions

Do not let product enter drains, if safe to do so.

6.3 Methods and materials for containment and cleanup

Construct temporary dikes of dirt or any appropriate readily available material to prevent spreading of the material. Cover with appropriate absorbent and sweep or shovel into an appropriate container.

6.4 Reference to other sections

For protective clothing, see Section 8. For disposal, see Section 13.

7. HANDLING AND STORAGE

7.1 Precautions for safe handling

Avoid contact with skin and eyes. Avoid formation of aerosols. Provide adequate exhaust ventilation at places where aerosols are formed. For precautions, see Section 2.2. Handle and use in a manner consistent with good industrial/manufacturing techniques and practices.

7.2 Conditions for safe storage

Keep container tightly closed in a dry, cool, and well-ventilated place. Do not store with, or close to, strong acids.

7.3 Specific end uses(s)

Apart from the uses mentioned in Section 1.2, no other specific uses are stipulated.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

8.1 Control parameters

Components with workplace control parameters
No PELs, TLVs, or OELs for this product or its ingredients are listed in the current issue of ACGIH's Guide to Occupational Exposure Values, nor have they been determined by the manufacturer.

8.2 Exposure controls

Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of the workday.

Personal protective equipment

Eye/face protection
Safety glasses with side-shields conforming to EN166. Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN166 (EU).

Skin protection
Handle with chemical-resistant gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Body protection
Impervious clothing. The type of protective equipment must be selected according to the amount of dangerous substance at the specific workplace.

Control of environmental exposure
Do not let product enter drains.

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9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: aqueous liquid Color: translucent
b)	Odor Boiling	Odorless
c)	point Freeze	Approximately 100°C
d)	point	0°C
e)	Density	1.05 g/mL
f)	Flash point	Not flammable
g)	pH	Approximately 9
h)	Evaporation factor	Not determined
i)	Solubility	Soluble in water
j)	Vapor pressure	Not determined
k)	Oxidizing properties	Not determined
l)	Vapor density	Not determined
m)	Viscosity	Not determined

9.2 Other safety information

No data available.

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10. STABILITY AND REACTIVITY

10.1 Reactivity

Strong acids. Oxidizing materials.

10.2 Chemical stability

The product is stable under normal ambient conditions of temperature and pressure.

10.3 Possibility of hazardous reactions

Will not polymerize.

10.4 Conditions to avoid

Extreme cold.

10.5 Incompatible materials

Strong acids. Oxidizing materials.

10.6 Hazardous decomposition products

None.

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11. . TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects

Acute toxicity – oral
Based on available data the classification criteria are not met.

Acute toxicity – dermal
Based on available data the classification criteria are not met.

Acute toxicity – inhalation
Based on available data the classification criteria are not met.

Skin corrosion/irritation
Skin irritant 2 – H315 Causes skin irritation.

Serious eye damage/irritation
Eye irritant 2 – H319 May cause severe eye irritation.

Respiratory sensitization
Based on available data the classification criteria are not met.

Skin sensitization
Based on available data the classification criteria are not met.

Germ cell mutagenicity

Genotoxicity – in vitro
Based on available data the classification criteria are not met.

Genotoxicity- in vivo
Based on available data the classification criteria are not met.

Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible, or confirmed human carcinogen by IARC.

ACGIH: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP

OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity

Reproductive toxicity – fertility
Based on available data the classification criteria are not met.

Reproductive toxicity – development
Based on available data the classification criteria are not met.

Specific target organ toxicity – single exposure
STOT SE 3 – H335 May cause respiratory irritation.

Specific target organ toxicity – repeated exposure
Based on available data the classification criteria are not met.

Aspiration hazard
Not anticipated to present an aspiration hazard, based on chemical structure.

Additional information
RTECS: Not available.

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

12. ECOLOGICAL INFORMATION

12.1 Toxicity

No data available.

12.2 Persistence and degradability

Presumed to be persistent.

12.3 Bioaccumulative potential

No data available.

12.4 Mobility in soil

No data available.

12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment are not available as chemical safety assessment not required/ not conducted.

12.6 Other adverse effects

No data available.

13. DISPOSAL CONSIDERATIONS

13.1 Waste treatment methods

Product
Dispose of at a supervised appropriate waste disposal facility according to current applicable laws and regulations and product characteristics at time of disposal.

Contaminated packaging
Contaminated containers should be cleaned and disposed of in the same manner as the product in accordance with applicable regulations.

14. TRANSPORT INFORMATION

DOT (US)
Not dangerous goods.

IMDG
Not dangerous goods.

IATA
Not dangerous goods.

15. REGULATORY INFORMATION

SARA 302 Components
SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

SARA 311/312 Hazards
SAR 311/312: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 311/312.

CERCLA (Comprehensive Response, Compensation, and Liability Act)
Not Applicable.

TSCA (Toxic Substance Control Act)
The components of this product are in compliance with the chemical notification requirements of TSCA.

16. OTHER INFORMATION

HMIS Rating

Health Hazard:	1
Chronic Health Hazard:	
Flammability:	0
Physical Hazard:	0

NFPA Rating

Health Hazard:	1
Fire Hazard:	0
Reactivity Hazard:	0

MANUFACTURER DISCLAIMER: Information given herein is offered in good faith as accurate, but without guarantee. Conditions of use and suitability of the product for particular uses are beyond our control; all risks of use of the product are therefore assumed by the user. Nothing is intended as a recommendation for uses which infringe valid patents or as extending license under valid patents. Appropriate warnings and safe handling procedures should be provided to handlers and users.

Prepared by: ProTechnics Environmental Compliance Department

Contact information: 713-328-2320

SAFETY DATA SHEET

Date-Issued: 05-2015
SDS Ref. No: CFT
Date-Revised: 5/26/2016
Revision No:002

1. PRODUCT AND COMPANY IDENTIFICATION

1.1 Product Identifiers

Product name	:	2,3,4,5-Tetrafluorobenzoic acid
Generic name	:	2345-TTFBA

1.2 Relevant identified used of the substance or mixture and uses advised against

Identified uses	:	Diagnostic
Uses advised against	:	Not available

1.3 Details of the supplier of the safety data sheet

Importer	:	ProTechnics International Division of Core Laboratories 31-35 George St. Thebarton, SA, AUSTRALIA 5031
Telephone	:	(08) 8152 0244

1.4 Emergency telephone number

Poisons Information Centre	:	13 11 26 (24 hour)
Ambulance, Fire, Police	:	000

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

GHS classification in accordance with 29 CFR 1910 (OSHA HCS)
Skin irritation (Category 2), H315
Eye irritation (Category 2), H319
Specific target organ toxicity – single exposure (Category 3), Respiratory system, H335

2.2 GHS Label elements, including precautionary statements

Pictogram



Signal word Warning

Hazard statement(s)

H315	Causes skin irritation.
H319	Causes serious eye irritation.
H335	May cause respiratory irritation.

Precautionary statement(s)

P261	Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray.
P264	Wash skin thoroughly after handling.
P280	Wear protective gloves.
P302 + P352	IF ON SKIN: Wash with plenty of soap and water.
P304 + P340	IF INHALED: Remove affected person into fresh air and keep at rest in a position comfortable for breathing.
P332 + P313	If skin irritation occurs: Get medical advice/ attention.

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

---

3. COMPOSITION / INFORMATION ON INGREDIENTS

3.1 Substances

Substance/ mixture Mixture

Ingredient	CAS/Exempt No	Percent	Hazardous
2,3,4,5-Tetrafluorobenzoic acid	1201-31-6	10	No
Water	7732-18-5	90	No

---

4. FIRST AID MEASURES

4.1 Description of first aid measures

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance. Move out of dangerous area.

If inhaled
Move person into fresh air. If cough or other symptoms develop, consult a physician.

In case of skin contact
Remove contaminated clothing including shoes and immediately wash affected area with plenty of soap and water. If irritation continues, consult a physician. Wash contaminated clothing and shoes before reuse.

In case of eye contact
Immediately flush eyes with plenty of water for two to three minutes. Remove any contact lenses and continue flushing for 15 minutes. If irritation continues, consult a physician.

If swallowed
Wash out mouth with water and keep at rest. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed

The most important known symptoms and effects are described in the labeling (see Section 2.2) and/or in Section 11.

4.3 Indication of any immediate medical attention and special treatment needed

No data available.

5. FIRE FIGHTING MEASURES

5.1 Extinguishing media

Suitable extinguishing media
Use fire-extinguishing media appropriate for surrounding materials.

5.2 Special hazards arising from the substance or mixture

Carbon oxides, halogenated hydrogen gas.

5.3 Advice for firefighters

As in any fire, wear full protective clothing and equipment.

5.4 Further information

No data available.

6. ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures

Use personal protective equipment. Avoid breathing vapours or mist. Evacuate personnel to safe areas.

6.2 Environmental precautions

Do not let product enter drains, if safe to do so.

6.3 Methods and materials for containment and cleanup

Construct temporary dikes of dirt or any appropriate readily available material to prevent spreading of the material. Cover with appropriate absorbent and sweep or shovel into an appropriate container.

6.4 Reference to other sections

For protective clothing, see Section 8. For disposal, see Section 13.

7. HANDLING AND STORAGE

7.1 Precautions for safe handling

Avoid contact with skin and eyes. Avoid formation of aerosols. Provide adequate exhaust ventilation at places where aerosols are formed. For precautions, see Section 2.2. Handle and use in a manner consistent with good industrial/manufacturing techniques and practices.

7.2 Conditions for safe storage

Keep container tightly closed in a dry, cool, and well-ventilated place. Do not store with, or close to, strong acids.

7.3 Specific end uses(s)

Apart from the uses mentioned in Section 1.2, no other specific uses are stipulated.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

8.1 Control parameters

Components with workplace control parameters
No PELs, TLVs, or OELs for this product or its ingredients are listed in the current issue of ACGIH's Guide to Occupational Exposure Values, nor have they been determined by the manufacturer.

8.2 Exposure controls

Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of the workday.

Personal protective equipment

Eye/face protection
Safety glasses with side-shields conforming to EN166. Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN166 (EU).

Skin protection
Handle with chemical-resistant gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Body protection
Impervious clothing. The type of protective equipment must be selected according to the amount of dangerous substance at the specific workplace.

Control of environmental exposure
Do not let product enter drains.

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9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: aqueous liquid Color: translucent
b)	Odor Boiling	Odorless
c)	point Freeze	Approximately 100°C
d)	point	0°C
e)	Density	1.05 g/mL
f)	Flash point	Not flammable
g)	pH	Approximately 9
h)	Evaporation factor	Not determined
i)	Solubility	Soluble in water
j)	Vapor pressure	Not determined
k)	Oxidizing properties	Not determined
l)	Vapor density	Not determined
m)	Viscosity	Not determined

9.2 Other safety information

No data available.

---

10. STABILITY AND REACTIVITY

10.1 Reactivity

Strong acids. Oxidizing materials.

10.2 Chemical stability

The product is stable under normal ambient conditions of temperature and pressure.

10.3 Possibility of hazardous reactions

Will not polymerize.

10.4 Conditions to avoid

Extreme cold.

10.5 Incompatible materials

Strong acids. Oxidizing materials.

10.6 Hazardous decomposition products

None.

---

11. . TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects

Acute toxicity – oral
Based on available data the classification criteria are not met.

Acute toxicity – dermal
Based on available data the classification criteria are not met.

Acute toxicity – inhalation
Based on available data the classification criteria are not met.

Skin corrosion/irritation
Skin irritant 2 – H315 Causes skin irritation.

Serious eye damage/irritation
Eye irritant 2 – H319 May cause severe eye irritation.

Respiratory sensitization
Based on available data the classification criteria are not met.

Skin sensitization
Based on available data the classification criteria are not met.

Germ cell mutagenicity

Genotoxicity – in vitro
Based on available data the classification criteria are not met.

Genotoxicity- in vivo
Based on available data the classification criteria are not met.

Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible, or confirmed human carcinogen by IARC.

ACGIH: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP

OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity

Reproductive toxicity – fertility
Based on available data the classification criteria are not met.

Reproductive toxicity – development
Based on available data the classification criteria are not met.

Specific target organ toxicity – single exposure
STOT SE 3 – H335 May cause respiratory irritation.

Specific target organ toxicity – repeated exposure
Based on available data the classification criteria are not met.

Aspiration hazard
Not anticipated to present an aspiration hazard, based on chemical structure.

Additional information
RTECS: Not available.

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

12. ECOLOGICAL INFORMATION

12.1 Toxicity

No data available.

12.2 Persistence and degradability

Presumed to be persistent.

12.3 Bioaccumulative potential

No data available.

12.4 Mobility in soil

No data available.

12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment are not available as chemical safety assessment not required/ not conducted.

12.6 Other adverse effects

No data available.

13. DISPOSAL CONSIDERATIONS

13.1 Waste treatment methods

Product
Dispose of at a supervised appropriate waste disposal facility according to current applicable laws and regulations and product characteristics at time of disposal.

Contaminated packaging
Contaminated containers should be cleaned and disposed of in the same manner as the product in accordance with applicable regulations.

14. TRANSPORT INFORMATION

DOT (US)
Not dangerous goods.

IMDG
Not dangerous goods.

IATA
Not dangerous goods.

15. REGULATORY INFORMATION

SARA 302 Components
SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

SARA 311/312 Hazards
SAR 311/312: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 311/312.

CERCLA (Comprehensive Response, Compensation, and Liability Act)
Not Applicable.

TSCA (Toxic Substance Control Act)
The components of this product are in compliance with the chemical notification requirements of TSCA.

16. OTHER INFORMATION

HMIS Rating

Health Hazard:	1
Chronic Health Hazard:	
Flammability:	0
Physical Hazard:	0

NFPA Rating

Health Hazard:	1
Fire Hazard:	0
Reactivity Hazard:	0

MANUFACTURER DISCLAIMER: Information given herein is offered in good faith as accurate, but without guarantee. Conditions of use and suitability of the product for particular uses are beyond our control; all risks of use of the product are therefore assumed by the user. Nothing is intended as a recommendation for uses which infringe valid patents or as extending license under valid patents. Appropriate warnings and safe handling procedures should be provided to handlers and users.

Prepared by: ProTechnics Environmental Compliance Department

Contact information: 713-328-2320

SAFETY DATA SHEET

Date-Issued: 05-2015
SDS Ref. No: CFT
Date-Revised: 5/26/2016
Revision No:002

1. PRODUCT AND COMPANY IDENTIFICATION

1.1 Product Identifiers

Product name	:	2,4,5-Trifluorobenzoic acid
Generic name	:	245-TFBA

1.2 Relevant identified used of the substance or mixture and uses advised against

Identified uses	:	Diagnostic
Uses advised against	:	Not available

1.3 Details of the supplier of the safety data sheet

Importer	:	ProTechnics International Division of Core Laboratories 31-35 George St. Thebarton, SA, AUSTRALIA 5031
Telephone	:	(08) 8152 0244

1.4 Emergency telephone number

Poisons Information Centre	:	13 11 26 (24 hour)
Ambulance, Fire, Police	:	000

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

GHS classification in accordance with 29 CFR 1910 (OSHA HCS)
Skin irritation (Category 2), H315
Eye irritation (Category 2), H319
Specific target organ toxicity – single exposure (Category 3), Respiratory system, H335

2.2 GHS Label elements, including precautionary statements

Pictogram



Signal word Warning

Hazard statement(s)

H315	Causes skin irritation.
H319	Causes serious eye irritation.
H335	May cause respiratory irritation.

Precautionary statement(s)

P261	Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray.
P264	Wash skin thoroughly after handling.
P280	Wear protective gloves.
P302 + P352	IF ON SKIN: Wash with plenty of soap and water.
P304 + P340	IF INHALED: Remove affected person into fresh air and keep at rest in a position comfortable for breathing.
P332 + P313	If skin irritation occurs: Get medical advice/ attention.

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

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3. COMPOSITION / INFORMATION ON INGREDIENTS

3.1 Substances

Substance/ mixture Mixture

Ingredient	CAS/Exempt No	Percent	Hazardous
2,4,5-Trifluorobenzoic acid	446-17-3	10	No
Water	7732-18-5	90	No

---

4. FIRST AID MEASURES

4.1 Description of first aid measures

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance. Move out of dangerous area.

If inhaled
Move person into fresh air. If cough or other symptoms develop, consult a physician.

In case of skin contact
Remove contaminated clothing including shoes and immediately wash affected area with plenty of soap and water. If irritation continues, consult a physician. Wash contaminated clothing and shoes before reuse.

In case of eye contact
Immediately flush eyes with plenty of water for two to three minutes. Remove any contact lenses and continue flushing for 15 minutes. If irritation continues, consult a physician.

If swallowed
Wash out mouth with water and keep at rest. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed

The most important known symptoms and effects are described in the labeling (see Section 2.2) and/or in Section 11.

4.3 Indication of any immediate medical attention and special treatment needed

No data available.

5. FIRE FIGHTING MEASURES

5.1 Extinguishing media

Suitable extinguishing media
Use fire-extinguishing media appropriate for surrounding materials.

5.2 Special hazards arising from the substance or mixture

Carbon oxides, halogenated hydrogen gas.

5.3 Advice for firefighters

As in any fire, wear full protective clothing and equipment.

5.4 Further information

No data available.

6. ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures

Use personal protective equipment. Avoid breathing vapours or mist. Evacuate personnel to safe areas.

6.2 Environmental precautions

Do not let product enter drains, if safe to do so.

6.3 Methods and materials for containment and cleanup

Construct temporary dikes of dirt or any appropriate readily available material to prevent spreading of the material. Cover with appropriate absorbent and sweep or shovel into an appropriate container.

6.4 Reference to other sections

For protective clothing, see Section 8. For disposal, see Section 13.

7. HANDLING AND STORAGE

7.1 Precautions for safe handling

Avoid contact with skin and eyes. Avoid formation of aerosols. Provide adequate exhaust ventilation at places where aerosols are formed. For precautions, see Section 2.2. Handle and use in a manner consistent with good industrial/manufacturing techniques and practices.

7.2 Conditions for safe storage

Keep container tightly closed in a dry, cool, and well-ventilated place. Do not store with, or close to, strong acids.

7.3 Specific end uses(s)

Apart from the uses mentioned in Section 1.2, no other specific uses are stipulated.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

8.1 Control parameters

Components with workplace control parameters
No PELs, TLVs, or OELs for this product or its ingredients are listed in the current issue of ACGIH's Guide to Occupational Exposure Values, nor have they been determined by the manufacturer.

8.2 Exposure controls

Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of the workday.

Personal protective equipment

Eye/face protection
Safety glasses with side-shields conforming to EN166. Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN166 (EU).

Skin protection
Handle with chemical-resistant gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Body protection
Impervious clothing. The type of protective equipment must be selected according to the amount of dangerous substance at the specific workplace.

Control of environmental exposure
Do not let product enter drains.

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9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: aqueous liquid Color: translucent
b)	Odor Boiling	Odorless
c)	point Freeze	Approximately 100°C
d)	point	0°C
e)	Density	1.05 g/mL
f)	Flash point	Not flammable
g)	pH	Approximately 9
h)	Evaporation factor	Not determined
i)	Solubility	Soluble in water
j)	Vapor pressure	Not determined
k)	Oxidizing properties	Not determined
l)	Vapor density	Not determined
m)	Viscosity	Not determined

9.2 Other safety information

No data available.

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10. STABILITY AND REACTIVITY

10.1 Reactivity

Strong acids. Oxidizing materials.

10.2 Chemical stability

The product is stable under normal ambient conditions of temperature and pressure.

10.3 Possibility of hazardous reactions

Will not polymerize.

10.4 Conditions to avoid

Extreme cold.

10.5 Incompatible materials

Strong acids. Oxidizing materials.

10.6 Hazardous decomposition products

None.

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11. . TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects

Acute toxicity – oral
Based on available data the classification criteria are not met.

Acute toxicity – dermal
Based on available data the classification criteria are not met.

Acute toxicity – inhalation
Based on available data the classification criteria are not met.

Skin corrosion/irritation
Skin irritant 2 – H315 Causes skin irritation.

Serious eye damage/irritation
Eye irritant 2 – H319 May cause severe eye irritation.

Respiratory sensitization
Based on available data the classification criteria are not met.

Skin sensitization
Based on available data the classification criteria are not met.

Germ cell mutagenicity

Genotoxicity – in vitro
Based on available data the classification criteria are not met.

Genotoxicity- in vivo
Based on available data the classification criteria are not met.

Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible, or confirmed human carcinogen by IARC.

ACGIH: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP

OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity

Reproductive toxicity – fertility
Based on available data the classification criteria are not met.

Reproductive toxicity – development
Based on available data the classification criteria are not met.

Specific target organ toxicity – single exposure
STOT SE 3 – H335 May cause respiratory irritation.

Specific target organ toxicity – repeated exposure
Based on available data the classification criteria are not met.

Aspiration hazard
Not anticipated to present an aspiration hazard, based on chemical structure.

Additional information
RTECS: Not available.

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

12. ECOLOGICAL INFORMATION

12.1 Toxicity

No data available.

12.2 Persistence and degradability

Presumed to be persistent.

12.3 Bioaccumulative potential

No data available.

12.4 Mobility in soil

No data available.

12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment are not available as chemical safety assessment not required/ not conducted.

12.6 Other adverse effects

No data available.

13. DISPOSAL CONSIDERATIONS

13.1 Waste treatment methods

Product
Dispose of at a supervised appropriate waste disposal facility according to current applicable laws and regulations and product characteristics at time of disposal.

Contaminated packaging
Contaminated containers should be cleaned and disposed of in the same manner as the product in accordance with applicable regulations.

14. TRANSPORT INFORMATION

DOT (US)
Not dangerous goods.

IMDG
Not dangerous goods.

IATA
Not dangerous goods.

15. REGULATORY INFORMATION

SARA 302 Components
SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

SARA 311/312 Hazards
SAR 311/312: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 311/312.

CERCLA (Comprehensive Response, Compensation, and Liability Act)
Not Applicable.

TSCA (Toxic Substance Control Act)
The components of this product are in compliance with the chemical notification requirements of TSCA.

16. OTHER INFORMATION

HMIS Rating

Health Hazard:	1
Chronic Health Hazard:	
Flammability:	0
Physical Hazard:	0

NFPA Rating

Health Hazard:	1
Fire Hazard:	0
Reactivity Hazard:	0

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Prepared by: ProTechnics Environmental Compliance Department

Contact information: 713-328-2320

SAFETY DATA SHEET

Date-Issued: 05-2015
SDS Ref. No: CFT
Date-Revised: 5/26/2016
Revision No:002

1. PRODUCT AND COMPANY IDENTIFICATION

1.1 Product Identifiers

Product name	:	2,3,4-Trifluorobenzoic acid
Generic name	:	234-TFBA

1.2 Relevant identified used of the substance or mixture and uses advised against

Identified uses	:	Diagnostic
Uses advised against	:	Not available

1.3 Details of the supplier of the safety data sheet

Importer	:	ProTechnics International Division of Core Laboratories 31-35 George St. Thebarton, SA, AUSTRALIA 5031
Telephone	:	(08) 8152 0244

1.4 Emergency telephone number

Poisons Information Centre	:	13 11 26 (24 hour)
Ambulance, Fire, Police	:	000

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

GHS classification in accordance with 29 CFR 1910 (OSHA HCS)
Skin irritation (Category 2), H315
Eye irritation (Category 2), H319
Specific target organ toxicity – single exposure (Category 3), Respiratory system, H335

2.2 GHS Label elements, including precautionary statements

Pictogram



Signal word Warning

Hazard statement(s)

H315	Causes skin irritation.
H319	Causes serious eye irritation.
H335	May cause respiratory irritation.

Precautionary statement(s)

P261	Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray.
P264	Wash skin thoroughly after handling.
P280	Wear protective gloves.
P302 + P352	IF ON SKIN: Wash with plenty of soap and water.
P304 + P340	IF INHALED: Remove affected person into fresh air and keep at rest in a position comfortable for breathing.
P332 + P313	If skin irritation occurs: Get medical advice/ attention.

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

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3. COMPOSITION / INFORMATION ON INGREDIENTS

3.1 Substances

Substance/ mixture Mixture

Ingredient	CAS/Exempt No	Percent	Hazardous
2,3,4-Trifluorobenzoic acid	61079-72-9	10	No
Water	7732-18-5	90	No

---

4. FIRST AID MEASURES

4.1 Description of first aid measures

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance. Move out of dangerous area.

If inhaled
Move person into fresh air. If cough or other symptoms develop, consult a physician.

In case of skin contact
Remove contaminated clothing including shoes and immediately wash affected area with plenty of soap and water. If irritation continues, consult a physician. Wash contaminated clothing and shoes before reuse.

In case of eye contact
Immediately flush eyes with plenty of water for two to three minutes. Remove any contact lenses and continue flushing for 15 minutes. If irritation continues, consult a physician.

If swallowed
Wash out mouth with water and keep at rest. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed

The most important known symptoms and effects are described in the labeling (see Section 2.2) and/or in Section 11.

4.3 Indication of any immediate medical attention and special treatment needed

No data available.

5. FIRE FIGHTING MEASURES

5.1 Extinguishing media

Suitable extinguishing media
Use fire-extinguishing media appropriate for surrounding materials.

5.2 Special hazards arising from the substance or mixture

Carbon oxides, halogenated hydrogen gas.

5.3 Advice for firefighters

As in any fire, wear full protective clothing and equipment.

5.4 Further information

No data available.

6. ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures

Use personal protective equipment. Avoid breathing vapours or mist. Evacuate personnel to safe areas.

6.2 Environmental precautions

Do not let product enter drains, if safe to do so.

6.3 Methods and materials for containment and cleanup

Construct temporary dikes of dirt or any appropriate readily available material to prevent spreading of the material. Cover with appropriate absorbent and sweep or shovel into an appropriate container.

6.4 Reference to other sections

For protective clothing, see Section 8. For disposal, see Section 13.

7. HANDLING AND STORAGE

7.1 Precautions for safe handling

Avoid contact with skin and eyes. Avoid formation of aerosols. Provide adequate exhaust ventilation at places where aerosols are formed. For precautions, see Section 2.2. Handle and use in a manner consistent with good industrial/manufacturing techniques and practices.

7.2 Conditions for safe storage

Keep container tightly closed in a dry, cool, and well-ventilated place. Do not store with, or close to, strong acids.

7.3 Specific end uses(s)

Apart from the uses mentioned in Section 1.2, no other specific uses are stipulated.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

8.1 Control parameters

Components with workplace control parameters
No PELs, TLVs, or OELs for this product or its ingredients are listed in the current issue of ACGIH's Guide to Occupational Exposure Values, nor have they been determined by the manufacturer.

8.2 Exposure controls

Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of the workday.

Personal protective equipment

Eye/face protection
Safety glasses with side-shields conforming to EN166. Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN166 (EU).

Skin protection
Handle with chemical-resistant gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Body protection
Impervious clothing. The type of protective equipment must be selected according to the amount of dangerous substance at the specific workplace.

Control of environmental exposure
Do not let product enter drains.

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9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: aqueous liquid Color: translucent
b)	Odor Boiling	Odorless
c)	point Freeze	Approximately 100°C
d)	point	0°C
e)	Density	1.05 g/mL
f)	Flash point	Not flammable
g)	pH	Approximately 9
h)	Evaporation factor	Not determined
i)	Solubility	Soluble in water
j)	Vapor pressure	Not determined
k)	Oxidizing properties	Not determined
l)	Vapor density	Not determined
m)	Viscosity	Not determined

9.2 Other safety information

No data available.

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10. STABILITY AND REACTIVITY

10.1 Reactivity

Strong acids. Oxidizing materials.

10.2 Chemical stability

The product is stable under normal ambient conditions of temperature and pressure.

10.3 Possibility of hazardous reactions

Will not polymerize.

10.4 Conditions to avoid

Extreme cold.

10.5 Incompatible materials

Strong acids. Oxidizing materials.

10.6 Hazardous decomposition products

None.

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11. . TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects

Acute toxicity – oral
Based on available data the classification criteria are not met.

Acute toxicity – dermal
Based on available data the classification criteria are not met.

Acute toxicity – inhalation
Based on available data the classification criteria are not met.

Skin corrosion/irritation
Skin irritant 2 – H315 Causes skin irritation.

Serious eye damage/irritation
Eye irritant 2 – H319 May cause severe eye irritation.

Respiratory sensitization
Based on available data the classification criteria are not met.

Skin sensitization
Based on available data the classification criteria are not met.

Germ cell mutagenicity

Genotoxicity – in vitro
Based on available data the classification criteria are not met.

Genotoxicity- in vivo
Based on available data the classification criteria are not met.

Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible, or confirmed human carcinogen by IARC.

ACGIH: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP

OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity

Reproductive toxicity – fertility
Based on available data the classification criteria are not met.

Reproductive toxicity – development
Based on available data the classification criteria are not met.

Specific target organ toxicity – single exposure
STOT SE 3 – H335 May cause respiratory irritation.

Specific target organ toxicity – repeated exposure
Based on available data the classification criteria are not met.

Aspiration hazard
Not anticipated to present an aspiration hazard, based on chemical structure.

Additional information
RTECS: Not available.

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

12. ECOLOGICAL INFORMATION

12.1 Toxicity

No data available.

12.2 Persistence and degradability

Presumed to be persistent.

12.3 Bioaccumulative potential

No data available.

12.4 Mobility in soil

No data available.

12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment are not available as chemical safety assessment not required/ not conducted.

12.6 Other adverse effects

No data available.

13. DISPOSAL CONSIDERATIONS

13.1 Waste treatment methods

Product
Dispose of at a supervised appropriate waste disposal facility according to current applicable laws and regulations and product characteristics at time of disposal.

Contaminated packaging
Contaminated containers should be cleaned and disposed of in the same manner as the product in accordance with applicable regulations.

14. TRANSPORT INFORMATION

DOT (US)
Not dangerous goods.

IMDG
Not dangerous goods.

IATA
Not dangerous goods.

15. REGULATORY INFORMATION

SARA 302 Components
SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

SARA 311/312 Hazards
SAR 311/312: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 311/312.

CERCLA (Comprehensive Response, Compensation, and Liability Act)
Not Applicable.

TSCA (Toxic Substance Control Act)
The components of this product are in compliance with the chemical notification requirements of TSCA.

16. OTHER INFORMATION

HMIS Rating

Health Hazard:	1
Chronic Health Hazard:	
Flammability:	0
Physical Hazard:	0

NFPA Rating

Health Hazard:	1
Fire Hazard:	0
Reactivity Hazard:	0

MANUFACTURER DISCLAIMER: Information given herein is offered in good faith as accurate, but without guarantee. Conditions of use and suitability of the product for particular uses are beyond our control; all risks of use of the product are therefore assumed by the user. Nothing is intended as a recommendation for uses which infringe valid patents or as extending license under valid patents. Appropriate warnings and safe handling procedures should be provided to handlers and users.

Prepared by: ProTechnics Environmental Compliance Department

Contact information: 713-328-2320

SAFETY DATA SHEET

Date-Issued: 05-2015
SDS Ref. No: CFT
Date-Revised: 5/26/2016
Revision No:002

1. PRODUCT AND COMPANY IDENTIFICATION

1.1 Product Identifiers

Product name	:	3,5-Difluorobenzoic acid
Generic name	:	35-DFBA

1.2 Relevant identified used of the substance or mixture and uses advised against

Identified uses	:	Diagnostic
Uses advised against	:	Not available

1.3 Details of the supplier of the safety data sheet

Importer	:	ProTechnics International Division of Core Laboratories 31-35 George St. Thebarton, SA, AUSTRALIA 5031
Telephone	:	(08) 8152 0244

1.4 Emergency telephone number

Poisons Information Centre	:	13 11 26 (24 hour)
Ambulance, Fire, Police	:	000

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

GHS classification in accordance with 29 CFR 1910 (OSHA HCS)
Skin irritation (Category 2), H315
Eye irritation (Category 2), H319
Specific target organ toxicity – single exposure (Category 3), Respiratory system, H335

2.2 GHS Label elements, including precautionary statements

Pictogram



Signal word Warning

Hazard statement(s)

H315	Causes skin irritation.
H319	Causes serious eye irritation.
H335	May cause respiratory irritation.

Precautionary statement(s)

P261	Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray.
P264	Wash skin thoroughly after handling.
P280	Wear protective gloves.
P302 + P352	IF ON SKIN: Wash with plenty of soap and water.
P304 + P340	IF INHALED: Remove affected person into fresh air and keep at rest in a position comfortable for breathing.
P332 + P313	If skin irritation occurs: Get medical advice/ attention.

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

---

3. COMPOSITION / INFORMATION ON INGREDIENTS

3.1 Substances

Substance/ mixture Mixture

Ingredient	CAS/Exempt No	Percent	Hazardous
3,5-Difluorobenzoic acid	455-40-3	10	No
Water	7732-18-5	90	No

---

4. FIRST AID MEASURES

4.1 Description of first aid measures

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance. Move out of dangerous area.

If inhaled
Move person into fresh air. If cough or other symptoms develop, consult a physician.

In case of skin contact
Remove contaminated clothing including shoes and immediately wash affected area with plenty of soap and water. If irritation continues, consult a physician. Wash contaminated clothing and shoes before reuse.

In case of eye contact
Immediately flush eyes with plenty of water for two to three minutes. Remove any contact lenses and continue flushing for 15 minutes. If irritation continues, consult a physician.

If swallowed
Wash out mouth with water and keep at rest. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed

The most important known symptoms and effects are described in the labeling (see Section 2.2) and/or in Section 11.

4.3 Indication of any immediate medical attention and special treatment needed

No data available.

5. FIRE FIGHTING MEASURES

5.1 Extinguishing media

Suitable extinguishing media
Use fire-extinguishing media appropriate for surrounding materials.

5.2 Special hazards arising from the substance or mixture

Carbon oxides, halogenated hydrogen gas.

5.3 Advice for firefighters

As in any fire, wear full protective clothing and equipment.

5.4 Further information

No data available.

6. ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures

Use personal protective equipment. Avoid breathing vapours or mist. Evacuate personnel to safe areas.

6.2 Environmental precautions

Do not let product enter drains, if safe to do so.

6.3 Methods and materials for containment and cleanup

Construct temporary dikes of dirt or any appropriate readily available material to prevent spreading of the material. Cover with appropriate absorbent and sweep or shovel into an appropriate container.

6.4 Reference to other sections

For protective clothing, see Section 8. For disposal, see Section 13.

7. HANDLING AND STORAGE

7.1 Precautions for safe handling

Avoid contact with skin and eyes. Avoid formation of aerosols. Provide adequate exhaust ventilation at places where aerosols are formed. For precautions, see Section 2.2. Handle and use in a manner consistent with good industrial/manufacturing techniques and practices.

7.2 Conditions for safe storage

Keep container tightly closed in a dry, cool, and well-ventilated place. Do not store with, or close to, strong acids.

7.3 Specific end uses(s)

Apart from the uses mentioned in Section 1.2, no other specific uses are stipulated.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

8.1 Control parameters

Components with workplace control parameters
No PELs, TLVs, or OELs for this product or its ingredients are listed in the current issue of ACGIH's Guide to Occupational Exposure Values, nor have they been determined by the manufacturer.

8.2 Exposure controls

Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of the workday.

Personal protective equipment

Eye/face protection
Safety glasses with side-shields conforming to EN166. Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN166 (EU).

Skin protection
Handle with chemical-resistant gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Body protection
Impervious clothing. The type of protective equipment must be selected according to the amount of dangerous substance at the specific workplace.

Control of environmental exposure
Do not let product enter drains.

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9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: aqueous liquid Color: translucent
b)	Odor Boiling	Odorless
c)	point Freeze	Approximately 100°C
d)	point	0°C
e)	Density	1.05 g/mL
f)	Flash point	Not flammable
g)	pH	Approximately 9
h)	Evaporation factor	Not determined
i)	Solubility	Soluble in water
j)	Vapor pressure	Not determined
k)	Oxidizing properties	Not determined
l)	Vapor density	Not determined
m)	Viscosity	Not determined

9.2 Other safety information

No data available.

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10. STABILITY AND REACTIVITY

10.1 Reactivity

Strong acids. Oxidizing materials.

10.2 Chemical stability

The product is stable under normal ambient conditions of temperature and pressure.

10.3 Possibility of hazardous reactions

Will not polymerize.

10.4 Conditions to avoid

Extreme cold.

10.5 Incompatible materials

Strong acids. Oxidizing materials.

10.6 Hazardous decomposition products

None.

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11. . TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects

Acute toxicity – oral
Based on available data the classification criteria are not met.

Acute toxicity – dermal
Based on available data the classification criteria are not met.

Acute toxicity – inhalation
Based on available data the classification criteria are not met.

Skin corrosion/irritation
Skin irritant 2 – H315 Causes skin irritation.

Serious eye damage/irritation
Eye irritant 2 – H319 May cause severe eye irritation.

Respiratory sensitization
Based on available data the classification criteria are not met.

Skin sensitization
Based on available data the classification criteria are not met.

Germ cell mutagenicity

Genotoxicity – in vitro
Based on available data the classification criteria are not met.

Genotoxicity- in vivo
Based on available data the classification criteria are not met.

Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible, or confirmed human carcinogen by IARC.

ACGIH: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP

OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity

Reproductive toxicity – fertility
Based on available data the classification criteria are not met.

Reproductive toxicity – development
Based on available data the classification criteria are not met.

Specific target organ toxicity – single exposure
STOT SE 3 – H335 May cause respiratory irritation.

Specific target organ toxicity – repeated exposure
Based on available data the classification criteria are not met.

Aspiration hazard
Not anticipated to present an aspiration hazard, based on chemical structure.

Additional information
RTECS: Not available.

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

12. ECOLOGICAL INFORMATION

12.1 Toxicity

No data available.

12.2 Persistence and degradability

Presumed to be persistent.

12.3 Bioaccumulative potential

No data available.

12.4 Mobility in soil

No data available.

12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment are not available as chemical safety assessment not required/ not conducted.

12.6 Other adverse effects

No data available.

13. DISPOSAL CONSIDERATIONS

13.1 Waste treatment methods

Product
Dispose of at a supervised appropriate waste disposal facility according to current applicable laws and regulations and product characteristics at time of disposal.

Contaminated packaging
Contaminated containers should be cleaned and disposed of in the same manner as the product in accordance with applicable regulations.

14. TRANSPORT INFORMATION

DOT (US)
Not dangerous goods.

IMDG
Not dangerous goods.

IATA
Not dangerous goods.

15. REGULATORY INFORMATION

SARA 302 Components
SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

SARA 311/312 Hazards
SAR 311/312: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 311/312.

CERCLA (Comprehensive Response, Compensation, and Liability Act)
Not Applicable.

TSCA (Toxic Substance Control Act)
The components of this product are in compliance with the chemical notification requirements of TSCA.

16. OTHER INFORMATION

HMIS Rating

Health Hazard:	1
Chronic Health Hazard:	
Flammability:	0
Physical Hazard:	0

NFPA Rating

Health Hazard:	1
Fire Hazard:	0
Reactivity Hazard:	0

MANUFACTURER DISCLAIMER: Information given herein is offered in good faith as accurate, but without guarantee. Conditions of use and suitability of the product for particular uses are beyond our control; all risks of use of the product are therefore assumed by the user. Nothing is intended as a recommendation for uses which infringe valid patents or as extending license under valid patents. Appropriate warnings and safe handling procedures should be provided to handlers and users.

Prepared by: ProTechnics Environmental Compliance Department

Contact information: 713-328-2320

SAFETY DATA SHEET

Date-Issued: 05-2015
SDS Ref. No: CFT
Date-Revised: 5/26/2016
Revision No:002

1. PRODUCT AND COMPANY IDENTIFICATION

1.1 Product Identifiers

Product name	:	3,4-Difluorobenzoic acid
Generic name	:	34-DFBA

1.2 Relevant identified used of the substance or mixture and uses advised against

Identified uses	:	Diagnostic
Uses advised against	:	Not available

1.3 Details of the supplier of the safety data sheet

Importer	:	ProTechnics International Division of Core Laboratories 31-35 George St. Thebarton, SA, AUSTRALIA 5031
Telephone	:	(08) 8152 0244

1.4 Emergency telephone number

Poisons Information Centre	:	13 11 26 (24 hour)
Ambulance, Fire, Police	:	000

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

GHS classification in accordance with 29 CFR 1910 (OSHA HCS)
Skin irritation (Category 2), H315
Eye irritation (Category 2), H319
Specific target organ toxicity – single exposure (Category 3), Respiratory system, H335

2.2 GHS Label elements, including precautionary statements

Pictogram



Signal word Warning

Hazard statement(s)

H315	Causes skin irritation.
H319	Causes serious eye irritation.
H335	May cause respiratory irritation.

Precautionary statement(s)

P261	Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray.
P264	Wash skin thoroughly after handling.
P280	Wear protective gloves.
P302 + P352	IF ON SKIN: Wash with plenty of soap and water.
P304 + P340	IF INHALED: Remove affected person into fresh air and keep at rest in a position comfortable for breathing.
P332 + P313	If skin irritation occurs: Get medical advice/ attention.

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

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3. COMPOSITION / INFORMATION ON INGREDIENTS

3.1 Substances

Substance/ mixture Mixture

Ingredient	CAS/Exempt No	Percent	Hazardous
3,4-Difluorobenzoic acid	455-86-7	10	No
Water	7732-18-5	90	No

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4. FIRST AID MEASURES

4.1 Description of first aid measures

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance. Move out of dangerous area.

If inhaled
Move person into fresh air. If cough or other symptoms develop, consult a physician.

In case of skin contact
Remove contaminated clothing including shoes and immediately wash affected area with plenty of soap and water. If irritation continues, consult a physician. Wash contaminated clothing and shoes before reuse.

In case of eye contact
Immediately flush eyes with plenty of water for two to three minutes. Remove any contact lenses and continue flushing for 15 minutes. If irritation continues, consult a physician.

If swallowed
Wash out mouth with water and keep at rest. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed

The most important known symptoms and effects are described in the labeling (see Section 2.2) and/or in Section 11.

4.3 Indication of any immediate medical attention and special treatment needed

No data available.

5. FIRE FIGHTING MEASURES

5.1 Extinguishing media

Suitable extinguishing media
Use fire-extinguishing media appropriate for surrounding materials.

5.2 Special hazards arising from the substance or mixture

Carbon oxides, halogenated hydrogen gas.

5.3 Advice for firefighters

As in any fire, wear full protective clothing and equipment.

5.4 Further information

No data available.

6. ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures

Use personal protective equipment. Avoid breathing vapours or mist. Evacuate personnel to safe areas.

6.2 Environmental precautions

Do not let product enter drains, if safe to do so.

6.3 Methods and materials for containment and cleanup

Construct temporary dikes of dirt or any appropriate readily available material to prevent spreading of the material. Cover with appropriate absorbent and sweep or shovel into an appropriate container.

6.4 Reference to other sections

For protective clothing, see Section 8. For disposal, see Section 13.

7. HANDLING AND STORAGE

7.1 Precautions for safe handling

Avoid contact with skin and eyes. Avoid formation of aerosols. Provide adequate exhaust ventilation at places where aerosols are formed. For precautions, see Section 2.2. Handle and use in a manner consistent with good industrial/manufacturing techniques and practices.

7.2 Conditions for safe storage

Keep container tightly closed in a dry, cool, and well-ventilated place. Do not store with, or close to, strong acids.

7.3 Specific end uses(s)

Apart from the uses mentioned in Section 1.2, no other specific uses are stipulated.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

8.1 Control parameters

Components with workplace control parameters
No PELs, TLVs, or OELs for this product or its ingredients are listed in the current issue of ACGIH's Guide to Occupational Exposure Values, nor have they been determined by the manufacturer.

8.2 Exposure controls

Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of the workday.

Personal protective equipment

Eye/face protection
Safety glasses with side-shields conforming to EN166. Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN166 (EU).

Skin protection
Handle with chemical-resistant gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Body protection
Impervious clothing. The type of protective equipment must be selected according to the amount of dangerous substance at the specific workplace.

Control of environmental exposure
Do not let product enter drains.

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9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: aqueous liquid Color: translucent
b)	Odor Boiling	Odorless
c)	point Freeze	Approximately 100°C
d)	point	0°C
e)	Density	1.05 g/mL
f)	Flash point	Not flammable
g)	pH	Approximately 9
h)	Evaporation factor	Not determined
i)	Solubility	Soluble in water
j)	Vapor pressure	Not determined
k)	Oxidizing properties	Not determined
l)	Vapor density	Not determined
m)	Viscosity	Not determined

9.2 Other safety information

No data available.

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10. STABILITY AND REACTIVITY

10.1 Reactivity

Strong acids. Oxidizing materials.

10.2 Chemical stability

The product is stable under normal ambient conditions of temperature and pressure.

10.3 Possibility of hazardous reactions

Will not polymerize.

10.4 Conditions to avoid

Extreme cold.

10.5 Incompatible materials

Strong acids. Oxidizing materials.

10.6 Hazardous decomposition products

None.

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11. . TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects

Acute toxicity – oral
Based on available data the classification criteria are not met.

Acute toxicity – dermal
Based on available data the classification criteria are not met.

Acute toxicity – inhalation
Based on available data the classification criteria are not met.

Skin corrosion/irritation
Skin irritant 2 – H315 Causes skin irritation.

Serious eye damage/irritation
Eye irritant 2 – H319 May cause severe eye irritation.

Respiratory sensitization
Based on available data the classification criteria are not met.

Skin sensitization
Based on available data the classification criteria are not met.

Germ cell mutagenicity

Genotoxicity – in vitro
Based on available data the classification criteria are not met.

Genotoxicity- in vivo
Based on available data the classification criteria are not met.

Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible, or confirmed human carcinogen by IARC.

ACGIH: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP

OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity

Reproductive toxicity – fertility
Based on available data the classification criteria are not met.

Reproductive toxicity – development
Based on available data the classification criteria are not met.

Specific target organ toxicity – single exposure
STOT SE 3 – H335 May cause respiratory irritation.

Specific target organ toxicity – repeated exposure
Based on available data the classification criteria are not met.

Aspiration hazard
Not anticipated to present an aspiration hazard, based on chemical structure.

Additional information
RTECS: Not available.

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

12. ECOLOGICAL INFORMATION

12.1 Toxicity

No data available.

12.2 Persistence and degradability

Presumed to be persistent.

12.3 Bioaccumulative potential

No data available.

12.4 Mobility in soil

No data available.

12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment are not available as chemical safety assessment not required/ not conducted.

12.6 Other adverse effects

No data available.

13. DISPOSAL CONSIDERATIONS

13.1 Waste treatment methods

Product
Dispose of at a supervised appropriate waste disposal facility according to current applicable laws and regulations and product characteristics at time of disposal.

Contaminated packaging
Contaminated containers should be cleaned and disposed of in the same manner as the product in accordance with applicable regulations.

14. TRANSPORT INFORMATION

DOT (US)
Not dangerous goods.

IMDG
Not dangerous goods.

IATA
Not dangerous goods.

15. REGULATORY INFORMATION

SARA 302 Components
SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

SARA 311/312 Hazards
SAR 311/312: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 311/312.

CERCLA (Comprehensive Response, Compensation, and Liability Act)
Not Applicable.

TSCA (Toxic Substance Control Act)
The components of this product are in compliance with the chemical notification requirements of TSCA.

16. OTHER INFORMATION

HMIS Rating

Health Hazard:	1
Chronic Health Hazard:	
Flammability:	0
Physical Hazard:	0

NFPA Rating

Health Hazard:	1
Fire Hazard:	0
Reactivity Hazard:	0

MANUFACTURER DISCLAIMER: Information given herein is offered in good faith as accurate, but without guarantee. Conditions of use and suitability of the product for particular uses are beyond our control; all risks of use of the product are therefore assumed by the user. Nothing is intended as a recommendation for uses which infringe valid patents or as extending license under valid patents. Appropriate warnings and safe handling procedures should be provided to handlers and users.

Prepared by: ProTechnics Environmental Compliance Department

Contact information: 713-328-2320

SAFETY DATA SHEET

Date-Issued: 05-2015
SDS Ref. No: CFT
Date-Revised: 5/26/2016
Revision No:002

1. PRODUCT AND COMPANY IDENTIFICATION

1.1 Product Identifiers

Product name	:	2,6-Difluorobenzoic acid
Generic name	:	26-DFBA

1.2 Relevant identified used of the substance or mixture and uses advised against

Identified uses	:	Diagnostic
Uses advised against	:	Not available

1.3 Details of the supplier of the safety data sheet

Importer	:	ProTechnics International Division of Core Laboratories 31-35 George St. Thebarton, SA, AUSTRALIA 5031
Telephone	:	(08) 8152 0244

1.4 Emergency telephone number

Poisons Information Centre	:	13 11 26 (24 hour)
Ambulance, Fire, Police	:	000

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

GHS classification in accordance with 29 CFR 1910 (OSHA HCS)
Skin irritation (Category 2), H315
Eye irritation (Category 2), H319
Specific target organ toxicity – single exposure (Category 3), Respiratory system, H335

2.2 GHS Label elements, including precautionary statements

Pictogram



Signal word Warning

Hazard statement(s)

H315	Causes skin irritation.
H319	Causes serious eye irritation.
H335	May cause respiratory irritation.

Precautionary statement(s)

P261	Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray.
P264	Wash skin thoroughly after handling.
P280	Wear protective gloves.
P302 + P352	IF ON SKIN: Wash with plenty of soap and water.
P304 + P340	IF INHALED: Remove affected person into fresh air and keep at rest in a position comfortable for breathing.
P332 + P313	If skin irritation occurs: Get medical advice/ attention.

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

---

3. COMPOSITION / INFORMATION ON INGREDIENTS

3.1 Substances

Substance/ mixture Mixture

Ingredient	CAS/Exempt No	Percent	Hazardous
2,6-Difluorobenzoic acid	385-00-2	10	No
Water	7732-18-5	90	No

---

4. FIRST AID MEASURES

4.1 Description of first aid measures

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance. Move out of dangerous area.

If inhaled
Move person into fresh air. If cough or other symptoms develop, consult a physician.

In case of skin contact
Remove contaminated clothing including shoes and immediately wash affected area with plenty of soap and water. If irritation continues, consult a physician. Wash contaminated clothing and shoes before reuse.

In case of eye contact
Immediately flush eyes with plenty of water for two to three minutes. Remove any contact lenses and continue flushing for 15 minutes. If irritation continues, consult a physician.

If swallowed
Wash out mouth with water and keep at rest. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed

The most important known symptoms and effects are described in the labeling (see Section 2.2) and/or in Section 11.

4.3 Indication of any immediate medical attention and special treatment needed

No data available.

5. FIRE FIGHTING MEASURES

5.1 Extinguishing media

Suitable extinguishing media
Use fire-extinguishing media appropriate for surrounding materials.

5.2 Special hazards arising from the substance or mixture

Carbon oxides, halogenated hydrogen gas.

5.3 Advice for firefighters

As in any fire, wear full protective clothing and equipment.

5.4 Further information

No data available.

6. ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures

Use personal protective equipment. Avoid breathing vapours or mist. Evacuate personnel to safe areas.

6.2 Environmental precautions

Do not let product enter drains, if safe to do so.

6.3 Methods and materials for containment and cleanup

Construct temporary dikes of dirt or any appropriate readily available material to prevent spreading of the material. Cover with appropriate absorbent and sweep or shovel into an appropriate container.

6.4 Reference to other sections

For protective clothing, see Section 8. For disposal, see Section 13.

7. HANDLING AND STORAGE

7.1 Precautions for safe handling

Avoid contact with skin and eyes. Avoid formation of aerosols. Provide adequate exhaust ventilation at places where aerosols are formed. For precautions, see Section 2.2. Handle and use in a manner consistent with good industrial/manufacturing techniques and practices.

7.2 Conditions for safe storage

Keep container tightly closed in a dry, cool, and well-ventilated place. Do not store with, or close to, strong acids.

7.3 Specific end uses(s)

Apart from the uses mentioned in Section 1.2, no other specific uses are stipulated.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

8.1 Control parameters

Components with workplace control parameters
No PELs, TLVs, or OELs for this product or its ingredients are listed in the current issue of ACGIH's Guide to Occupational Exposure Values, nor have they been determined by the manufacturer.

8.2 Exposure controls

Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of the workday.

Personal protective equipment

Eye/face protection
Safety glasses with side-shields conforming to EN166. Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN166 (EU).

Skin protection
Handle with chemical-resistant gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Body protection
Impervious clothing. The type of protective equipment must be selected according to the amount of dangerous substance at the specific workplace.

Control of environmental exposure
Do not let product enter drains.

---

9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: aqueous liquid Color: translucent
b)	Odor Boiling	Odorless
c)	point Freeze	Approximately 100°C
d)	point	0°C
e)	Density	1.05 g/mL
f)	Flash point	Not flammable
g)	pH	Approximately 9
h)	Evaporation factor	Not determined
i)	Solubility	Soluble in water
j)	Vapor pressure	Not determined
k)	Oxidizing properties	Not determined
l)	Vapor density	Not determined
m)	Viscosity	Not determined

9.2 Other safety information

No data available.

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10. STABILITY AND REACTIVITY

10.1 Reactivity

Strong acids. Oxidizing materials.

10.2 Chemical stability

The product is stable under normal ambient conditions of temperature and pressure.

10.3 Possibility of hazardous reactions

Will not polymerize.

10.4 Conditions to avoid

Extreme cold.

10.5 Incompatible materials

Strong acids. Oxidizing materials.

10.6 Hazardous decomposition products

None.

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11. . TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects

Acute toxicity – oral
Based on available data the classification criteria are not met.

Acute toxicity – dermal
Based on available data the classification criteria are not met.

Acute toxicity – inhalation
Based on available data the classification criteria are not met.

Skin corrosion/irritation
Skin irritant 2 – H315 Causes skin irritation.

Serious eye damage/irritation
Eye irritant 2 – H319 May cause severe eye irritation.

Respiratory sensitization
Based on available data the classification criteria are not met.

Skin sensitization
Based on available data the classification criteria are not met.

Germ cell mutagenicity

Genotoxicity – in vitro
Based on available data the classification criteria are not met.

Genotoxicity- in vivo
Based on available data the classification criteria are not met.

Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible, or confirmed human carcinogen by IARC.

ACGIH: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP

OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity

Reproductive toxicity – fertility
Based on available data the classification criteria are not met.

Reproductive toxicity – development
Based on available data the classification criteria are not met.

Specific target organ toxicity – single exposure
STOT SE 3 – H335 May cause respiratory irritation.

Specific target organ toxicity – repeated exposure
Based on available data the classification criteria are not met.

Aspiration hazard
Not anticipated to present an aspiration hazard, based on chemical structure.

Additional information
RTECS: Not available.

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

12. ECOLOGICAL INFORMATION

12.1 Toxicity

No data available.

12.2 Persistence and degradability

Presumed to be persistent.

12.3 Bioaccumulative potential

No data available.

12.4 Mobility in soil

No data available.

12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment are not available as chemical safety assessment not required/ not conducted.

12.6 Other adverse effects

No data available.

13. DISPOSAL CONSIDERATIONS

13.1 Waste treatment methods

Product
Dispose of at a supervised appropriate waste disposal facility according to current applicable laws and regulations and product characteristics at time of disposal.

Contaminated packaging
Contaminated containers should be cleaned and disposed of in the same manner as the product in accordance with applicable regulations.

14. TRANSPORT INFORMATION

DOT (US)
Not dangerous goods.

IMDG
Not dangerous goods.

IATA
Not dangerous goods.

15. REGULATORY INFORMATION

SARA 302 Components
SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

SARA 311/312 Hazards
SAR 311/312: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 311/312.

CERCLA (Comprehensive Response, Compensation, and Liability Act)
Not Applicable.

TSCA (Toxic Substance Control Act)
The components of this product are in compliance with the chemical notification requirements of TSCA.

16. OTHER INFORMATION

HMIS Rating

Health Hazard:	1
Chronic Health Hazard:	
Flammability:	0
Physical Hazard:	0

NFPA Rating

Health Hazard:	1
Fire Hazard:	0
Reactivity Hazard:	0

MANUFACTURER DISCLAIMER: Information given herein is offered in good faith as accurate, but without guarantee. Conditions of use and suitability of the product for particular uses are beyond our control; all risks of use of the product are therefore assumed by the user. Nothing is intended as a recommendation for uses which infringe valid patents or as extending license under valid patents. Appropriate warnings and safe handling procedures should be provided to handlers and users.

Prepared by: ProTechnics Environmental Compliance Department

Contact information: 713-328-2320

SAFETY DATA SHEET

Date-Issued: 05-2015
SDS Ref. No: CFT
Date-Revised: 5/26/2016
Revision No:002

1. PRODUCT AND COMPANY IDENTIFICATION

1.1 Product Identifiers

Product name	:	2,5-Difluorobenzoic acid
Generic name	:	25-DFBA

1.2 Relevant identified used of the substance or mixture and uses advised against

Identified uses	:	Diagnostic
Uses advised against	:	Not available

1.3 Details of the supplier of the safety data sheet

Importer	:	ProTechnics International Division of Core Laboratories 31-35 George St. Thebarton, SA, AUSTRALIA 5031
Telephone	:	(08) 8152 0244

1.4 Emergency telephone number

Poisons Information Centre	:	13 11 26 (24 hour)
Ambulance, Fire, Police	:	000

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

GHS classification in accordance with 29 CFR 1910 (OSHA HCS)
Skin irritation (Category 2), H315
Eye irritation (Category 2), H319
Specific target organ toxicity – single exposure (Category 3), Respiratory system, H335

2.2 GHS Label elements, including precautionary statements

Pictogram



Signal word Warning

Hazard statement(s)

H315	Causes skin irritation.
H319	Causes serious eye irritation.
H335	May cause respiratory irritation.

Precautionary statement(s)

P261	Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray.
P264	Wash skin thoroughly after handling.
P280	Wear protective gloves.
P302 + P352	IF ON SKIN: Wash with plenty of soap and water.
P304 + P340	IF INHALED: Remove affected person into fresh air and keep at rest in a position comfortable for breathing.
P332 + P313	If skin irritation occurs: Get medical advice/ attention.

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

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3. COMPOSITION / INFORMATION ON INGREDIENTS

3.1 Substances

Substance/ mixture Mixture

Ingredient	CAS/Exempt No	Percent	Hazardous
2,5-Difluorobenzoic acid	2991-28-8	10	No
Water	7732-18-5	90	No

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4. FIRST AID MEASURES

4.1 Description of first aid measures

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance. Move out of dangerous area.

If inhaled
Move person into fresh air. If cough or other symptoms develop, consult a physician.

In case of skin contact
Remove contaminated clothing including shoes and immediately wash affected area with plenty of soap and water. If irritation continues, consult a physician. Wash contaminated clothing and shoes before reuse.

In case of eye contact
Immediately flush eyes with plenty of water for two to three minutes. Remove any contact lenses and continue flushing for 15 minutes. If irritation continues, consult a physician.

If swallowed
Wash out mouth with water and keep at rest. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed

The most important known symptoms and effects are described in the labeling (see Section 2.2) and/or in Section 11.

4.3 Indication of any immediate medical attention and special treatment needed

No data available.

5. FIRE FIGHTING MEASURES

5.1 Extinguishing media

Suitable extinguishing media
Use fire-extinguishing media appropriate for surrounding materials.

5.2 Special hazards arising from the substance or mixture

Carbon oxides, halogenated hydrogen gas.

5.3 Advice for firefighters

As in any fire, wear full protective clothing and equipment.

5.4 Further information

No data available.

6. ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures

Use personal protective equipment. Avoid breathing vapours or mist. Evacuate personnel to safe areas.

6.2 Environmental precautions

Do not let product enter drains, if safe to do so.

6.3 Methods and materials for containment and cleanup

Construct temporary dikes of dirt or any appropriate readily available material to prevent spreading of the material. Cover with appropriate absorbent and sweep or shovel into an appropriate container.

6.4 Reference to other sections

For protective clothing, see Section 8. For disposal, see Section 13.

7. HANDLING AND STORAGE

7.1 Precautions for safe handling

Avoid contact with skin and eyes. Avoid formation of aerosols. Provide adequate exhaust ventilation at places where aerosols are formed. For precautions, see Section 2.2. Handle and use in a manner consistent with good industrial/manufacturing techniques and practices.

7.2 Conditions for safe storage

Keep container tightly closed in a dry, cool, and well-ventilated place. Do not store with, or close to, strong acids.

7.3 Specific end uses(s)

Apart from the uses mentioned in Section 1.2, no other specific uses are stipulated.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

8.1 Control parameters

Components with workplace control parameters
No PELs, TLVs, or OELs for this product or its ingredients are listed in the current issue of ACGIH's Guide to Occupational Exposure Values, nor have they been determined by the manufacturer.

8.2 Exposure controls

Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of the workday.

Personal protective equipment

Eye/face protection
Safety glasses with side-shields conforming to EN166. Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN166 (EU).

Skin protection
Handle with chemical-resistant gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Body protection
Impervious clothing. The type of protective equipment must be selected according to the amount of dangerous substance at the specific workplace.

Control of environmental exposure
Do not let product enter drains.

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9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: aqueous liquid Color: translucent
b)	Odor Boiling	Odorless
c)	point Freeze	Approximately 100°C
d)	point	0°C
e)	Density	1.05 g/mL
f)	Flash point	Not flammable
g)	pH	Approximately 9
h)	Evaporation factor	Not determined
i)	Solubility	Soluble in water
j)	Vapor pressure	Not determined
k)	Oxidizing properties	Not determined
l)	Vapor density	Not determined
m)	Viscosity	Not determined

9.2 Other safety information

No data available.

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10. STABILITY AND REACTIVITY

10.1 Reactivity

Strong acids. Oxidizing materials.

10.2 Chemical stability

The product is stable under normal ambient conditions of temperature and pressure.

10.3 Possibility of hazardous reactions

Will not polymerize.

10.4 Conditions to avoid

Extreme cold.

10.5 Incompatible materials

Strong acids. Oxidizing materials.

10.6 Hazardous decomposition products

None.

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11. . TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects

Acute toxicity – oral
Based on available data the classification criteria are not met.

Acute toxicity – dermal
Based on available data the classification criteria are not met.

Acute toxicity – inhalation
Based on available data the classification criteria are not met.

Skin corrosion/irritation
Skin irritant 2 – H315 Causes skin irritation.

Serious eye damage/irritation
Eye irritant 2 – H319 May cause severe eye irritation.

Respiratory sensitization
Based on available data the classification criteria are not met.

Skin sensitization
Based on available data the classification criteria are not met.

Germ cell mutagenicity

Genotoxicity – in vitro
Based on available data the classification criteria are not met.

Genotoxicity- in vivo
Based on available data the classification criteria are not met.

Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible, or confirmed human carcinogen by IARC.

ACGIH: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP

OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity

Reproductive toxicity – fertility
Based on available data the classification criteria are not met.

Reproductive toxicity – development
Based on available data the classification criteria are not met.

Specific target organ toxicity – single exposure
STOT SE 3 – H335 May cause respiratory irritation.

Specific target organ toxicity – repeated exposure
Based on available data the classification criteria are not met.

Aspiration hazard
Not anticipated to present an aspiration hazard, based on chemical structure.

Additional information
RTECS: Not available.

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

12. ECOLOGICAL INFORMATION

12.1 Toxicity

No data available.

12.2 Persistence and degradability

Presumed to be persistent.

12.3 Bioaccumulative potential

No data available.

12.4 Mobility in soil

No data available.

12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment are not available as chemical safety assessment not required/ not conducted.

12.6 Other adverse effects

No data available.

13. DISPOSAL CONSIDERATIONS

13.1 Waste treatment methods

Product
Dispose of at a supervised appropriate waste disposal facility according to current applicable laws and regulations and product characteristics at time of disposal.

Contaminated packaging
Contaminated containers should be cleaned and disposed of in the same manner as the product in accordance with applicable regulations.

14. TRANSPORT INFORMATION

DOT (US)
Not dangerous goods.

IMDG
Not dangerous goods.

IATA
Not dangerous goods.

15. REGULATORY INFORMATION

SARA 302 Components
SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

SARA 311/312 Hazards
SAR 311/312: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 311/312.

CERCLA (Comprehensive Response, Compensation, and Liability Act)
Not Applicable.

TSCA (Toxic Substance Control Act)
The components of this product are in compliance with the chemical notification requirements of TSCA.

16. OTHER INFORMATION

HMIS Rating

Health Hazard:	1
Chronic Health Hazard:	
Flammability:	0
Physical Hazard:	0

NFPA Rating

Health Hazard:	1
Fire Hazard:	0
Reactivity Hazard:	0

MANUFACTURER DISCLAIMER: Information given herein is offered in good faith as accurate, but without guarantee. Conditions of use and suitability of the product for particular uses are beyond our control; all risks of use of the product are therefore assumed by the user. Nothing is intended as a recommendation for uses which infringe valid patents or as extending license under valid patents. Appropriate warnings and safe handling procedures should be provided to handlers and users.

Prepared by: ProTechnics Environmental Compliance Department

Contact information: 713-328-2320

SAFETY DATA SHEET

Date-Issued: 05-2015
SDS Ref. No: CFT
Date-Revised: 5/26/2016
Revision No:002

1. PRODUCT AND COMPANY IDENTIFICATION

1.1 Product Identifiers

Product name	:	2,4-Difluorobenzoic acid
Generic name	:	24-DFBA

1.2 Relevant identified used of the substance or mixture and uses advised against

Identified uses	:	Diagnostic
Uses advised against	:	Not available

1.3 Details of the supplier of the safety data sheet

Importer	:	ProTechnics International Division of Core Laboratories 31-35 George St. Thebarton, SA, AUSTRALIA 5031
Telephone	:	(08) 8152 0244

1.4 Emergency telephone number

Poisons Information Centre	:	13 11 26 (24 hour)
Ambulance, Fire, Police	:	000

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

GHS classification in accordance with 29 CFR 1910 (OSHA HCS)
Skin irritation (Category 2), H315
Eye irritation (Category 2), H319
Specific target organ toxicity – single exposure (Category 3), Respiratory system, H335

2.2 GHS Label elements, including precautionary statements

Pictogram



Signal word Warning

Hazard statement(s)

H315	Causes skin irritation.
H319	Causes serious eye irritation.
H335	May cause respiratory irritation.

Precautionary statement(s)

P261	Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray.
P264	Wash skin thoroughly after handling.
P280	Wear protective gloves.
P302 + P352	IF ON SKIN: Wash with plenty of soap and water.
P304 + P340	IF INHALED: Remove affected person into fresh air and keep at rest in a position comfortable for breathing.
P332 + P313	If skin irritation occurs: Get medical advice/ attention.

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

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3. COMPOSITION / INFORMATION ON INGREDIENTS

3.1 Substances

Substance/ mixture Mixture

Ingredient	CAS/Exempt No	Percent	Hazardous
2,4-Difluorobenzoic acid	1583-58-0	10	No
Water	7732-18-5	90	No

---

4. FIRST AID MEASURES

4.1 Description of first aid measures

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance. Move out of dangerous area.

If inhaled
Move person into fresh air. If cough or other symptoms develop, consult a physician.

In case of skin contact
Remove contaminated clothing including shoes and immediately wash affected area with plenty of soap and water. If irritation continues, consult a physician. Wash contaminated clothing and shoes before reuse.

In case of eye contact
Immediately flush eyes with plenty of water for two to three minutes. Remove any contact lenses and continue flushing for 15 minutes. If irritation continues, consult a physician.

If swallowed
Wash out mouth with water and keep at rest. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed

The most important known symptoms and effects are described in the labeling (see Section 2.2) and/or in Section 11.

4.3 Indication of any immediate medical attention and special treatment needed

No data available.

5. FIRE FIGHTING MEASURES

5.1 Extinguishing media

Suitable extinguishing media
Use fire-extinguishing media appropriate for surrounding materials.

5.2 Special hazards arising from the substance or mixture

Carbon oxides, halogenated hydrogen gas.

5.3 Advice for firefighters

As in any fire, wear full protective clothing and equipment.

5.4 Further information

No data available.

6. ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures

Use personal protective equipment. Avoid breathing vapours or mist. Evacuate personnel to safe areas.

6.2 Environmental precautions

Do not let product enter drains, if safe to do so.

6.3 Methods and materials for containment and cleanup

Construct temporary dikes of dirt or any appropriate readily available material to prevent spreading of the material. Cover with appropriate absorbent and sweep or shovel into an appropriate container.

6.4 Reference to other sections

For protective clothing, see Section 8. For disposal, see Section 13.

7. HANDLING AND STORAGE

7.1 Precautions for safe handling

Avoid contact with skin and eyes. Avoid formation of aerosols. Provide adequate exhaust ventilation at places where aerosols are formed. For precautions, see Section 2.2. Handle and use in a manner consistent with good industrial/manufacturing techniques and practices.

7.2 Conditions for safe storage

Keep container tightly closed in a dry, cool, and well-ventilated place. Do not store with, or close to, strong acids.

7.3 Specific end uses(s)

Apart from the uses mentioned in Section 1.2, no other specific uses are stipulated.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

8.1 Control parameters

Components with workplace control parameters
No PELs, TLVs, or OELs for this product or its ingredients are listed in the current issue of ACGIH's Guide to Occupational Exposure Values, nor have they been determined by the manufacturer.

8.2 Exposure controls

Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of the workday.

Personal protective equipment

Eye/face protection
Safety glasses with side-shields conforming to EN166. Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN166 (EU).

Skin protection
Handle with chemical-resistant gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Body protection
Impervious clothing. The type of protective equipment must be selected according to the amount of dangerous substance at the specific workplace.

Control of environmental exposure
Do not let product enter drains.

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9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: aqueous liquid Color: translucent
b)	Odor Boiling	Odorless
c)	point Freeze	Approximately 100°C
d)	point	0°C
e)	Density	1.05 g/mL
f)	Flash point	Not flammable
g)	pH	Approximately 9
h)	Evaporation factor	Not determined
i)	Solubility	Soluble in water
j)	Vapor pressure	Not determined
k)	Oxidizing properties	Not determined
l)	Vapor density	Not determined
m)	Viscosity	Not determined

9.2 Other safety information

No data available.

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10. STABILITY AND REACTIVITY

10.1 Reactivity

Strong acids. Oxidizing materials.

10.2 Chemical stability

The product is stable under normal ambient conditions of temperature and pressure.

10.3 Possibility of hazardous reactions

Will not polymerize.

10.4 Conditions to avoid

Extreme cold.

10.5 Incompatible materials

Strong acids. Oxidizing materials.

10.6 Hazardous decomposition products

None.

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11. . TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects

Acute toxicity – oral
Based on available data the classification criteria are not met.

Acute toxicity – dermal
Based on available data the classification criteria are not met.

Acute toxicity – inhalation
Based on available data the classification criteria are not met.

Skin corrosion/irritation
Skin irritant 2 – H315 Causes skin irritation.

Serious eye damage/irritation
Eye irritant 2 – H319 May cause severe eye irritation.

Respiratory sensitization
Based on available data the classification criteria are not met.

Skin sensitization
Based on available data the classification criteria are not met.

Germ cell mutagenicity

Genotoxicity – in vitro
Based on available data the classification criteria are not met.

Genotoxicity- in vivo
Based on available data the classification criteria are not met.

Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible, or confirmed human carcinogen by IARC.

ACGIH: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP

OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity

Reproductive toxicity – fertility
Based on available data the classification criteria are not met.

Reproductive toxicity – development
Based on available data the classification criteria are not met.

Specific target organ toxicity – single exposure
STOT SE 3 – H335 May cause respiratory irritation.

Specific target organ toxicity – repeated exposure
Based on available data the classification criteria are not met.

Aspiration hazard
Not anticipated to present an aspiration hazard, based on chemical structure.

Additional information
RTECS: Not available.

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

12. ECOLOGICAL INFORMATION

12.1 Toxicity

No data available.

12.2 Persistence and degradability

Presumed to be persistent.

12.3 Bioaccumulative potential

No data available.

12.4 Mobility in soil

No data available.

12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment are not available as chemical safety assessment not required/ not conducted.

12.6 Other adverse effects

No data available.

13. DISPOSAL CONSIDERATIONS

13.1 Waste treatment methods

Product
Dispose of at a supervised appropriate waste disposal facility according to current applicable laws and regulations and product characteristics at time of disposal.

Contaminated packaging
Contaminated containers should be cleaned and disposed of in the same manner as the product in accordance with applicable regulations.

14. TRANSPORT INFORMATION

DOT (US)
Not dangerous goods.

IMDG
Not dangerous goods.

IATA
Not dangerous goods.

15. REGULATORY INFORMATION

SARA 302 Components
SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

SARA 311/312 Hazards
SAR 311/312: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 311/312.

CERCLA (Comprehensive Response, Compensation, and Liability Act)
Not Applicable.

TSCA (Toxic Substance Control Act)
The components of this product are in compliance with the chemical notification requirements of TSCA.

16. OTHER INFORMATION

HMIS Rating

Health Hazard:	1
Chronic Health Hazard:	
Flammability:	0
Physical Hazard:	0

NFPA Rating

Health Hazard:	1
Fire Hazard:	0
Reactivity Hazard:	0

MANUFACTURER DISCLAIMER: Information given herein is offered in good faith as accurate, but without guarantee. Conditions of use and suitability of the product for particular uses are beyond our control; all risks of use of the product are therefore assumed by the user. Nothing is intended as a recommendation for uses which infringe valid patents or as extending license under valid patents. Appropriate warnings and safe handling procedures should be provided to handlers and users.

Prepared by: ProTechnics Environmental Compliance Department

Contact information: 713-328-2320

SAFETY DATA SHEET

Date-Issued: 05-2015
SDS Ref. No: CFT
Date-Revised: 5/26/2016
Revision No:002

1. PRODUCT AND COMPANY IDENTIFICATION

1.1 Product Identifiers

Product name	:	4-(Trifluoromethyl)benzoic acid
Generic name	:	4-TFMBA

1.2 Relevant identified used of the substance or mixture and uses advised against

Identified uses	:	Diagnostic
Uses advised against	:	Not available

1.3 Details of the supplier of the safety data sheet

Importer	:	ProTechnics International Division of Core Laboratories 31-35 George St. Thebarton, SA, AUSTRALIA 5031
Telephone	:	(08) 8152 0244

1.4 Emergency telephone number

Poisons Information Centre	:	13 11 26 (24 hour)
Ambulance, Fire, Police	:	000

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

GHS classification in accordance with 29 CFR 1910 (OSHA HCS)
Skin irritation (Category 2), H315
Eye irritation (Category 2), H319
Specific target organ toxicity – single exposure (Category 3), Respiratory system, H335

2.2 GHS Label elements, including precautionary statements

Pictogram



Signal word Warning

Hazard statement(s)

H315	Causes skin irritation.
H319	Causes serious eye irritation.
H335	May cause respiratory irritation.

Precautionary statement(s)

P261	Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray.
P264	Wash skin thoroughly after handling.
P280	Wear protective gloves.
P302 + P352	IF ON SKIN: Wash with plenty of soap and water.
P304 + P340	IF INHALED: Remove affected person into fresh air and keep at rest in a position comfortable for breathing.
P332 + P313	If skin irritation occurs: Get medical advice/ attention.

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

---

3. COMPOSITION / INFORMATION ON INGREDIENTS

3.1 Substances

Substance/ mixture Mixture

Ingredient	CAS/Exempt No	Percent	Hazardous
4-(Trifluoromethyl)benzoic acid	455-24-3	10	No
Water	7732-18-5	90	No

---

4. FIRST AID MEASURES

4.1 Description of first aid measures

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance. Move out of dangerous area.

If inhaled
Move person into fresh air. If cough or other symptoms develop, consult a physician.

In case of skin contact
Remove contaminated clothing including shoes and immediately wash affected area with plenty of soap and water. If irritation continues, consult a physician. Wash contaminated clothing and shoes before reuse.

In case of eye contact
Immediately flush eyes with plenty of water for two to three minutes. Remove any contact lenses and continue flushing for 15 minutes. If irritation continues, consult a physician.

If swallowed
Wash out mouth with water and keep at rest. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed

The most important known symptoms and effects are described in the labeling (see Section 2.2) and/or in Section 11.

4.3 Indication of any immediate medical attention and special treatment needed

No data available.

5. FIRE FIGHTING MEASURES

5.1 Extinguishing media

Suitable extinguishing media
Use fire-extinguishing media appropriate for surrounding materials.

5.2 Special hazards arising from the substance or mixture

Carbon oxides, halogenated hydrogen gas.

5.3 Advice for firefighters

As in any fire, wear full protective clothing and equipment.

5.4 Further information

No data available.

6. ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures

Use personal protective equipment. Avoid breathing vapours or mist. Evacuate personnel to safe areas.

6.2 Environmental precautions

Do not let product enter drains, if safe to do so.

6.3 Methods and materials for containment and cleanup

Construct temporary dikes of dirt or any appropriate readily available material to prevent spreading of the material. Cover with appropriate absorbent and sweep or shovel into an appropriate container.

6.4 Reference to other sections

For protective clothing, see Section 8. For disposal, see Section 13.

7. HANDLING AND STORAGE

7.1 Precautions for safe handling

Avoid contact with skin and eyes. Avoid formation of aerosols. Provide adequate exhaust ventilation at places where aerosols are formed. For precautions, see Section 2.2. Handle and use in a manner consistent with good industrial/manufacturing techniques and practices.

7.2 Conditions for safe storage

Keep container tightly closed in a dry, cool, and well-ventilated place. Do not store with, or close to, strong acids.

7.3 Specific end uses(s)

Apart from the uses mentioned in Section 1.2, no other specific uses are stipulated.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

8.1 Control parameters

Components with workplace control parameters
No PELs, TLVs, or OELs for this product or its ingredients are listed in the current issue of ACGIH's Guide to Occupational Exposure Values, nor have they been determined by the manufacturer.

8.2 Exposure controls

Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of the workday.

Personal protective equipment

Eye/face protection
Safety glasses with side-shields conforming to EN166. Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN166 (EU).

Skin protection
Handle with chemical-resistant gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Body protection
Impervious clothing. The type of protective equipment must be selected according to the amount of dangerous substance at the specific workplace.

Control of environmental exposure
Do not let product enter drains.

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9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: aqueous liquid Color: translucent
b)	Odor Boiling	Odorless
c)	point Freeze	Approximately 100°C
d)	point	0°C
e)	Density	1.05 g/mL
f)	Flash point	Not flammable
g)	pH	Approximately 9
h)	Evaporation factor	Not determined
i)	Solubility	Soluble in water
j)	Vapor pressure	Not determined
k)	Oxidizing properties	Not determined
l)	Vapor density	Not determined
m)	Viscosity	Not determined

9.2 Other safety information

No data available.

---

10. STABILITY AND REACTIVITY

10.1 Reactivity

Strong acids. Oxidizing materials.

10.2 Chemical stability

The product is stable under normal ambient conditions of temperature and pressure.

10.3 Possibility of hazardous reactions

Will not polymerize.

10.4 Conditions to avoid

Extreme cold.

10.5 Incompatible materials

Strong acids. Oxidizing materials.

10.6 Hazardous decomposition products

None.

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11. . TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects

Acute toxicity – oral
Based on available data the classification criteria are not met.

Acute toxicity – dermal
Based on available data the classification criteria are not met.

Acute toxicity – inhalation
Based on available data the classification criteria are not met.

Skin corrosion/irritation
Skin irritant 2 – H315 Causes skin irritation.

Serious eye damage/irritation
Eye irritant 2 – H319 May cause severe eye irritation.

Respiratory sensitization
Based on available data the classification criteria are not met.

Skin sensitization
Based on available data the classification criteria are not met.

Germ cell mutagenicity

Genotoxicity – in vitro
Based on available data the classification criteria are not met.

Genotoxicity- in vivo
Based on available data the classification criteria are not met.

Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible, or confirmed human carcinogen by IARC.

ACGIH: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP

OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity

Reproductive toxicity – fertility
Based on available data the classification criteria are not met.

Reproductive toxicity – development
Based on available data the classification criteria are not met.

Specific target organ toxicity – single exposure
STOT SE 3 – H335 May cause respiratory irritation.

Specific target organ toxicity – repeated exposure
Based on available data the classification criteria are not met.

Aspiration hazard
Not anticipated to present an aspiration hazard, based on chemical structure.

Additional information
RTECS: Not available.

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

12. ECOLOGICAL INFORMATION

12.1 Toxicity

No data available.

12.2 Persistence and degradability

Presumed to be persistent.

12.3 Bioaccumulative potential

No data available.

12.4 Mobility in soil

No data available.

12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment are not available as chemical safety assessment not required/ not conducted.

12.6 Other adverse effects

No data available.

13. DISPOSAL CONSIDERATIONS

13.1 Waste treatment methods

Product
Dispose of at a supervised appropriate waste disposal facility according to current applicable laws and regulations and product characteristics at time of disposal.

Contaminated packaging
Contaminated containers should be cleaned and disposed of in the same manner as the product in accordance with applicable regulations.

14. TRANSPORT INFORMATION

DOT (US)
Not dangerous goods.

IMDG
Not dangerous goods.

IATA
Not dangerous goods.

15. REGULATORY INFORMATION

SARA 302 Components
SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

SARA 311/312 Hazards
SAR 311/312: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 311/312.

CERCLA (Comprehensive Response, Compensation, and Liability Act)
Not Applicable.

TSCA (Toxic Substance Control Act)
The components of this product are in compliance with the chemical notification requirements of TSCA.

16. OTHER INFORMATION

HMIS Rating

Health Hazard:	1
Chronic Health Hazard:	
Flammability:	0
Physical Hazard:	0

NFPA Rating

Health Hazard:	1
Fire Hazard:	0
Reactivity Hazard:	0

MANUFACTURER DISCLAIMER: Information given herein is offered in good faith as accurate, but without guarantee. Conditions of use and suitability of the product for particular uses are beyond our control; all risks of use of the product are therefore assumed by the user. Nothing is intended as a recommendation for uses which infringe valid patents or as extending license under valid patents. Appropriate warnings and safe handling procedures should be provided to handlers and users.

Prepared by: ProTechnics Environmental Compliance Department

Contact information: 713-328-2320

SAFETY DATA SHEET

Date-Issued: 05-2015
SDS Ref. No: CFT
Date-Revised: 5/26/2016
Revision No:002

1. PRODUCT AND COMPANY IDENTIFICATION

1.1 Product Identifiers

Product name	:	4-Fluorobenzoic acid
Generic name	:	4-FBA

1.2 Relevant identified used of the substance or mixture and uses advised against

Identified uses	:	Diagnostic
Uses advised against	:	Not available

1.3 Details of the supplier of the safety data sheet

Importer	:	ProTechnics International Division of Core Laboratories 31-35 George St. Thebarton, SA, AUSTRALIA 5031
Telephone	:	(08) 8152 0244

1.4 Emergency telephone number

Poisons Information Centre	:	13 11 26 (24 hour)
Ambulance, Fire, Police	:	000

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

GHS classification in accordance with 29 CFR 1910 (OSHA HCS)
Skin irritation (Category 2), H315
Eye irritation (Category 2), H319
Specific target organ toxicity – single exposure (Category 3), Respiratory system, H335

2.2 GHS Label elements, including precautionary statements

Pictogram



Signal word Warning

Hazard statement(s)

H315	Causes skin irritation.
H319	Causes serious eye irritation.
H335	May cause respiratory irritation.

Precautionary statement(s)

P261	Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray.
P264	Wash skin thoroughly after handling.
P280	Wear protective gloves.
P302 + P352	IF ON SKIN: Wash with plenty of soap and water.
P304 + P340	IF INHALED: Remove affected person into fresh air and keep at rest in a position comfortable for breathing.
P332 + P313	If skin irritation occurs: Get medical advice/ attention.

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

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3. COMPOSITION / INFORMATION ON INGREDIENTS

3.1 Substances

Substance/ mixture Mixture

Ingredient	CAS/Exempt No	Percent	Hazardous
4-Fluorobenzoic acid	456-22-4	10	No
Water	7732-18-5	90	No

---

4. FIRST AID MEASURES

4.1 Description of first aid measures

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance. Move out of dangerous area.

If inhaled
Move person into fresh air. If cough or other symptoms develop, consult a physician.

In case of skin contact
Remove contaminated clothing including shoes and immediately wash affected area with plenty of soap and water. If irritation continues, consult a physician. Wash contaminated clothing and shoes before reuse.

In case of eye contact
Immediately flush eyes with plenty of water for two to three minutes. Remove any contact lenses and continue flushing for 15 minutes. If irritation continues, consult a physician.

If swallowed
Wash out mouth with water and keep at rest. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed

The most important known symptoms and effects are described in the labeling (see Section 2.2) and/or in Section 11.

4.3 Indication of any immediate medical attention and special treatment needed

No data available.

5. FIRE FIGHTING MEASURES

5.1 Extinguishing media

Suitable extinguishing media
Use fire-extinguishing media appropriate for surrounding materials.

5.2 Special hazards arising from the substance or mixture

Carbon oxides, halogenated hydrogen gas.

5.3 Advice for firefighters

As in any fire, wear full protective clothing and equipment.

5.4 Further information

No data available.

6. ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures

Use personal protective equipment. Avoid breathing vapours or mist. Evacuate personnel to safe areas.

6.2 Environmental precautions

Do not let product enter drains, if safe to do so.

6.3 Methods and materials for containment and cleanup

Construct temporary dikes of dirt or any appropriate readily available material to prevent spreading of the material. Cover with appropriate absorbent and sweep or shovel into an appropriate container.

6.4 Reference to other sections

For protective clothing, see Section 8. For disposal, see Section 13.

7. HANDLING AND STORAGE

7.1 Precautions for safe handling

Avoid contact with skin and eyes. Avoid formation of aerosols. Provide adequate exhaust ventilation at places where aerosols are formed. For precautions, see Section 2.2. Handle and use in a manner consistent with good industrial/manufacturing techniques and practices.

7.2 Conditions for safe storage

Keep container tightly closed in a dry, cool, and well-ventilated place. Do not store with, or close to, strong acids.

7.3 Specific end uses(s)

Apart from the uses mentioned in Section 1.2, no other specific uses are stipulated.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

8.1 Control parameters

Components with workplace control parameters
No PELs, TLVs, or OELs for this product or its ingredients are listed in the current issue of ACGIH's Guide to Occupational Exposure Values, nor have they been determined by the manufacturer.

8.2 Exposure controls

Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of the workday.

Personal protective equipment

Eye/face protection
Safety glasses with side-shields conforming to EN166. Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN166 (EU).

Skin protection
Handle with chemical-resistant gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Body protection
Impervious clothing. The type of protective equipment must be selected according to the amount of dangerous substance at the specific workplace.

Control of environmental exposure
Do not let product enter drains.

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9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: aqueous liquid Color: translucent
b)	Odor Boiling	Odorless
c)	point Freeze	Approximately 100°C
d)	point	0°C
e)	Density	1.05 g/mL
f)	Flash point	Not flammable
g)	pH	Approximately 9
h)	Evaporation factor	Not determined
i)	Solubility	Soluble in water
j)	Vapor pressure	Not determined
k)	Oxidizing properties	Not determined
l)	Vapor density	Not determined
m)	Viscosity	Not determined

9.2 Other safety information

No data available.

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10. STABILITY AND REACTIVITY

10.1 Reactivity

Strong acids. Oxidizing materials.

10.2 Chemical stability

The product is stable under normal ambient conditions of temperature and pressure.

10.3 Possibility of hazardous reactions

Will not polymerize.

10.4 Conditions to avoid

Extreme cold.

10.5 Incompatible materials

Strong acids. Oxidizing materials.

10.6 Hazardous decomposition products

None.

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11. . TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects

Acute toxicity – oral
Based on available data the classification criteria are not met.

Acute toxicity – dermal
Based on available data the classification criteria are not met.

Acute toxicity – inhalation
Based on available data the classification criteria are not met.

Skin corrosion/irritation
Skin irritant 2 – H315 Causes skin irritation.

Serious eye damage/irritation
Eye irritant 2 – H319 May cause severe eye irritation.

Respiratory sensitization
Based on available data the classification criteria are not met.

Skin sensitization
Based on available data the classification criteria are not met.

Germ cell mutagenicity

Genotoxicity – in vitro
Based on available data the classification criteria are not met.

Genotoxicity- in vivo
Based on available data the classification criteria are not met.

Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible, or confirmed human carcinogen by IARC.

ACGIH: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP

OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity

Reproductive toxicity – fertility
Based on available data the classification criteria are not met.

Reproductive toxicity – development
Based on available data the classification criteria are not met.

Specific target organ toxicity – single exposure
STOT SE 3 – H335 May cause respiratory irritation.

Specific target organ toxicity – repeated exposure
Based on available data the classification criteria are not met.

Aspiration hazard
Not anticipated to present an aspiration hazard, based on chemical structure.

Additional information
RTECS: Not available.

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

12. ECOLOGICAL INFORMATION

12.1 Toxicity

No data available.

12.2 Persistence and degradability

Presumed to be persistent.

12.3 Bioaccumulative potential

No data available.

12.4 Mobility in soil

No data available.

12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment are not available as chemical safety assessment not required/ not conducted.

12.6 Other adverse effects

No data available.

13. DISPOSAL CONSIDERATIONS

13.1 Waste treatment methods

Product
Dispose of at a supervised appropriate waste disposal facility according to current applicable laws and regulations and product characteristics at time of disposal.

Contaminated packaging
Contaminated containers should be cleaned and disposed of in the same manner as the product in accordance with applicable regulations.

14. TRANSPORT INFORMATION

DOT (US)
Not dangerous goods.

IMDG
Not dangerous goods.

IATA
Not dangerous goods.

15. REGULATORY INFORMATION

SARA 302 Components
SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

SARA 311/312 Hazards
SAR 311/312: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 311/312.

CERCLA (Comprehensive Response, Compensation, and Liability Act)
Not Applicable.

TSCA (Toxic Substance Control Act)
The components of this product are in compliance with the chemical notification requirements of TSCA.

16. OTHER INFORMATION

HMIS Rating

Health Hazard:	1
Chronic Health Hazard:	
Flammability:	0
Physical Hazard:	0

NFPA Rating

Health Hazard:	1
Fire Hazard:	0
Reactivity Hazard:	0

MANUFACTURER DISCLAIMER: Information given herein is offered in good faith as accurate, but without guarantee. Conditions of use and suitability of the product for particular uses are beyond our control; all risks of use of the product are therefore assumed by the user. Nothing is intended as a recommendation for uses which infringe valid patents or as extending license under valid patents. Appropriate warnings and safe handling procedures should be provided to handlers and users.

Prepared by: ProTechnics Environmental Compliance Department

Contact information: 713-328-2320

SAFETY DATA SHEET

Date-Issued: 05-2015
SDS Ref. No: CFT
Date-Revised: 5/26/2016
Revision No:002

1. PRODUCT AND COMPANY IDENTIFICATION

1.1 Product Identifiers

Product name	:	3-(Trifluoromethyl)benzoic acid
Generic name	:	3-TFMBA

1.2 Relevant identified used of the substance or mixture and uses advised against

Identified uses	:	Diagnostic
Uses advised against	:	Not available

1.3 Details of the supplier of the safety data sheet

Importer	:	ProTechnics International Division of Core Laboratories 31-35 George St. Thebarton, SA, AUSTRALIA 5031
Telephone	:	(08) 8152 0244

1.4 Emergency telephone number

Poisons Information Centre	:	13 11 26 (24 hour)
Ambulance, Fire, Police	:	000

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

GHS classification in accordance with 29 CFR 1910 (OSHA HCS)
Skin irritation (Category 2), H315
Eye irritation (Category 2), H319
Specific target organ toxicity – single exposure (Category 3), Respiratory system, H335

2.2 GHS Label elements, including precautionary statements

Pictogram



Signal word Warning

Hazard statement(s)

H315	Causes skin irritation.
H319	Causes serious eye irritation.
H335	May cause respiratory irritation.

Precautionary statement(s)

P261	Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray.
P264	Wash skin thoroughly after handling.
P280	Wear protective gloves.
P302 + P352	IF ON SKIN: Wash with plenty of soap and water.
P304 + P340	IF INHALED: Remove affected person into fresh air and keep at rest in a position comfortable for breathing.
P332 + P313	If skin irritation occurs: Get medical advice/ attention.

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

---

3. COMPOSITION / INFORMATION ON INGREDIENTS

3.1 Substances

Substance/ mixture Mixture

Ingredient	CAS/Exempt No	Percent	Hazardous
3-(Trifluoromethyl)benzoic acid	454-92-2	10	No
Water	7732-18-5	90	No

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4. FIRST AID MEASURES

4.1 Description of first aid measures

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance. Move out of dangerous area.

If inhaled
Move person into fresh air. If cough or other symptoms develop, consult a physician.

In case of skin contact
Remove contaminated clothing including shoes and immediately wash affected area with plenty of soap and water. If irritation continues, consult a physician. Wash contaminated clothing and shoes before reuse.

In case of eye contact
Immediately flush eyes with plenty of water for two to three minutes. Remove any contact lenses and continue flushing for 15 minutes. If irritation continues, consult a physician.

If swallowed
Wash out mouth with water and keep at rest. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed

The most important known symptoms and effects are described in the labeling (see Section 2.2) and/or in Section 11.

4.3 Indication of any immediate medical attention and special treatment needed

No data available.

5. FIRE FIGHTING MEASURES

5.1 Extinguishing media

Suitable extinguishing media
Use fire-extinguishing media appropriate for surrounding materials.

5.2 Special hazards arising from the substance or mixture

Carbon oxides, halogenated hydrogen gas.

5.3 Advice for firefighters

As in any fire, wear full protective clothing and equipment.

5.4 Further information

No data available.

6. ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures

Use personal protective equipment. Avoid breathing vapours or mist. Evacuate personnel to safe areas.

6.2 Environmental precautions

Do not let product enter drains, if safe to do so.

6.3 Methods and materials for containment and cleanup

Construct temporary dikes of dirt or any appropriate readily available material to prevent spreading of the material. Cover with appropriate absorbent and sweep or shovel into an appropriate container.

6.4 Reference to other sections

For protective clothing, see Section 8. For disposal, see Section 13.

7. HANDLING AND STORAGE

7.1 Precautions for safe handling

Avoid contact with skin and eyes. Avoid formation of aerosols. Provide adequate exhaust ventilation at places where aerosols are formed. For precautions, see Section 2.2. Handle and use in a manner consistent with good industrial/manufacturing techniques and practices.

7.2 Conditions for safe storage

Keep container tightly closed in a dry, cool, and well-ventilated place. Do not store with, or close to, strong acids.

7.3 Specific end uses(s)

Apart from the uses mentioned in Section 1.2, no other specific uses are stipulated.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

8.1 Control parameters

Components with workplace control parameters
No PELs, TLVs, or OELs for this product or its ingredients are listed in the current issue of ACGIH's Guide to Occupational Exposure Values, nor have they been determined by the manufacturer.

8.2 Exposure controls

Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of the workday.

Personal protective equipment

Eye/face protection
Safety glasses with side-shields conforming to EN166. Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN166 (EU).

Skin protection
Handle with chemical-resistant gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Body protection
Impervious clothing. The type of protective equipment must be selected according to the amount of dangerous substance at the specific workplace.

Control of environmental exposure
Do not let product enter drains.

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9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: aqueous liquid Color: translucent
b)	Odor Boiling	Odorless
c)	point Freeze	Approximately 100°C
d)	point	0°C
e)	Density	1.05 g/mL
f)	Flash point	Not flammable
g)	pH	Approximately 9
h)	Evaporation factor	Not determined
i)	Solubility	Soluble in water
j)	Vapor pressure	Not determined
k)	Oxidizing properties	Not determined
l)	Vapor density	Not determined
m)	Viscosity	Not determined

9.2 Other safety information

No data available.

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10. STABILITY AND REACTIVITY

10.1 Reactivity

Strong acids. Oxidizing materials.

10.2 Chemical stability

The product is stable under normal ambient conditions of temperature and pressure.

10.3 Possibility of hazardous reactions

Will not polymerize.

10.4 Conditions to avoid

Extreme cold.

10.5 Incompatible materials

Strong acids. Oxidizing materials.

10.6 Hazardous decomposition products

None.

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11. . TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects

Acute toxicity – oral
Based on available data the classification criteria are not met.

Acute toxicity – dermal
Based on available data the classification criteria are not met.

Acute toxicity – inhalation
Based on available data the classification criteria are not met.

Skin corrosion/irritation
Skin irritant 2 – H315 Causes skin irritation.

Serious eye damage/irritation
Eye irritant 2 – H319 May cause severe eye irritation.

Respiratory sensitization
Based on available data the classification criteria are not met.

Skin sensitization
Based on available data the classification criteria are not met.

Germ cell mutagenicity

Genotoxicity – in vitro
Based on available data the classification criteria are not met.

Genotoxicity- in vivo
Based on available data the classification criteria are not met.

Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible, or confirmed human carcinogen by IARC.

ACGIH: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP

OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity

Reproductive toxicity – fertility
Based on available data the classification criteria are not met.

Reproductive toxicity – development
Based on available data the classification criteria are not met.

Specific target organ toxicity – single exposure
STOT SE 3 – H335 May cause respiratory irritation.

Specific target organ toxicity – repeated exposure
Based on available data the classification criteria are not met.

Aspiration hazard
Not anticipated to present an aspiration hazard, based on chemical structure.

Additional information
RTECS: Not available.

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

12. ECOLOGICAL INFORMATION

12.1 Toxicity

No data available.

12.2 Persistence and degradability

Presumed to be persistent.

12.3 Bioaccumulative potential

No data available.

12.4 Mobility in soil

No data available.

12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment are not available as chemical safety assessment not required/ not conducted.

12.6 Other adverse effects

No data available.

13. DISPOSAL CONSIDERATIONS

13.1 Waste treatment methods

Product
Dispose of at a supervised appropriate waste disposal facility according to current applicable laws and regulations and product characteristics at time of disposal.

Contaminated packaging
Contaminated containers should be cleaned and disposed of in the same manner as the product in accordance with applicable regulations.

14. TRANSPORT INFORMATION

DOT (US)
Not dangerous goods.

IMDG
Not dangerous goods.

IATA
Not dangerous goods.

15. REGULATORY INFORMATION

SARA 302 Components
SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

SARA 311/312 Hazards
SAR 311/312: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 311/312.

CERCLA (Comprehensive Response, Compensation, and Liability Act)
Not Applicable.

TSCA (Toxic Substance Control Act)
The components of this product are in compliance with the chemical notification requirements of TSCA.

16. OTHER INFORMATION

HMIS Rating

Health Hazard:	1
Chronic Health Hazard:	
Flammability:	0
Physical Hazard:	0

NFPA Rating

Health Hazard:	1
Fire Hazard:	0
Reactivity Hazard:	0

MANUFACTURER DISCLAIMER: Information given herein is offered in good faith as accurate, but without guarantee. Conditions of use and suitability of the product for particular uses are beyond our control; all risks of use of the product are therefore assumed by the user. Nothing is intended as a recommendation for uses which infringe valid patents or as extending license under valid patents. Appropriate warnings and safe handling procedures should be provided to handlers and users.

Prepared by: ProTechnics Environmental Compliance Department

Contact information: 713-328-2320

SAFETY DATA SHEET

Date-Issued: 05-2015
SDS Ref. No: CFT
Date-Revised: 5/26/2016
Revision No:002

1. PRODUCT AND COMPANY IDENTIFICATION

1.1 Product Identifiers

Product name	:	3-Fluorobenzoic acid
Generic name	:	3-FBA

1.2 Relevant identified used of the substance or mixture and uses advised against

Identified uses	:	Diagnostic
Uses advised against	:	Not available

1.3 Details of the supplier of the safety data sheet

Importer	:	ProTechnics International Division of Core Laboratories 31-35 George St. Thebarton, SA, AUSTRALIA 5031
Telephone	:	(08) 8152 0244

1.4 Emergency telephone number

Poisons Information Centre	:	13 11 26 (24 hour)
Ambulance, Fire, Police	:	000

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

GHS classification in accordance with 29 CFR 1910 (OSHA HCS)
Skin irritation (Category 2), H315
Eye irritation (Category 2), H319
Specific target organ toxicity – single exposure (Category 3), Respiratory system, H335

2.2 GHS Label elements, including precautionary statements

Pictogram



Signal word Warning

Hazard statement(s)

H315	Causes skin irritation.
H319	Causes serious eye irritation.
H335	May cause respiratory irritation.

Precautionary statement(s)

P261	Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray.
P264	Wash skin thoroughly after handling.
P280	Wear protective gloves.
P302 + P352	IF ON SKIN: Wash with plenty of soap and water.
P304 + P340	IF INHALED: Remove affected person into fresh air and keep at rest in a position comfortable for breathing.
P332 + P313	If skin irritation occurs: Get medical advice/ attention.

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

---

3. COMPOSITION / INFORMATION ON INGREDIENTS

3.1 Substances

Substance/ mixture Mixture

Ingredient	CAS/Exempt No	Percent	Hazardous
3-Fluorobenzoic acid	455-38-9	10	No
Water	7732-18-5	90	No

---

4. FIRST AID MEASURES

4.1 Description of first aid measures

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance. Move out of dangerous area.

If inhaled
Move person into fresh air. If cough or other symptoms develop, consult a physician.

In case of skin contact
Remove contaminated clothing including shoes and immediately wash affected area with plenty of soap and water. If irritation continues, consult a physician. Wash contaminated clothing and shoes before reuse.

In case of eye contact
Immediately flush eyes with plenty of water for two to three minutes. Remove any contact lenses and continue flushing for 15 minutes. If irritation continues, consult a physician.

If swallowed
Wash out mouth with water and keep at rest. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed

The most important known symptoms and effects are described in the labeling (see Section 2.2) and/or in Section 11.

4.3 Indication of any immediate medical attention and special treatment needed

No data available.

5. FIRE FIGHTING MEASURES

5.1 Extinguishing media

Suitable extinguishing media
Use fire-extinguishing media appropriate for surrounding materials.

5.2 Special hazards arising from the substance or mixture

Carbon oxides, halogenated hydrogen gas.

5.3 Advice for firefighters

As in any fire, wear full protective clothing and equipment.

5.4 Further information

No data available.

6. ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures

Use personal protective equipment. Avoid breathing vapours or mist. Evacuate personnel to safe areas.

6.2 Environmental precautions

Do not let product enter drains, if safe to do so.

6.3 Methods and materials for containment and cleanup

Construct temporary dikes of dirt or any appropriate readily available material to prevent spreading of the material. Cover with appropriate absorbent and sweep or shovel into an appropriate container.

6.4 Reference to other sections

For protective clothing, see Section 8. For disposal, see Section 13.

7. HANDLING AND STORAGE

7.1 Precautions for safe handling

Avoid contact with skin and eyes. Avoid formation of aerosols. Provide adequate exhaust ventilation at places where aerosols are formed. For precautions, see Section 2.2. Handle and use in a manner consistent with good industrial/manufacturing techniques and practices.

7.2 Conditions for safe storage

Keep container tightly closed in a dry, cool, and well-ventilated place. Do not store with, or close to, strong acids.

7.3 Specific end uses(s)

Apart from the uses mentioned in Section 1.2, no other specific uses are stipulated.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

8.1 Control parameters

Components with workplace control parameters
No PELs, TLVs, or OELs for this product or its ingredients are listed in the current issue of ACGIH's Guide to Occupational Exposure Values, nor have they been determined by the manufacturer.

8.2 Exposure controls

Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of the workday.

Personal protective equipment

Eye/face protection
Safety glasses with side-shields conforming to EN166. Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN166 (EU).

Skin protection
Handle with chemical-resistant gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Body protection
Impervious clothing. The type of protective equipment must be selected according to the amount of dangerous substance at the specific workplace.

Control of environmental exposure
Do not let product enter drains.

---

9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: aqueous liquid Color: translucent
b)	Odor Boiling	Odorless
c)	point Freeze	Approximately 100°C
d)	point	0°C
e)	Density	1.05 g/mL
f)	Flash point	Not flammable
g)	pH	Approximately 9
h)	Evaporation factor	Not determined
i)	Solubility	Soluble in water
j)	Vapor pressure	Not determined
k)	Oxidizing properties	Not determined
l)	Vapor density	Not determined
m)	Viscosity	Not determined

9.2 Other safety information

No data available.

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10. STABILITY AND REACTIVITY

10.1 Reactivity

Strong acids. Oxidizing materials.

10.2 Chemical stability

The product is stable under normal ambient conditions of temperature and pressure.

10.3 Possibility of hazardous reactions

Will not polymerize.

10.4 Conditions to avoid

Extreme cold.

10.5 Incompatible materials

Strong acids. Oxidizing materials.

10.6 Hazardous decomposition products

None.

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11. . TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects

Acute toxicity – oral
Based on available data the classification criteria are not met.

Acute toxicity – dermal
Based on available data the classification criteria are not met.

Acute toxicity – inhalation
Based on available data the classification criteria are not met.

Skin corrosion/irritation
Skin irritant 2 – H315 Causes skin irritation.

Serious eye damage/irritation
Eye irritant 2 – H319 May cause severe eye irritation.

Respiratory sensitization
Based on available data the classification criteria are not met.

Skin sensitization
Based on available data the classification criteria are not met.

Germ cell mutagenicity

Genotoxicity – in vitro
Based on available data the classification criteria are not met.

Genotoxicity- in vivo
Based on available data the classification criteria are not met.

Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible, or confirmed human carcinogen by IARC.

ACGIH: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP

OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity

Reproductive toxicity – fertility
Based on available data the classification criteria are not met.

Reproductive toxicity – development
Based on available data the classification criteria are not met.

Specific target organ toxicity – single exposure
STOT SE 3 – H335 May cause respiratory irritation.

Specific target organ toxicity – repeated exposure
Based on available data the classification criteria are not met.

Aspiration hazard
Not anticipated to present an aspiration hazard, based on chemical structure.

Additional information
RTECS: Not available.

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

12. ECOLOGICAL INFORMATION

12.1 Toxicity

No data available.

12.2 Persistence and degradability

Presumed to be persistent.

12.3 Bioaccumulative potential

No data available.

12.4 Mobility in soil

No data available.

12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment are not available as chemical safety assessment not required/ not conducted.

12.6 Other adverse effects

No data available.

13. DISPOSAL CONSIDERATIONS

13.1 Waste treatment methods

Product
Dispose of at a supervised appropriate waste disposal facility according to current applicable laws and regulations and product characteristics at time of disposal.

Contaminated packaging
Contaminated containers should be cleaned and disposed of in the same manner as the product in accordance with applicable regulations.

14. TRANSPORT INFORMATION

DOT (US)
Not dangerous goods.

IMDG
Not dangerous goods.

IATA
Not dangerous goods.

15. REGULATORY INFORMATION

SARA 302 Components
SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

SARA 311/312 Hazards
SAR 311/312: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 311/312.

CERCLA (Comprehensive Response, Compensation, and Liability Act)
Not Applicable.

TSCA (Toxic Substance Control Act)
The components of this product are in compliance with the chemical notification requirements of TSCA.

16. OTHER INFORMATION

HMIS Rating

Health Hazard:	1
Chronic Health Hazard:	
Flammability:	0
Physical Hazard:	0

NFPA Rating

Health Hazard:	1
Fire Hazard:	0
Reactivity Hazard:	0

MANUFACTURER DISCLAIMER: Information given herein is offered in good faith as accurate, but without guarantee. Conditions of use and suitability of the product for particular uses are beyond our control; all risks of use of the product are therefore assumed by the user. Nothing is intended as a recommendation for uses which infringe valid patents or as extending license under valid patents. Appropriate warnings and safe handling procedures should be provided to handlers and users.

Prepared by: ProTechnics Environmental Compliance Department

Contact information: 713-328-2320

SAFETY DATA SHEET

Date-Issued: 05-2015
SDS Ref. No: CFT
Date-Revised: 5/26/2016
Revision No:002

1. PRODUCT AND COMPANY IDENTIFICATION

1.1 Product Identifiers

Product name	:	2-(Trifluoromethyl)benzoic acid
Generic name	:	2-TFMBA

1.2 Relevant identified used of the substance or mixture and uses advised against

Identified uses	:	Diagnostic
Uses advised against	:	Not available

1.3 Details of the supplier of the safety data sheet

Importer	:	ProTechnics International Division of Core Laboratories 31-35 George St. Thebarton, SA, AUSTRALIA 5031
Telephone	:	(08) 8152 0244

1.4 Emergency telephone number

Poisons Information Centre	:	13 11 26 (24 hour)
Ambulance, Fire, Police	:	000

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

GHS classification in accordance with 29 CFR 1910 (OSHA HCS)
Skin irritation (Category 2), H315
Eye irritation (Category 2), H319
Specific target organ toxicity – single exposure (Category 3), Respiratory system, H335

2.2 GHS Label elements, including precautionary statements

Pictogram



Signal word Warning

Hazard statement(s)

H315	Causes skin irritation.
H319	Causes serious eye irritation.
H335	May cause respiratory irritation.

Precautionary statement(s)

P261	Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray.
P264	Wash skin thoroughly after handling.
P280	Wear protective gloves.
P302 + P352	IF ON SKIN: Wash with plenty of soap and water.
P304 + P340	IF INHALED: Remove affected person into fresh air and keep at rest in a position comfortable for breathing.
P332 + P313	If skin irritation occurs: Get medical advice/ attention.

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

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3. COMPOSITION / INFORMATION ON INGREDIENTS

3.1 Substances

Substance/ mixture Mixture

Ingredient	CAS/Exempt No	Percent	Hazardous
2-(Trifluoromethyl)benzoic acid	433-97-6	10	No
Water	7732-18-5	90	No

---

4. FIRST AID MEASURES

4.1 Description of first aid measures

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance. Move out of dangerous area.

If inhaled
Move person into fresh air. If cough or other symptoms develop, consult a physician.

In case of skin contact
Remove contaminated clothing including shoes and immediately wash affected area with plenty of soap and water. If irritation continues, consult a physician. Wash contaminated clothing and shoes before reuse.

In case of eye contact
Immediately flush eyes with plenty of water for two to three minutes. Remove any contact lenses and continue flushing for 15 minutes. If irritation continues, consult a physician.

If swallowed
Wash out mouth with water and keep at rest. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed

The most important known symptoms and effects are described in the labeling (see Section 2.2) and/or in Section 11.

4.3 Indication of any immediate medical attention and special treatment needed

No data available.

5. FIRE FIGHTING MEASURES

5.1 Extinguishing media

Suitable extinguishing media
Use fire-extinguishing media appropriate for surrounding materials.

5.2 Special hazards arising from the substance or mixture

Carbon oxides, halogenated hydrogen gas.

5.3 Advice for firefighters

As in any fire, wear full protective clothing and equipment.

5.4 Further information

No data available.

6. ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures

Use personal protective equipment. Avoid breathing vapours or mist. Evacuate personnel to safe areas.

6.2 Environmental precautions

Do not let product enter drains, if safe to do so.

6.3 Methods and materials for containment and cleanup

Construct temporary dikes of dirt or any appropriate readily available material to prevent spreading of the material. Cover with appropriate absorbent and sweep or shovel into an appropriate container.

6.4 Reference to other sections

For protective clothing, see Section 8. For disposal, see Section 13.

7. HANDLING AND STORAGE

7.1 Precautions for safe handling

Avoid contact with skin and eyes. Avoid formation of aerosols. Provide adequate exhaust ventilation at places where aerosols are formed. For precautions, see Section 2.2. Handle and use in a manner consistent with good industrial/manufacturing techniques and practices.

7.2 Conditions for safe storage

Keep container tightly closed in a dry, cool, and well-ventilated place. Do not store with, or close to, strong acids.

7.3 Specific end uses(s)

Apart from the uses mentioned in Section 1.2, no other specific uses are stipulated.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

8.1 Control parameters

Components with workplace control parameters
No PELs, TLVs, or OELs for this product or its ingredients are listed in the current issue of ACGIH's Guide to Occupational Exposure Values, nor have they been determined by the manufacturer.

8.2 Exposure controls

Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of the workday.

Personal protective equipment

Eye/face protection
Safety glasses with side-shields conforming to EN166. Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN166 (EU).

Skin protection
Handle with chemical-resistant gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Body protection
Impervious clothing. The type of protective equipment must be selected according to the amount of dangerous substance at the specific workplace.

Control of environmental exposure
Do not let product enter drains.

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9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: aqueous liquid Color: translucent
b)	Odor Boiling	Odorless
c)	point Freeze	Approximately 100°C
d)	point	0°C
e)	Density	1.05 g/mL
f)	Flash point	Not flammable
g)	pH	Approximately 9
h)	Evaporation factor	Not determined
i)	Solubility	Soluble in water
j)	Vapor pressure	Not determined
k)	Oxidizing properties	Not determined
l)	Vapor density	Not determined
m)	Viscosity	Not determined

9.2 Other safety information

No data available.

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10. STABILITY AND REACTIVITY

10.1 Reactivity

Strong acids. Oxidizing materials.

10.2 Chemical stability

The product is stable under normal ambient conditions of temperature and pressure.

10.3 Possibility of hazardous reactions

Will not polymerize.

10.4 Conditions to avoid

Extreme cold.

10.5 Incompatible materials

Strong acids. Oxidizing materials.

10.6 Hazardous decomposition products

None.

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11. . TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects

Acute toxicity – oral
Based on available data the classification criteria are not met.

Acute toxicity – dermal
Based on available data the classification criteria are not met.

Acute toxicity – inhalation
Based on available data the classification criteria are not met.

Skin corrosion/irritation
Skin irritant 2 – H315 Causes skin irritation.

Serious eye damage/irritation
Eye irritant 2 – H319 May cause severe eye irritation.

Respiratory sensitization
Based on available data the classification criteria are not met.

Skin sensitization
Based on available data the classification criteria are not met.

Germ cell mutagenicity

Genotoxicity – in vitro
Based on available data the classification criteria are not met.

Genotoxicity- in vivo
Based on available data the classification criteria are not met.

Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible, or confirmed human carcinogen by IARC.

ACGIH: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP

OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity

Reproductive toxicity – fertility
Based on available data the classification criteria are not met.

Reproductive toxicity – development
Based on available data the classification criteria are not met.

Specific target organ toxicity – single exposure
STOT SE 3 – H335 May cause respiratory irritation.

Specific target organ toxicity – repeated exposure
Based on available data the classification criteria are not met.

Aspiration hazard
Not anticipated to present an aspiration hazard, based on chemical structure.

Additional information
RTECS: Not available.

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

12. ECOLOGICAL INFORMATION

12.1 Toxicity

No data available.

12.2 Persistence and degradability

Presumed to be persistent.

12.3 Bioaccumulative potential

No data available.

12.4 Mobility in soil

No data available.

12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment are not available as chemical safety assessment not required/ not conducted.

12.6 Other adverse effects

No data available.

13. DISPOSAL CONSIDERATIONS

13.1 Waste treatment methods

Product
Dispose of at a supervised appropriate waste disposal facility according to current applicable laws and regulations and product characteristics at time of disposal.

Contaminated packaging
Contaminated containers should be cleaned and disposed of in the same manner as the product in accordance with applicable regulations.

14. TRANSPORT INFORMATION

DOT (US)
Not dangerous goods.

IMDG
Not dangerous goods.

IATA
Not dangerous goods.

15. REGULATORY INFORMATION

SARA 302 Components
SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

SARA 311/312 Hazards
SAR 311/312: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 311/312.

CERCLA (Comprehensive Response, Compensation, and Liability Act)
Not Applicable.

TSCA (Toxic Substance Control Act)
The components of this product are in compliance with the chemical notification requirements of TSCA.

16. OTHER INFORMATION

HMIS Rating

Health Hazard:	1
Chronic Health Hazard:	
Flammability:	0
Physical Hazard:	0

NFPA Rating

Health Hazard:	1
Fire Hazard:	0
Reactivity Hazard:	0

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Prepared by: ProTechnics Environmental Compliance Department

Contact information: 713-328-2320

SAFETY DATA SHEET

Date-Issued: 05-2015
SDS Ref. No: CFT
Date-Revised: 5/26/2016
Revision No:002

1. PRODUCT AND COMPANY IDENTIFICATION

1.1 Product Identifiers

Product name	:	2-Fluorobenzoic acid
Generic name	:	2-FBA

1.2 Relevant identified used of the substance or mixture and uses advised against

Identified uses	:	Diagnostic
Uses advised against	:	Not available

1.3 Details of the supplier of the safety data sheet

Importer	:	ProTechnics International Division of Core Laboratories 31-35 George St. Thebarton, SA, AUSTRALIA 5031
Telephone	:	(08) 8152 0244

1.4 Emergency telephone number

Poisons Information Centre	:	13 11 26 (24 hour)
Ambulance, Fire, Police	:	000

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

GHS classification in accordance with 29 CFR 1910 (OSHA HCS)
Skin irritation (Category 2), H315
Eye irritation (Category 2), H319
Specific target organ toxicity – single exposure (Category 3), Respiratory system, H335

2.2 GHS Label elements, including precautionary statements

Pictogram



Signal word Warning

Hazard statement(s)

H315	Causes skin irritation.
H319	Causes serious eye irritation.
H335	May cause respiratory irritation.

Precautionary statement(s)

P261	Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray.
P264	Wash skin thoroughly after handling.
P280	Wear protective gloves.
P302 + P352	IF ON SKIN: Wash with plenty of soap and water.
P304 + P340	IF INHALED: Remove affected person into fresh air and keep at rest in a position comfortable for breathing.
P332 + P313	If skin irritation occurs: Get medical advice/ attention.

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

---

3. COMPOSITION / INFORMATION ON INGREDIENTS

3.1 Substances

Substance/ mixture Mixture

Ingredient	CAS/Exempt No	Percent	Hazardous
2-Fluorobenzoic acid	445-29-4	10	No
Water	7732-18-5	90	No

---

4. FIRST AID MEASURES

4.1 Description of first aid measures

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance. Move out of dangerous area.

If inhaled
Move person into fresh air. If cough or other symptoms develop, consult a physician.

In case of skin contact
Remove contaminated clothing including shoes and immediately wash affected area with plenty of soap and water. If irritation continues, consult a physician. Wash contaminated clothing and shoes before reuse.

In case of eye contact
Immediately flush eyes with plenty of water for two to three minutes. Remove any contact lenses and continue flushing for 15 minutes. If irritation continues, consult a physician.

If swallowed
Wash out mouth with water and keep at rest. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed

The most important known symptoms and effects are described in the labeling (see Section 2.2) and/or in Section 11.

4.3 Indication of any immediate medical attention and special treatment needed

No data available.

5. FIRE FIGHTING MEASURES

5.1 Extinguishing media

Suitable extinguishing media
Use fire-extinguishing media appropriate for surrounding materials.

5.2 Special hazards arising from the substance or mixture

Carbon oxides, halogenated hydrogen gas.

5.3 Advice for firefighters

As in any fire, wear full protective clothing and equipment.

5.4 Further information

No data available.

6. ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures

Use personal protective equipment. Avoid breathing vapours or mist. Evacuate personnel to safe areas.

6.2 Environmental precautions

Do not let product enter drains, if safe to do so.

6.3 Methods and materials for containment and cleanup

Construct temporary dikes of dirt or any appropriate readily available material to prevent spreading of the material. Cover with appropriate absorbent and sweep or shovel into an appropriate container.

6.4 Reference to other sections

For protective clothing, see Section 8. For disposal, see Section 13.

7. HANDLING AND STORAGE

7.1 Precautions for safe handling

Avoid contact with skin and eyes. Avoid formation of aerosols. Provide adequate exhaust ventilation at places where aerosols are formed. For precautions, see Section 2.2. Handle and use in a manner consistent with good industrial/manufacturing techniques and practices.

7.2 Conditions for safe storage

Keep container tightly closed in a dry, cool, and well-ventilated place. Do not store with, or close to, strong acids.

7.3 Specific end uses(s)

Apart from the uses mentioned in Section 1.2, no other specific uses are stipulated.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

8.1 Control parameters

Components with workplace control parameters
No PELs, TLVs, or OELs for this product or its ingredients are listed in the current issue of ACGIH's Guide to Occupational Exposure Values, nor have they been determined by the manufacturer.

8.2 Exposure controls

Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of the workday.

Personal protective equipment

Eye/face protection
Safety glasses with side-shields conforming to EN166. Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN166 (EU).

Skin protection
Handle with chemical-resistant gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Body protection
Impervious clothing. The type of protective equipment must be selected according to the amount of dangerous substance at the specific workplace.

Control of environmental exposure
Do not let product enter drains.

---

9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: aqueous liquid Color: translucent
b)	Odor Boiling	Odorless
c)	point Freeze	Approximately 100°C
d)	point	0°C
e)	Density	1.05 g/mL
f)	Flash point	Not flammable
g)	pH	Approximately 9
h)	Evaporation factor	Not determined
i)	Solubility	Soluble in water
j)	Vapor pressure	Not determined
k)	Oxidizing properties	Not determined
l)	Vapor density	Not determined
m)	Viscosity	Not determined

9.2 Other safety information

No data available.

---

10. STABILITY AND REACTIVITY

10.1 Reactivity

Strong acids. Oxidizing materials.

10.2 Chemical stability

The product is stable under normal ambient conditions of temperature and pressure.

10.3 Possibility of hazardous reactions

Will not polymerize.

10.4 Conditions to avoid

Extreme cold.

10.5 Incompatible materials

Strong acids. Oxidizing materials.

10.6 Hazardous decomposition products

None.

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11. . TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects

Acute toxicity – oral
Based on available data the classification criteria are not met.

Acute toxicity – dermal
Based on available data the classification criteria are not met.

Acute toxicity – inhalation
Based on available data the classification criteria are not met.

Skin corrosion/irritation
Skin irritant 2 – H315 Causes skin irritation.

Serious eye damage/irritation
Eye irritant 2 – H319 May cause severe eye irritation.

Respiratory sensitization
Based on available data the classification criteria are not met.

Skin sensitization
Based on available data the classification criteria are not met.

Germ cell mutagenicity

Genotoxicity – in vitro
Based on available data the classification criteria are not met.

Genotoxicity- in vivo
Based on available data the classification criteria are not met.

Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible, or confirmed human carcinogen by IARC.

ACGIH: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP

OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity

Reproductive toxicity – fertility
Based on available data the classification criteria are not met.

Reproductive toxicity – development
Based on available data the classification criteria are not met.

Specific target organ toxicity – single exposure
STOT SE 3 – H335 May cause respiratory irritation.

Specific target organ toxicity – repeated exposure
Based on available data the classification criteria are not met.

Aspiration hazard
Not anticipated to present an aspiration hazard, based on chemical structure.

Additional information
RTECS: Not available.

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

12. ECOLOGICAL INFORMATION

12.1 Toxicity

No data available.

12.2 Persistence and degradability

Presumed to be persistent.

12.3 Bioaccumulative potential

No data available.

12.4 Mobility in soil

No data available.

12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment are not available as chemical safety assessment not required/ not conducted.

12.6 Other adverse effects

No data available.

13. DISPOSAL CONSIDERATIONS

13.1 Waste treatment methods

Product
Dispose of at a supervised appropriate waste disposal facility according to current applicable laws and regulations and product characteristics at time of disposal.

Contaminated packaging
Contaminated containers should be cleaned and disposed of in the same manner as the product in accordance with applicable regulations.

14. TRANSPORT INFORMATION

DOT (US)
Not dangerous goods.

IMDG
Not dangerous goods.

IATA
Not dangerous goods.

15. REGULATORY INFORMATION

SARA 302 Components
SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

SARA 311/312 Hazards
SAR 311/312: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 311/312.

CERCLA (Comprehensive Response, Compensation, and Liability Act)
Not Applicable.

TSCA (Toxic Substance Control Act)
The components of this product are in compliance with the chemical notification requirements of TSCA.

16. OTHER INFORMATION

HMIS Rating

Health Hazard:	1
Chronic Health Hazard:	
Flammability:	0
Physical Hazard:	0

NFPA Rating

Health Hazard:	1
Fire Hazard:	0
Reactivity Hazard:	0

MANUFACTURER DISCLAIMER: Information given herein is offered in good faith as accurate, but without guarantee. Conditions of use and suitability of the product for particular uses are beyond our control; all risks of use of the product are therefore assumed by the user. Nothing is intended as a recommendation for uses which infringe valid patents or as extending license under valid patents. Appropriate warnings and safe handling procedures should be provided to handlers and users.

Prepared by: ProTechnics Environmental Compliance Department

Contact information: 713-328-2320

MEMO

To: Deirdre Crilly

From: Tom Biksey

CC: Nigel Goulding

Date: October 23, 2018

Re: **NALCO® EC1331A Arcadia Irrigation Hazard Assessment and Screening Evaluation**

Introduction

Santos GLNG (Santos) is proposing to use a new combined biocide and corrosion inhibitor NALCO® EC1331A to manage biogrowth and CO_2 corrosion in their compressors throughout the blended amended irrigation water management system. This Technical Memo will assess the potential exposure to human and environmental receptors during the beneficial reuse of blended amended water for irrigation, and specifically to Benzyl-(C12-C16 Linear Alkyl)-Dimethyl-Ammonium Chloride (ADBAC), which is the primary chemical in NALCO® EC1331A. The objective of the Technical Memo is to confirm the long-term suitability of using NALCO® EC1331A in the blended amended irrigation water using a qualitative chemical risk assessment process. Because of the significant dilution of ADBAC throughout the blended amended irrigation water management system before beneficial reuse for irrigation, a quantitative chemical risk assessment process was not necessary.

Qualitative Assessment

The qualitative assessment includes exposure to ADBAC that may occur during activities that do not intentionally result in a release to the environment, but where a potential release may occur. These potential releases primarily are focused on ADBAC used in the beneficial reuse of blended produced water for irrigation water including during transportation and mixing preparation activities at the compressor station. Potential exposure to ADBAC may occur as a result of release from shipping containers and storage tanks either during transport from supplier warehouse to compressor station, storage and preparation of ADBAC blending at the compressor station, or during irrigation application. Potential complete exposure scenarios for the intended release by irrigation of agricultural areas includes direct contact by workers applying the irrigation waters, and aquatic and terrestrial environmental receptors that come in contact with the irrigation waters and the soils in the fields.

Summary Information on ADBAC

Human health and environmental profiles were prepared for ADBAC (Attachment 1) to compile toxicological, chemical, and regulatory information. In addition, the profiles were used to develop initial screening criteria for human health and environmental exposure scenarios. ADBAC is readily biodegradable (half life = 15 days); will strongly adsorb on soil and sediments; and has a low potential to bioaccumulate. It has moderate acute toxicity by the oral routes. ADBAC is corrosive. It is not a skin sensitizer. No target organ effects were seen in rodents from repeated oral or dermal exposure. ADBAC is not carcinogenic to rodents; nor does it show genotoxic potential. Animals studies show no reproductive or developmental effects from oral exposures to ADBAC. ADBAC is highly toxic to aquatic organisms. It is moderately toxic to birds on an acute basis.

A summary of potential human health and ecological hazards that should be considered for the potential exposure during activities that do not intentionally result in a release to the environment, but where a potential release may occur, as noted above, for human health and environmental receptors. Where a potential hazard exists, additional information is provided in the human health and environmental profiles and the Safety Data Sheet (SDS) and product information for NALCO® EC1331A (Attachment 2) are available to emergency responders, health and safety managers, and environmental hazard clean-up teams.

Chemical Name	CAS No.	Australian Dangerous Goods Code	Human Health Hazard	Ecological Hazard
Benzyl-(C12-C16 linear alkyl)-dimethyl-ammonium chloride	68424-85-1	Class 8 [Corrosive Substance]*	Corrosive	Very toxic to aquatic life. Very toxic to aquatic life with long lasting effects.

*Environmentally hazardous substance.

A PBT (persistence, bioaccumulative, toxic) assessment was conducted in accordance with the guidance developed by DEWHA (2009), as presented in the RA Compendium. The PBT assessment is conducted because of specific concerns for substances that can be shown to persist for long periods in the environment, to bioaccumulate in food chains, and can give rise to toxic effects after a longer time and over a greater spatial scale than chemicals without these properties. These effects may be difficult to detect at an early stage because of long-term exposures at normally low concentration levels and long life-cycles of species at the top of the food chain. The following summarizes the results of the PBT assessment, and presents the overall conclusion that ADBAC is not a PBT.

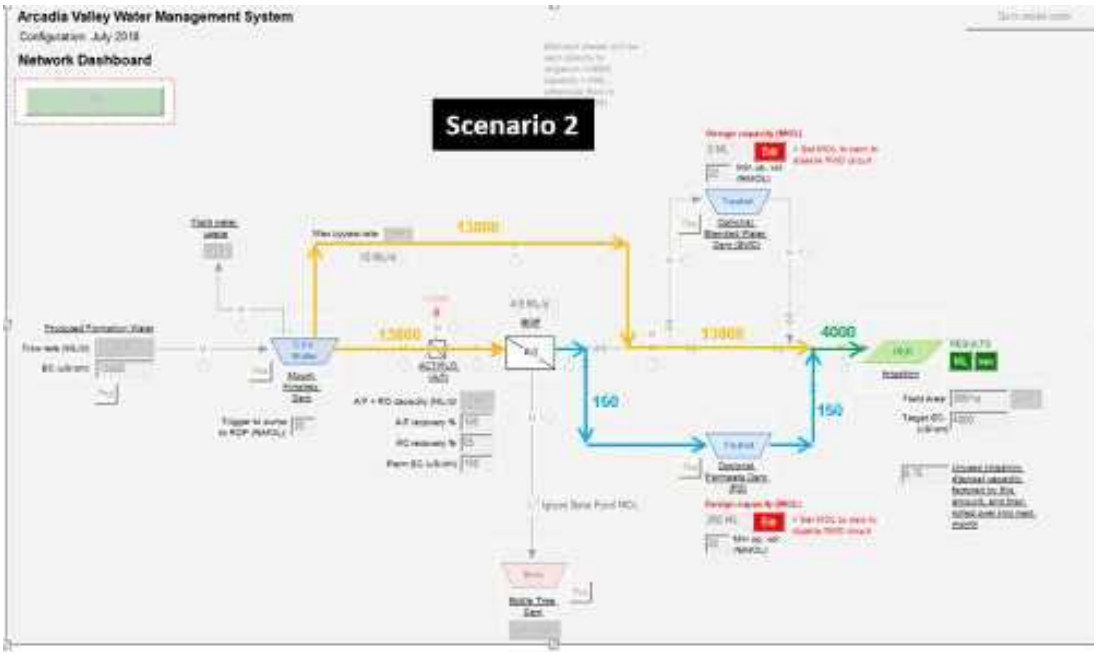
Substance	P/vP criteria fulfilled?	B/vB criteria fulfilled?	T criteria fulfilled?	Overall conclusion
ADBAC	No (screening data available)	No (experimental data available)	Yes (experimental data available)	Not PBT (based on screening and experimental data)

Mass balance

The theoretical exposure point concentration (EPC) was assessed based on risk-based screening values developed from the available toxicological data presented in the profiles (Attachment 1). The calculation of the EPC is based on the current understanding of the blended amended irrigation water management system as provided below.

The blended amended water for irrigation is generated using partially RO-treated (14,000 us/cm) water to generate a 4,000 us/cm blend. Low (5 L/d) and high (12 L/d) dose scenarios were modelled to provide a range of operational efficacy dosing scenarios. Produced water containing ADBAC will be processed through an oily water separator with bentonite, stored in a CSG feed dam, partially processed through the ROP, and then used as blended amended water for irrigation. Approximately 1 to 3 mg/l of reagent agent is being dosed (5 -12 L of reagent being added to 4.5 million litres of water

being treated). The ADBAC portion is 0.3 to 1 mg/l of the NALCO® EC1331A product (10 – 30% concentration of the ADBAC from SDS). Approximately 99 percent of ADBAC is rejected (i.e., small compound) with only 0.003 and 0.01 mg/l of ADBAC remaining in the permeate. The process flow diagram below shows 4 million litres of permeate blended with 10 million litres of raw water resulting in an additional 2.5 fold dilution.



The resulting EPCs (without biodecay) for aquatic exposures are 0.004 mg/L for the low dose scenario, and 0.0012 mg/L for the high dosing scenario in the blended permeate and raw water (final effluent to irrigation). Mass loss will occur in the ponds with around 50 days of retention time and ultimately in the soil column with biodecay and mass losses. As noted in the toxicological summary, ADBAC is readily biodegradable (half life = 15 days); will strongly adsorb on soil and sediments; and has a low potential to bioaccumulate. Using the 50 days of retention time in the ponds and a half life = 15 day, the EPCs for aquatic exposure are 0.0004 mg/L for the low dose scenario to 0.00012 mg/L for the high dose.

A highly conservative scenario was also assessed where 0.5 ML of water was treated with the same volumes of chemicals (as an alternative to the 4.5 ML) and then blended at a ratio of 1:2.5 with untreated water. This would lead to an increase in the EPC (pre-biodegradation) of approximately 10 fold but critically would lead to a 9 fold increase in hold times and degradation rates within the holding ponds). The net effect of this process would be that the EPC in the water being applied to land would be technically unchanged. However, using the 50 days of retention time in the ponds (same as previous) and a half life = 15 day, the EPCs for aquatic exposure to the 0.5 ML treated conservative scenario are 0.004 mg/L for the low dose scenario to 0.0012 mg/L for the high dose.

For potential soil exposure from a concentration of ADBAC in irrigation water for the original 4.5 ML treated water scenario, the approximate irrigation rate (high range) of 10 million litres/ha/yr is assumed. In addition, a soil assimilative thickness of 150 mm consistent with the ANZECC Cumulative Contaminant Loading (CCL) calculations and a soil density of 1.45g/cc is assumed. The estimated mass of ADBAC in soil will be as follows:

- Soil mass = 2,175,000 kg
- Concentrations of reagent = 0.00012 mg/L/0.0005 mg/L

- Volume of water per ha = 10,000,000 litres
- Mass of contaminant = 1.2 g/5g
- Mass in soil = 5.51 x 10^{-10} mg/kg/2.3 x 10^{-9} mg/kg

Comparison to Risk-Based Screening Criteria

The EPCs were compared to risk-based screening criteria based on the screening process presented in the RA Compendium using drinking water criteria and predicted no-effects concentration (PNEC) for potential ADBAC exposure. The following tables summarize the toxicological information presented in the human health and environmental profiles (Attachment 1).

Oral Reference Dose and Drinking Water Guidance Value

Constituent (CAS No.)	Study	Critical Effect/Target Organ(s)	Oral Reference Dose (mg/kg-day)	Drinking Water Guideline (mg/L)
ADBAC (68424-85-1)	2-yr rat oral study	Decreased body weights and body weight gain (NOAEL = 44 mg/kg-day)	0.4	1.5

PNEC Values for ADBAC (CAS No. 68424-85-1)

	Endpoint	EC_{50} or NOEC	Assessment Factor	Value
$PNEC_{water}$	Chronic *Daphnia*	0.00415	10	0.000415 mg/L
$PNEC_{soil}$	Acute plant	277	100	0.28 mg/kg dry weight

Comparing the EPC concentrations for the 4.5 ML treated water scenarios of low and high dose of ADBAC to the calculated drinking water criteria and PNEC values for soil and sediment indicate there were no unacceptable ADBAC EPC concentrations based on the human health drinking water standard and the PNECs. However, the highly conservative 0.5 ML treated water scenario did have unacceptable ADBAC EPC concentrations when compared to the $PNEC_{water}$ value. It is noted that there is a lack of waterways adjacent to the irrigation sites that would be habitat to support a breeding and foraging aquatic community, therefore the potential probability of an adverse aquatic community affect is very low.

The primary exposure route would be for beef cattle via soil ingestion. To address this exposure pathway, a TRV_{cattle} of 7.3 mg/kg-day was calculated from the ADBAC profiles and compared to the ADBAC-dose intake exposure equation using the methodologies including exposure assumptions for beef cattle from the RA Compendium. The potential risk to beef cattle from soil ingestion of soils irrigated with ADBAC would be acceptable due to the very low levels of ADBAC in the modelled soils.

Summary

The potential complete exposure scenarios for the intended release of ADBAC-containing water by irrigation of agricultural areas were assessed. The assessment included a summary of potential human health and ecological hazards, and the findings that ADBAC is not a PBT. A mass balance was conducted on 4.5 ML and 0.5 ML treated water scenarios using two dosing schemes to estimate EPCs

for the workers coming in direct contact with the irrigation water during application, and the aquatic and terrestrial environmental receptors that come in contact with the irrigation waters and the soils in the fields (including beef cattle). All exposures to ADBAC are acceptable and sustainable for the 4.5 ML treated water scenario. It is noted the workers were evaluated based on drinking water standards, which was highly conservative and show the low potential for risk. For the 0.5 ML treated water scenario, only the $PNEC_{water}$ exposure, which has low probability of occurring due to the lack of habitat suitable waterways.

References

Australian Agency Party Ltd. (2009). Environmental Risk Assessment Guidance Manual for Industrial Chemicals, Commonwealth of Australia.

DEWHA. 2009. Environmental risk assessment guidance manual for industrial chemicals, Department of the Environment, Water, Heritage and the Arts, Commonwealth of Australia.

National Environmental Protection (Assessment of Site Contamination) Measure 1999. (National Environment Protection Council); and Monitoring and Sampling Manual 2009, Environmental Protection (Water) Policy 2009, DERM, Version 1, September 2009.

Santos GLNG Projects. 2016. Santos GLNG. Upstream Hydraulic Fracturing Risk Assessment Compendium of Assessed Fluid Systems

ATTACHMENT 1 – HUMAN HEALTH AND ENVIRONMENTAL ASSESSMEMNT PROFILES

Environmental Assessment

Benzyl-(C12-C16 linear alkyl)-Dimethyl-Ammonium Chloride
Alkyl (C_{12-16}) Dimethylbenzyl Ammonium Chloride [ADBAC]
(CAS No. 68424-85-1)

Biodegradation

ADBAC is considered to be readily biodegradable, although no data was provided (EU, 2012). Didecyldimethylammonium chloride (DDAC), a structural analog of ADBAC, showed 83.3% CO_2 evolution after 28 days in a simulated sewage treatment system. A biodegradation study in two water/sediment systems has been conducted on DDAC. DDAC easily migrated from the aqueous phase to the sediment phase and was easily adsorbed to sediments (high K_{oc}). The degradation in the sediment did not increase very much after the first month and the DT_{50} of the total system was not reached within the 120 days test duration (EU, 2012).

Bioaccumulation

The measured BCF in bluegill fish (whole body) after 36 days (35-day exposure plus 21-day depuration) was determined to be 79, with BCF values for edible tissues and non-edible tissues being 33 and 160, respectively (EU, 2012). Thus, ADBAC has a low potential for bioaccumulation (EU, 2012).

Aquatic Toxicity

Table 1 lists the results of acute aquatic toxicity studies on ADBAC.

Table 1: Acute Aquatic Toxicity Studies on ADBAC

Test Species	Endpoint	Results (mg a.i./L)	Klimisch score	Reference
Pimephales promelas	96-hr LC_{50}	0.28	2	EPA, 2006a; EU, 2012
Daphnia magna	48-hr EC_{50}	0.0058	2	EPA, 2006a; EU, 2012
Selenastrum capricornutum	72-hr EC_{50}	0.049	2	EU, 2012

The chronic aquatic toxicity studies on ADBAC are listed in Table 2.

Table 2: Chronic Aquatic Toxicity Studies on ADBAC

Test Species	Endpoint	Results (mg a.i./L)	Kl. score	Reference
Pimephales promelas	24-d NOEC	0.0322	2	EPA, 2006a,b; EU, 2012
Daphnia magna	21-d NOEC	≥0.00415	2	EPA, 2006a,b; EU, 2012
Selenastrum capricornutum	EC_{10}	0.009	2	EU, 2012
Lemna gibba	7-d EC_{50}	0.25	2	EU, 2012

Sediment Toxicity

The 28-day NOEC for the midge *Chironomus tentans* is 520 mg/kg dry weight (EU, 2012) [Kl. score = 2].

Terrestrial Toxicity

Table 3 lists the results of toxicity studies conducted on glutaraldehyde with earthworms, soil microorganisms, and birds.

Table 3: Terrestrial Toxicity Studies on ADBAC

Test Species (method)	Endpoint	Results	Kl. score	Reference
Earthworm *Eisenia fetida*	14-d LC_{50}	7,070 mg/kg soil dw	2	EU, 2012
Mustard plant	18-20-d EC_{50}	277 mg/kg soil dw	2	EU, 2012
Soil microorganisms	28-d EC_{50} 28-d EC_{50}	>1,000 mg/kg soil dw* >1,000 mg/kg soil dw**	2	EU, 2012
Northern bobwhite quail	Acute LC_{50}	164 mg/kg	2	EU, 2012
Northern bobwhite quail	Dietary LC_{50}	>3,813 mg/kg	2	EU, 2012
Mallard duck	Dietary LC_{50}	>2,463 mg/kg	2	EU, 2012

*Nitrogen transformation.
**Carbon transformation.

Derivation of PNECs

$PNEC_{water}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for fish (0.28 mg/L), *Daphnia* (0.0058 mg/L), and algae (0.049 mg/L). Results from chronic studies are also available for all three trophic levels, with the lowest NOEC or EC_{10} value being 0.00415 mg/L for invertebrates. On the basis that the data consists of short-term and long-term results from three trophic levels, an assessment factor of 10 has been applied to the lowest reported NOEC of 0.00415 mg/L for invertebrates. The $PNEC_{water}$ is 0.000415 mg/L or 0.415 µg/L.

$PNEC_{sediment}$: Experimental results are available for one sediment dwelling organism. In a chronic sediment-spiked test with *Chironomus tentans*, the 28-day NOEC was 520 mg/kg dry weight. Using an assessment factor of 100, the $PNEC_{sediment}$ was determined to 5.2 mg/kg dry weight.

$PNEC_{soil}$: Experimental results are available for three trophic levels. Acute $E(L)C_{50}$ values are available for earthworms (7,070 mg/kg dry weight) and plants (277 mg/kg dry weight). A long-term study has also been conducted on soil organisms. On the basis that the data consists of acute tests from two trophic levels and a long-term test on one trophic level, as assessment factor 100 has been applied to the lowest reported $E(L)C_{50}$ value of 277 mg/kg dry weight for plants. The $PNEC_{soil}$ is 0.28 mg/kg dry weight.

PBT Assessment

ADBAC is readily biodegradable; thus, it does not meet the screening criteria for persistence.

The measured BCF for ADBAC is 79; thus, ADBAC does not meet the screening criteria for bioaccumulation.

Chronic NOECs for fish, daphnia and algae are available for ADBAC; the lowest EC_{10} or NOEC value is <0.01 mg/L. Therefore, ADBAC meets the screening criteria for toxic.

The overall conclusion is that ADBAC is not a PBT substance.

References

EPA (2006a). Draft Alkyl Dimethyl Benzyl Ammonium Chloride (ADBAC) Preliminary Risk Assessment, Office of Pesticide Programs, Antimicrobial Division, U.S. Environmental Protection Agency, April 20, 2006. Available at: http://pi.ace.orst.edu/search/getDocketDocument.s?document=EPA-HQ-OPP-2006-0339-0002.

EPA (2006b). Reregistration Eligibility Decision for Alkyl Dimethyl Benzyl Ammonium Chloride (ADAC), Office of Prevention, EPA739-R-06-009. Office of Pesticides and Toxic Substances, United States Environmental Protection Agency, August 2006. Available at: https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P1005J4P.TXT.

EU (2012). Assessment report on alkyl (C_{12-16}) dimethylbenzyl ammonium chloride product-type 8 (wood preservative) for inclusion of active substance in Annex I to Directive 98/8/EC concerning the placing biocidal products on the market. Finalized in the Standing Committee on Biocidal Products, 21 September 2012. Available at: https://circabc.europa.eu/sd/a/1cd47df3-7593-44fa-be59-c61349a6fd4c/ADBAC%20-%20PT8%20(assessment%20report%20as%20finalised%20on%2021.09.12).pdf.

Toxicity Profile

Benzyl-(C12-C16 linear alkyl)-Dimethyl-Ammonium Chloride
Alkyl (C_{12-16}) Dimethylbenzyl Ammonium Chloride [ADBAC]
(CAS No. 68424-85-1)

Toxicokinetics/Metabolism

Following a single or repeated oral doses of ADBAC, >90% was excreted in the feces and 5-8% was eliminated via urine, <1% was present in the tissues seven days after dosing. Thus, it can be assumed that ADBAC is not readily absorbed from the gastrointestinal tract. An oral absorption of 10% can be assumed (EU, 2012).

In an *in vitro* study using human skin, dermal absorption of ADBAC was determined to be 8.3% (EU, 2012).

Acute Toxicity

The acute oral LD_{50} values in rats of ADBAC (purity 82.26%) are 510.9 mg/kg for males, 280.8mg/kg for females, and 204.5 mg/kg for both sexes combined (EPA, 2006a,b) [Kl. score = 2]. The oral LD_{50} in rats is 344 mg/kg (EU, 2012) [Kl. score = 2].

The LC_{50} value of ADBAC (purity 82.26%) is between 0.054 and 0.51 mg/L (EPA, 2006a,b).

The dermal LD_{50} values of ADBAC (purity 82.26%) in rats are 1,100 mg/kg for males, 704 mg/kg for females, and 930 mg/kg for both sexes combined (EPA, 2006a,b) [Kl. score = 2]. The dermal LD_{50} in rabbits is 2,848 mg/kg (EU, 2012) [Kl. score = 2].

Irritation

ADBAC is corrosive to the skin of rabbits; it is expected to be corrosive to the eyes of rabbits (EPA, 2006a,b; EU, 2012) [Kl. score = 2].

Sensitization

ADBAC was not a skin sensitizer when evaluated in a guinea pig Buehler test (EPA, 2006a,b; EU, 2012). Didecyldimethylammonium chloride, a structurally similar compound, was not a skin sensitizer in a guinea pig maximization test (EU, 2012) [Kl. score = 4].

Repeated Dose Toxicity

In subchronic oral toxicity studies, the NOAELs were 31, 85, and 13.1 mg/kg-day for rats, mice, and dogs, respectively. The adverse effects seen in these studies were mainly decreased body weights, reduced feed consumption, and appearance of clinical signs related to the irritation and tissue damage to the gastrointestinal tract. There were changes in the hematological and clinical

chemistry parameters in the high-dose animals that were interpreted as secondary to reduced feed intake and dehydration that led to reduced kidney blood flow (EU, 2012) [Kl. score = 4].

In a chronic oral toxicity study, decreased body weights and body weight gain were observed in rats given 88 mg/kg ADBAC. The NOAEL for the study is 44 mg/kg-day (EPA, 2006b; EU, 2012) [Kl. score = 2].

In a chronic oral toxicity study, the NOAEL for non-neoplastic effects in mice is 73 mg/kg-day (EU, 2012) [Kl. score = 4].

In a 90-day dermal toxicity study, there were no systemic effects seen at 20 mg/kg-day ADBAC (purity 81.09%), the highest dose that did not elicit excessive skin irritation. The NOAEL is 20 mg/kg-day (EPA, 2006a; EU, 2012) [Kl. score = 4].

Genotoxicity

The *in vitro* genotoxicity studies on ADBAC are presented below in Table 1.

Table 1: *In vitro* Genotoxicity Studies on ADBAC

Test System	**Results***		**Klimisch Score**	**Reference**
	-S9	**+S9**		
Bacterial reverse mutation (*S. typhimurium* strains)	-	-	4	EPA, 2006a; EU, 2012
Mammalian cell gene mutation (CHO cells)	-	-	4	EPA, 2006a; EU, 2012
Chromosomal aberration (human lymphocytes)	-	-	4	EPA, 2006a; EU, 2012
Unscheduled DNA synthesis assay	-	Not tested	2	EPA, 2006a

ADBAC was negative in an *in vivo* mouse micronucleus assay (EU, 2012) [Kl. score = 4].

Carcinogenicity

ADBAC was not carcinogenic to rats and mice; no details were provided, although the route of exposure is presumed to be oral based on the chronic toxicity study information (EPA, 2006a; EU, 2012) [Kl. score = 2].

Reproductive Toxicity

In a reproductive toxicity study (details not specified), reduced weight gain and feed consumption were noted in the parental and F_1 offspring. The LOAEL and NOAEL for the parental and F_1 offspring are 100 and 50 mg/kg-day, respectively. The NOAEL for the F_2 offspring is 50 mg/kg-

day. There were no reproductive effects at doses that were not maternally toxic (EU, 2012) [Kl. score = 4].

Developmental Toxicity

Pregnant female rats were administered ADBAC (route not specified) at doses of 0, 10, 30, or 100 mg/kg (duration not specified). Maternal toxicity was noted at $\geq$ 30 mg/kg; there was no indication of developmental toxicity at any dose level. The NOAEL for maternal toxicity is 10 mg/kg-day; the NOAEL for developmental toxicity is 100 mg/kg-day, the highest dose tested (EU, 2012) [Kl. score = 4].

In a rabbit developmental toxicity study, the NOAEL for maternal toxicity was 3 mg/kg-day. The NOAEL for developmental toxicity was 9 mg/kg-day, the highest dose tested (EU, 2012) [Kl. score = 4].

Derivation of Toxicological Reference and Drinking Water Guidance Values

For oral exposure, the lowest NOAEL is 44 mg/kg-day from a rat chronic toxicity study based on a LOEAL of 88 mg/kg-day for decreased body weights and body weight gain.

Oral Reference Dose (oral RfD)

Oral RfD = NOAEL / (UF_A x UF_H x UF_L x UF_{Sub} x UF_D)

Where:
UF_A (interspecies variability) = 10
UF_H (intraspecies variability) = 10
UF_L (LOAEL to NOAEL) = 1
UF_{Sub} (subchronic to chronic) = 1
UF_D (database uncertainty) = 1

Oral RfD = 44/(10 x 10 x 1 x 1 x 1) = 44/100 = 0.4 mg/kg-day

Drinking water guidance value

Drinking water guidance value = (animal dose) x (human weight) x (proportion of intake from water) / (volume of water consumed) x (safety factor)

Using the oral RfD,
Drinking water guidance value = (oral RfD) x (human weight) x (proportion of water consumed) / (volume of water consumed)

where:
Human weight = 70 kg (ADWG, 2011)
Proportion of water consumed = 10% (ADWG, 2011)
Volume of water consumed = 2L (ADWG, 2011)

Drinking water guidance value = (0.44 x 70 x 0.1)/2 = 1.5 mg/L

References

ADWG (2011). National Water Quality Management Strategy. Australian Drinking Water Guidelines, Section 6, Australian Government, National Health and Medical Research Council, Natural Resource Management Ministerial Council.

EPA (2006a). Draft Alkyl Dimethyl Benzyl Ammonium Chloride (ADBAC) Preliminary Risk Assessment, Office of Pesticide Programs, Antimicrobial Division, U.S. Environmental Protection Agency, April 20, 2006. Available at: http://pi.ace.orst.edu/search/getDocketDocument.s?document=EPA-HQ-OPP-2006-0339-0002.

EPA (2006b). Reregistration Eligibility Decision for Alkyl Dimethyl Benzyl Ammonium Chloride (ADAC), Office of Prevention, EPA739-R-06-009. Office of Pesticides and Toxic Substances, United States Environmental Protection Agency, August 2006. Available at: https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P1005J4P.TXT.

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ATTACHMENT 2 – SAFETY DATA SHEETS AND PRODUCT INFORMATION

NALCO Champion
An Ecolab Company

SAFETY DATA SHEET

NALCO® EC1331A

Section: 1. PRODUCT AND COMPANY IDENTIFICATION

Product name	:	NALCO® EC1331A
Other means of identification	:	Not applicable.
Recommended use	:	CORROSION INHIBITOR
Restrictions on use	:	Refer to available product literature or ask your local Sales Representative for restrictions on use and dose limits.
Company	:	ECOLAB PTY LTD 2 Drake Avenue Macquarie Park NSW 2113 Australia A.B.N. 59 000 449 990 TEL: 1300 654 224 FAX: +61 2 8870 8680
Emergency telephone number	:	1800 205 506 International: +64 7 958 2372
Issuing date	:	17.06.2016

Section: 2. HAZARDS IDENTIFICATION

GHS Classification

Acute toxicity (Oral)	:	Category 4
Skin corrosion/irritation	:	Category 1B
Serious eye damage/eye irritation	:	Category 1

GHS Label element

Hazard pictograms :



Signal Word : Danger

Hazard Statements : Harmful if swallowed.
Causes severe skin burns and eye damage.

Precautionary Statements : **Prevention:**
Do not breathe dust/fume/gas/mist/vapours/spray. Wash skin thoroughly after handling. Use only outdoors or in a well-ventilated area. Wear protective gloves/ protective clothing/ eye protection/ face protection. Wear respiratory protection.
Response:
IF SWALLOWED: Call a POISON CENTER or doctor/ physician if you feel unwell. Rinse mouth.IF SWALLOWED: Rinse mouth. Do NOT induce vomiting.IF ON SKIN (or hair): Remove/ Take off immediately all contaminated clothing. Rinse skin with water/ shower.IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing. Immediately call a POISON CENTER or doctor/ physician.IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Immediately call a POISON CENTER or doctor/ physician.

Other hazards : None known.

Section: 3. COMPOSITION/INFORMATION ON INGREDIENTS

Pure substance/mixture : Mixture

Chemical Name	CAS-No.	Concentration: (%)
Benzyl-(C12-C16 Linear Alkyl)-Dimethyl-Ammonium Chloride	68424-85-1	10 - 30

Section: 4. FIRST AID MEASURES

In case of eye contact : Rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Get medical attention immediately.

In case of skin contact : Wash off immediately with plenty of water for at least 15 minutes. Use a mild soap if available. Wash clothing before reuse. Thoroughly clean shoes before reuse. Get medical attention immediately.

If swallowed : Contact the Poison's Information Centre (eg Australia 13 1126; New Zealand 0800 764 766).

Rinse mouth with water. Do NOT induce vomiting. Never give anything by mouth to an unconscious person. Get medical attention immediately.

If inhaled : Remove to fresh air. Treat symptomatically. Get medical attention if symptoms occur.

Protection of first-aiders : In event of emergency assess the danger before taking action. Do not put yourself at risk of injury. If in doubt, contact emergency responders. Use personal protective equipment as required.

Notes to physician : Treat symptomatically.

Most important symptoms and effects, both acute and delayed : See Section 11 for more detailed information on health effects and symptoms.

Section: 5. FIREFIGHTING MEASURES

Suitable extinguishing media : Use extinguishing measures that are appropriate to local circumstances and the surrounding environment.

Unsuitable extinguishing media : None known.

Specific hazards during firefighting : Not flammable or combustible.

Hazardous combustion products : Decomposition products may include the following materials: Carbon oxides nitrogen oxides (NOx) Sulphur oxides Oxides of phosphorus

Special protective equipment for firefighters : Use personal protective equipment.

Specific extinguishing methods : Collect contaminated fire extinguishing water separately. This must not be discharged into drains. Fire residues and contaminated fire extinguishing water must be disposed of in accordance with local regulations.

Hazchem Code	:	2X

Section: 6. ACCIDENTAL RELEASE MEASURES

Initial Emergency Response Guide No	:	37
Personal precautions, protective equipment and emergency procedures	:	Ensure adequate ventilation. Keep people away from and upwind of spill/leak. Avoid inhalation, ingestion and contact with skin and eyes. When workers are facing concentrations above the exposure limit they must use appropriate certified respirators. Ensure clean-up is conducted by trained personnel only. Refer to protective measures listed in sections 7 and 8.
Environmental precautions	:	Do not allow contact with soil, surface or ground water.
Methods and materials for containment and cleaning up	:	Stop leak if safe to do so. Contain spillage, and then collect with non-combustible absorbent material, (e.g. sand, earth, diatomaceous earth, vermiculite) and place in container for disposal according to local / national regulations (see section 13). Flush away traces with water. For large spills, dike spilled material or otherwise contain material to ensure runoff does not reach a waterway.

Section: 7. HANDLING AND STORAGE

Advice on safe handling	:	Do not ingest. Do not breathe dust/fume/gas/mist/vapours/spray. Do not get in eyes, on skin, or on clothing. Wash hands thoroughly after handling. Use only with adequate ventilation.
Conditions for safe storage	:	Keep out of reach of children. Keep container tightly closed. Store in suitable labeled containers.
Suitable material	:	The following compatibility data is suggested based on similar product data and/or industry experience: HDPE (high density polyethylene), Polypropylene, Polyvinylidene difluoride, PVC, PTFE, Neoprene, Fluoroelastomer, Nitrile, Perfluoroelastomer, Stainless Steel 304, Stainless Steel 316L, CPVC (rigid), Plexiglass
Unsuitable material	:	The following compatibility data is suggested based on similar product data and/or industry experience: Carbon steel, Plasite 7122, Brass, Nylon

Section: 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Components with workplace control parameters

Contains no substances with occupational exposure limit values.

Engineering measures	:	Effective exhaust ventilation system. Maintain air concentrations below occupational exposure standards.

Personal protective equipment

Eye protection	:	Safety goggles Face-shield
Hand protection	:	Wear the following personal protective equipment: Standard glove type. Gloves should be discarded and replaced if there is any indication of degradation or chemical breakthrough.

Skin protection	:	Personal protective equipment comprising: suitable protective gloves, safety goggles and protective clothing
Respiratory protection	:	When workers are facing concentrations above the exposure limit they must use appropriate certified respirators.
Hygiene measures	:	Handle in accordance with good industrial hygiene and safety practice. Remove and wash contaminated clothing before re-use. Wash face, hands and any exposed skin thoroughly after handling. Provide suitable facilities for quick drenching or flushing of the eyes and body in case of contact or splash hazard.

Section: 9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance	:	Liquid
Colour	:	clear
Odour	:	no data available
Flash point	:	no data available
pH	:	8, 100 %
Odour Threshold	:	no data available
Melting point/freezing point	:	no data available
Initial boiling point and boiling range	:	no data available
Evaporation rate	:	no data available
Flammability (solid, gas)	:	no data available
Upper explosion limit	:	no data available
Lower explosion limit	:	no data available
Vapour pressure	:	no data available
Relative vapour density	:	no data available
Relative density	:	0.98 - 1.03, (25.0 °C),
Density	:	8.2 lb/gal
Water solubility	:	completely soluble
Solubility in other solvents	:	no data available
Partition coefficient: n-octanol/water	:	no data available
Auto-ignition temperature	:	no data available
Thermal decomposition temperature	:	no data available
Viscosity, dynamic	:	no data available
Viscosity, kinematic	:	no data available
Molecular weight	:	no data available
VOC	:	2.0 %

Section: 10. STABILITY AND REACTIVITY

Chemical stability	:	Stable under normal conditions.
Possibility of hazardous	:	No dangerous reaction known under conditions of normal use.

reactions

Conditions to avoid	:	None known.
Incompatible materials	:	Contact with strong oxidizers (e.g. chlorine, peroxides, chromates, nitric acid, perchlorate, concentrated oxygen, permanganate) may generate heat, fires, explosions and/or toxic vapors.
Hazardous decomposition products	:	Decomposition products may include the following materials: Carbon oxides nitrogen oxides (NOx) Sulphur oxides Oxides of phosphorus

Section: 11. TOXICOLOGICAL INFORMATION

Information on likely routes of exposure	:	Inhalation, Eye contact, Skin contact

Potential Health Effects

Eyes	:	Causes serious eye damage.
Skin	:	Causes severe skin burns.
Ingestion	:	Harmful if swallowed. Causes digestive tract burns.
Inhalation	:	May cause nose, throat, and lung irritation.
Chronic Exposure	:	Health injuries are not known or expected under normal use.

Experience with human exposure

Eye contact	:	Redness, Pain, Corrosion
Skin contact	:	Redness, Pain, Corrosion
Ingestion	:	Corrosion, Abdominal pain
Inhalation	:	Respiratory irritation, Cough

Toxicity

Product

Acute oral toxicity	:	Acute toxicity estimate: 1,955 mg/kg
Acute inhalation toxicity	:	Acute toxicity estimate: 0.28 mg/l Exposure time: 4 h
Acute dermal toxicity	:	no data available
Skin corrosion/irritation	:	no data available
Serious eye damage/eye irritation	:	no data available
Respiratory or skin sensitization	:	no data available
Carcinogenicity	:	No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.

Reproductive effects	:	No reproductive toxic effects expected.
Germ cell mutagenicity	:	Contains no ingredient listed as a mutagen
Teratogenicity	:	no data available
STOT - single exposure	:	no data available
STOT - repeated exposure	:	no data available
Aspiration toxicity	:	No aspiration toxicity classification

Components

Acute dermal toxicity	:	Benzyl-(C12-C16 Linear Alkyl)-Dimethyl-Ammonium Chloride LD50 rabbit: 3,340 mg/kg

Human Hazard Characterization

Based on our hazard characterization, the potential human hazard is: High

Section: 12. ECOLOGICAL INFORMATION

Ecotoxicity

Environmental Effects	:	This product has no known ecotoxicological effects. Very toxic to aquatic life. Toxic to aquatic life.

Product

Toxicity to fish	:	no data available
Toxicity to daphnia and other aquatic invertebrates	:	no data available
Toxicity to algae	:	no data available

Components

Toxicity to daphnia and other aquatic invertebrates	:	Benzyl-(C12-C16 Linear Alkyl)-Dimethyl-Ammonium Chloride EC50 Daphnia magna (Water flea): 0.016 mg/l Exposure time: 48 h

Persistence and degradability

The organic portion of this preparation is expected to be inherently biodegradable.

Mobility

The environmental fate was estimated using a level III fugacity model embedded in the EPI (estimation program interface) Suite TM, provided by the US EPA. The model assumes a steady state condition between the total input and output. The level III model does not require equilibrium between the defined media. The information provided is intended to give the user a general estimate of the environmental fate of this product under the defined conditions of the models.
If released into the environment this material is expected to distribute to the air, water and soil/sediment in the approximate respective percentages;

Air	:	<5%
Water	:	30 - 50%
Soil	:	50 - 70%

The portion in water is expected to be soluble or dispersible.

Bioaccumulative potential

Component substances have a low potential to bioconcentrate.

Other information

no data available

ENVIRONMENTAL HAZARD AND EXPOSURE CHARACTERIZATION
Based on our hazard characterization, the potential environmental hazard is: Low

Section: 13. DISPOSAL CONSIDERATIONS

Disposal methods	:	The product should not be allowed to enter drains, water courses or the soil. Where possible recycling is preferred to disposal or incineration. If recycling is not practicable, dispose of in compliance with local regulations. Dispose of wastes in an approved waste disposal facility.
Disposal considerations	:	Dispose of as unused product. Empty containers should be taken to an approved waste handling site for recycling or disposal. Do not re-use empty containers.

Section: 14. TRANSPORT INFORMATION

The shipper/consignor/sender is responsible to ensure that the packaging, labeling, and markings are in compliance with the selected mode of transport.

Land transport

Proper shipping name	:	CORROSIVE LIQUID, N.O.S.
Technical name(s):	:	Quaternary ammonium compound
UN/ID No.	:	UN 1760
Transport hazard class(es)	:	8
Packing group	:	III
IERG No	:	37
Hazchem Code	:	2X
Special precautions for user	:	Dangerous goods of Class 8 (Alkali) are incompatible in a placard load with any of the following: Class 1 Explosives Class 4.3 Dangerous when wet substances Class 5.1 Oxidising agents Class 5.2 Organic peroxides Class 7 Radioactive substances and are incompatible with food or food packaging in any quantity.

Air transport (IATA)

UN/ID No.	:	UN 1760
Proper shipping name	:	CORROSIVE LIQUID, N.O.S.
Technical name(s)	:	Quaternary ammonium compound
Transport hazard class(es)	:	8
Packing group	:	III

Sea transport (IMDG/IMO)

UN/ID No.	:	UN 1760
Proper shipping name	:	CORROSIVE LIQUID, N.O.S.
Technical name(s)	:	Quaternary ammonium compound
Transport hazard class(es)	:	8
Packing group	:	III

Section: 15. REGULATORY INFORMATION

Standard for the Uniform Scheduling of Medicines and Poisons : No poison schedule number allocated

INTERNATIONAL CHEMICAL CONTROL LAWS :

AUSTRALIA
All substances in this product comply with the National Industrial Chemicals Notification & Assessment Scheme (NICNAS).

CHINA
This product contains substance(s) which are not in compliance with the Provisions on the Environmental Administration of New Chemical Substances and may require additional review.

JAPAN
This product contains substance(s) which are not in compliance with the Law Regulating the Manufacture and Importation Of Chemical Substances and are not listed on the Existing and New Chemical Substances list (ENCS).

KOREA
All substances in this product comply with the Chemical Control Act (CCA) and are listed on the Existing Chemicals List (ECL)

NEW ZEALAND
All substances in this product comply with the Hazardous Substances and New Organisms (HSNO) Act 1996,and are listed on or are exempt from the New Zealand Inventory of Chemicals.

PHILIPPINES
All substances in this product comply with the Republic Act 6969 (RA 6969) and are listed on the Philippines Inventory of Chemicals & Chemical Substances (PICCS).

Section: 16. OTHER INFORMATION

REFERENCES

Hazardous Substances Data Bank, National Library of Medicine, Bethesda, Maryland (TOMES CPS™ CD-ROM Version), Micromedex, Inc., Englewood, CO.

IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man, Geneva: World Health Organization, International Agency for Research on Cancer.

Integrated Risk Information System, U.S. Environmental Protection Agency, Washington, D.C. (TOMES CPS™ CD-ROM Version),
Micromedex, Inc., Englewood, CO.

Annual Report on Carcinogens, National Toxicology Program, U.S. Department of Health and Human Services, Public Health Service.

Registry of Toxic Effects of Chemical Substances, National Institute for Occupational Safety and Health, Cincinnati, OH,
(TOMES CPS™ CD-ROM Version), Micromedex, Inc., Englewood, CO.

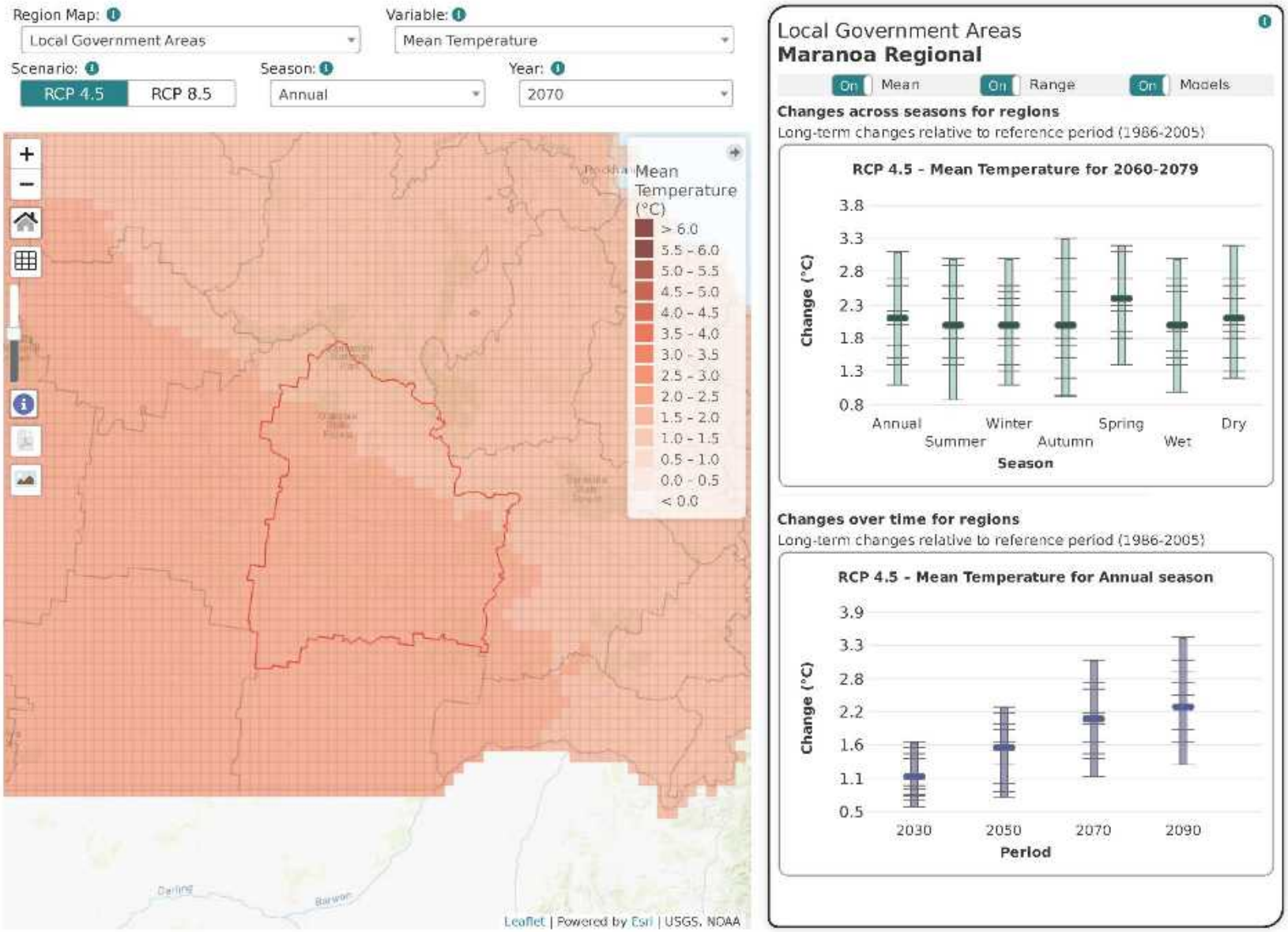
The Teratogen Information System, University of Washington, Seattle, WA (TOMES CPS™ CD-ROM Version), Micromedex, Inc., Englewood, CO.

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Prepared By	:	Regulatory Affairs

REVISED INFORMATION: Significant changes to regulatory or health information for this revision is indicated by a bar in the left-hand margin of the SDS.

The information provided in this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as a guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text.
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Appendix I: Representative Concentration Pathway (RCP) 4.5 Scenario for the Maranoa Region


Region Map:
Local Government Areas
Variable:
Mean Temperature
Scenario:
RCP 4.5
RCP 8.5
Season:
Annual
Year:
2070
Mean Temperature (°C)
> 6.0
5.5 - 6.0
5.0 - 5.5
4.5 - 5.0
4.0 - 4.5
3.5 - 4.0
3.0 - 3.5
2.5 - 3.0
2.0 - 2.5
1.5 - 2.0
1.0 - 1.5
0.5 - 1.0
0.0 - 0.5
< 0.0
Leaflet | Powered by Esri | USGS, NOAA
Local Government Areas
Maranoa Regional
On Mean
On Range
On Models
Changes across seasons for regions
Long-term changes relative to reference period (1986-2005)
RCP 4.5 - Mean Temperature for 2060-2079
Change (°C)
3.8
3.3
2.8
2.3
1.8
1.3
0.8
Annual
Summer
Winter
Autumn
Spring
Wet
Dry
Season
Changes over time for regions
Long-term changes relative to reference period (1986-2005)
RCP 4.5 - Mean Temperature for Annual season
Change (°C)
3.9
3.3
2.8
2.2
1.6
1.1
0.5
2030
2050
2070
2090
Period